International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Study the Influence of a Remote Lab System on Students' Academic Achievement

Jalal Miladi[1], Halil Ibrahim Akyuz[2]

[1]Kastamonu University, Institute of Science, Kuzeykent Campus, Kastamonu
Email: *jmiladi[at]gmail.com*
[2]Kastamonu University, Education Faculty, Kastamonu, Türkiye
E-mail: hakyuz@kastamonu.edu.tr; ORCID: 0000-0002-1614-3271
[*]The article was produced from the authors' PhD Thesis

Abstract: ***As a result of various emergency circumstances, such as natural disasters, the Coronavirus disease 2019 (COVID-19) pandemic, and wars, face-to-face learning stopped, and educational institutions' programs shifted to distance learning to ensure the continuation of study. One of the challenges facing academic institutions is the difficulty of teaching laboratory courses remotely and the risk of their negative impact on student achievement. This article aims to study the possibility that the remote laboratory can be a successful alternative solution to the traditional laboratory. The experimental study was conducted using a posttest-only control group design, where embedded systems students were randomly divided into two groups. The first group conducted seven experiments remotely, while the control group conducted the same experiments in the college laboratory. Students' academic performance was evaluated, and the results indicated no statistically significant differences between the two methods. This result proves the validity of the study's hypothesis, which states that the remote laboratory is a successful and effective alternative to the traditional laboratory in terms of its impact on the students' academic performance.***

Keywords: Student Assessment, Students' academic performance, Remote Lab.

1. Introduction

Universities are resorting to distance education due to the forced cessation of face-to-face education due to multiple factors, such as natural disasters, wars, security instability, and the outbreak of serious diseases such as COVID-19 [1].

Remote laboratory systems (RLS) are among the modern technologies in laboratory education and are considered a major advance. These systems allow students to access physical laboratory equipment and carry out and interact with their experiments. De Lima et al [2], defined a remote laboratory as a means that allows students to communicate, control, and monitor the physical components in the laboratory through computer network technologies. In addition, remote laboratories allow experiments to be conducted, monitored, and controlled remotely.

Remote laboratories differ from virtual laboratories. While experiments and physical components are simulated in virtual laboratories, students in remote laboratories deal with natural processes and equipment in order to carry out their experiments [3], [4], [5].

Teaching laboratory courses remotely is challenging for academic institutions. Most alternative solutions to traditional labs are ineffective and may impact student achievement [1].

1.1 Student Assessment

According to Bayer et al. [6], student evaluation is the systematic process in which students' performance, skills, and knowledge are evaluated within an educational context. Zhou [7] considers student evaluation to be one of the most important, effective, and decisive elements in the educational process, as it serves as a tool to evaluate, measure, and document various aspects of student learning and achievements.

Student evaluation is a necessary process. Evaluation aims to achieve educational goals by improving the quality of education, supporting the student, and the educational process [8].

1.1.1 Assessment Methods and Tools

The impact of assessment methods on student achievement and academic success is significant. The student's knowledge and information increase as the student studies hours increase in preparation for exams. Some other assessment methods that evaluate, for example, presentations or conducting laboratory experiments, have a noticeable impact not only on academic achievement but also on improving student skills such as teamwork, communication, problem-solving, and creative thinking [9].

There are many methods and tools for evaluating students, Fuentealba [8] explained this by stating that due to the multiplicity of teaching methods, the use of assessment tools must be diversified to achieve the objectives of assessment and ensure effective and fair assessment of students. The student Assessment process depends on several practices, such as examinations of various types or evaluating assignments, reports, and student projects [6].

The two main types of assessment are formative assessment and summative assessment. Born [10] explained that there is a difference between summative assessment and formative assessment. Summative assessment evaluates the student's cumulative achievement at the end of the course, while formative assessment is continuous and repeated from the beginning of the course until the end and is characterized by providing feedback to students, informing teachers, and improving teaching and learning processes.

Born [10] points out that while summative assessments are

widely criticized for their rigidity, formative assessments are praised for their originality and focus on solving real-world problems.

There are various methods for evaluating students' academic performance, including:
1) Traditional tests: including written and oral assessments.
2) Practical assessments require students to demonstrate their understanding through real-world applications.
3) Evaluation of student projects: This involves assessing students' ability to plan, implement, and present their projects.
4) Self-evaluation: Students benefit from identifying and improving weak points and recognizing their strengths and areas for improvement.

There are different assessment tools to assess students, it can be categorized into two main types:
1) Traditional assessment tools, such as written and oral tests.
2) Digital assessment tools, such as computerized tests, and custom assessment platforms used for electronic assessment. These digital tools offer flexibility and often include multimedia elements to enhance the assessment process.

With recent progress in the field of artificial intelligence and machine learning algorithms, attempts have emerged to build systems to classify and track student performance, and the world looks forward to seeing the use of these advanced technologies in student evaluation.

1.2 Research Aim and Hypothesis

This study aims to prove that there is no significant difference in the effect of remote laboratory learning and traditional laboratory learning on students' academic performance, which means that remote laboratory learning is a promising alternative that can be relied upon when face-to-face learning stops.

The null hypothesis (H0) and alternative hypothesis (Ha) can be expressed as follows:
- H0: $\mu 1 = \mu 2$ (The academic performance means of two study style groups are equal)
- Ha: $\mu 1 \neq \mu 2$ (The academic performance means of the two study style groups are not equal)

Where $\mu 1$ represents the mean value of academic performance for students in the face-to-face group, and $\mu 2$ represents the mean value of academic performance scores for students in the remote lab group.

2. Methods

To achieve the goal of this article, the researchers followed the following basic steps:
- Conducting an experimental study at the College of Electronic Technology - Tripoli, Libya, aiming to use the remote laboratory system and measure its impact on students' academic performance. An experimental study was designed using posttest only control group design, as it was difficult to assess students before the study began. Students were randomly assigned to an experimental group or a control group. The experimental group (GA) conducts its experiments using a remote laboratory system, while the control group (GB) conducts its experiments in the university laboratory.
- Evaluating students' academic performance using a combination of summative and formative assessments.
- Conduct a comparison statistical analysis using SPSS software system to determine the effect of the distance laboratory on students' academic performance and compare it with the results of face-to-face education.

3. The Experimental Study

This study utilized the posttest-only control group research design, which is an important experimental design. The participants were randomly assigned to either the experimental group (remote laboratory group) or the control group (face-to-face laboratory group). The experiment only used a final evaluation based on summative and formative assessments to compare the effects of the remote laboratory and the traditional face-to-face laboratory .

One of the objectives of this study is to evaluate a remote laboratory system as an alternative to traditional laboratory studies. Therefore, the researcher believed that the evaluation should be done by comparing the results of the two methods. In this case, there was no desired benefit from conducting the pre-test, therefore, a posttest-only control group design was adopted.
The experimental study aims to determine the effect of the laboratory method on students' academic performance. To achieve this goal, the experimental study followed a set of steps that began with preparing for the study, teaching the course, and then evaluating the students.

3.1 Preparation for the Course Teaching

The Embedded Systems course was developed and approved during the 2016/2017 academic year .

3.1.1 Course Objectives
Its goal is to teach students the basic concepts of microcontrollers, including their in-ternal architecture and programming, and how to design and build various electronic applications based on microcontrollers. The course also teaches students how to interface and communicate a microcontroller with external systems.

3.1.2 Course Learning Outcome
Upon completing the Microcomputer course, students will be:
- CLO1: Understanding the basics and techniques of microcontrollers and understand their basic components, such as Arithmetic Logic Unit (ALU), Memory, Ports, etc.
- CLO2: Understanding the different types of input and output (I/O) interfacing, connecting microcontrollers to external components, and controlling external devices.
- CLO3: Understanding different types of communication technologies, such as Universal Synchronous/Asynchronous Receiver Transmitter (USART), Inter – Integrated Circuit (IIC), Serial

Peripheral Interface (SPI), and Transmit Control Protocol /Internet Protocol (TCP/IP), and how to exchange data between microcontrollers and other devices using these technologies.

- CLO4: Able to understand and analyses embedded systems' hardware and software components.
- CLO5: Able to design, build, and program embedded systems applications based on microcontrollers.
- CLO6: Able to understand and analyses system requirements as a preliminary step before designing solutions; also able to select and use the right tools for the solution.
- CLO7: Develop the ability to collaborate effectively in a team setting.

3.1.3 Course Syllabuses

The course includes a theoretical topics and practical experiments, Table 1 shows the syllabuses of Embedded Systems Course.

Table 1: Embedded Systems Course Syllabuses

Week No.	*Lab Experiment*
1	Lab Introduction, Arduino Programming
2	Exp1: LED Blinking
3	Exp2: LED Scroll
4	Exp3: Traffic Light System
5	Exp4: Tow Button Stopwatch using 7 Segments
6	Exp5: One Button Stopwatch using LCD
7	Exp6: Light Intensity using PWM
8	Exp7: Voltmeter
9	Midterm Test
10	Exp8: PC interface example
11	Exp9: RFID card reader interface
12	Exp10: Interrupt based alarm system
13	Exp11: Bluetooth connection example
14	Exp12: Bluetooth connection example2

3.2 Course Teaching

In the first week of classes at the college, students in the embedded systems class were taught the basics of programming the Arduino control board in the college laboratory. From the second to the seventh week of study at the college, Students in the embedded systems class were randomly split into two groups according to study style; Group B (17 students) conducted laboratory experiments face-to-face in the college laboratory, while Group A (15 students) conducted laboratory experiments using the remote laboratory system was developed by Miladi and Akyüz [1].

This system allows the student to carry out his experiments remotely. It gives him the flexibility to choose the appropriate time from anywhere without the need to be in a specific laboratory at a specific time. The multi-user system allows more than one student to carry out his experiment simultaneously. It is characterized by a cost-effective and expandable design; it supports increasing the number of users working simultaneously at the lowest possible cost. Also, it allows the teacher to manage the system and follow up on students' work. Figure 1 shows the block diagram of remote laboratory system, while the home page of the RLS software is shown in Figure 2, and Figure 3 shows Experiment's conducted web page.

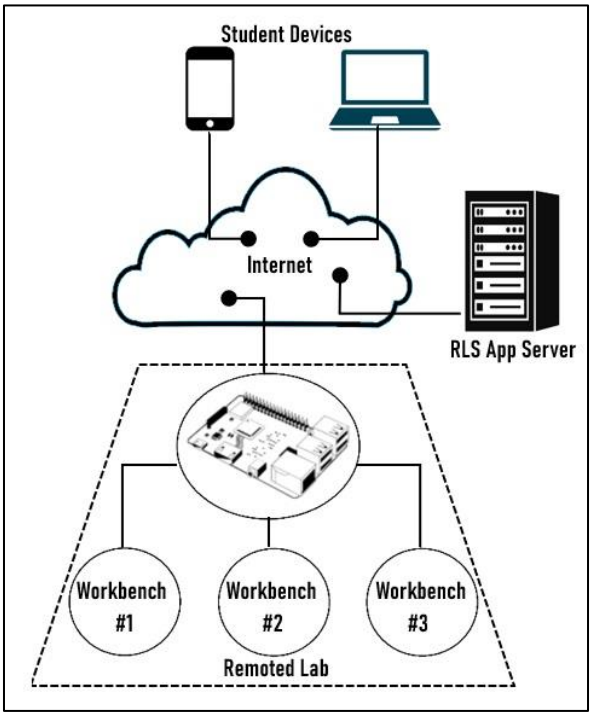

Figure 1: System Architecture of Remote Lab System

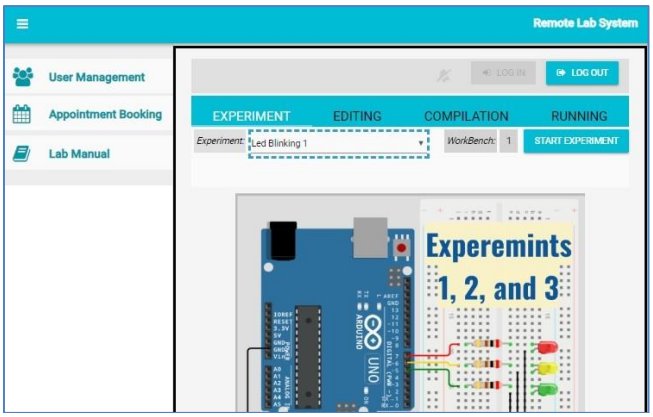

Figure 2: RLS Home Page

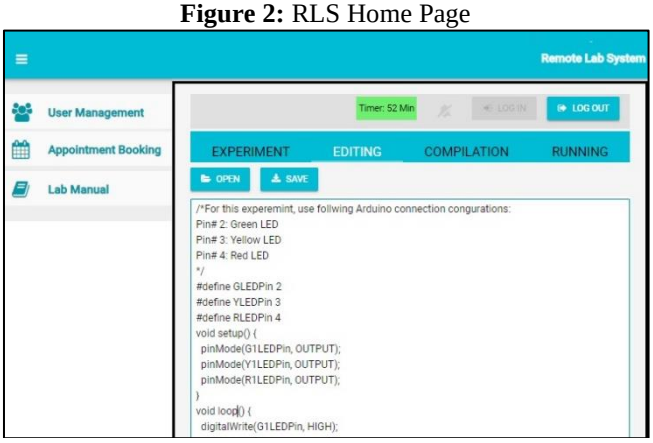

Figure 3: Experiment Conducted Web Page

During the fifth week, the students were arranged into small teams, each team consisting of two students from the same study style group, except one team (AB8 Team). The students were assigned projects as listed in Table 2.

The students in these projects were responsible for analyzing and clarifying the project idea, system design, implementation, and testing.

Table 2: Students' Projects

Project No	Group	Team No.	Project Title
1	Group A	A1	Remote Car
2	Group B	B1	Remote Car
3	Group A	A2	Access Control System
4	Group B	B2	Access Control System
5	Group A	A3	Safe Box Security System
6	Group B	B3	Safe Box Security System
7	Group A	A4	Advanced Traffic Controller System
8	Group B	B4	Advanced Traffic Controller System
9	Group A	A5	Remote Control for Home Automation
10	Group B	B5	Remote Control for Home Automation
11	Group A	A6	Smart Home
12	Group B	B6	Smart Home
13	Group A	A7	Game Controller
14	Group B	B7	Game Controller
15	Group A	A8	Intruder tracking system
16	Mixed Team	AB8	Intruder tracking system

3.3 Student Assessment and Data Collection

Three types of assessment were used in this study to evaluate students' performance

1) Formative Assessment It is used to assess weekly laboratory experiment reports.
2) Summative assessment It is a written exam in the eighth week at the end of the experimental study.
3) Evaluation of student projects. An oral exam dedicated for students' projects .

Students' scores are collected in an Excel sheet, Table 3 shows the first six rows of data collection table.

Table 3: The First 6 Rows of Data Collection Table

Student No.	*Team No.*	*Reports*	*Project*	*Test*
1	A1	85	85	76
2	A1	95	60	64
3	B1	95	65	72
4	B1	80	60	36
5	A2	82	60	53
6	A2	89	80	66

4. Results

The aim of the experimental study is to prove or reject research hypothesis:

H0: There is no significant difference between the effect of remote lab learning style and face to face learning style on students' academic performance.

To reach this result, the two-sided t-test analysis was used to compare two means and measure the probability of the null hypothesis H0 using SPSS software.

When conducting a two-sided t-test, it is important to consider that the data follows a normal distribution, especially when the sample size for each group in the study is not large, As shown in Figure 4 students' academic performance scores for each group are normally distributed.

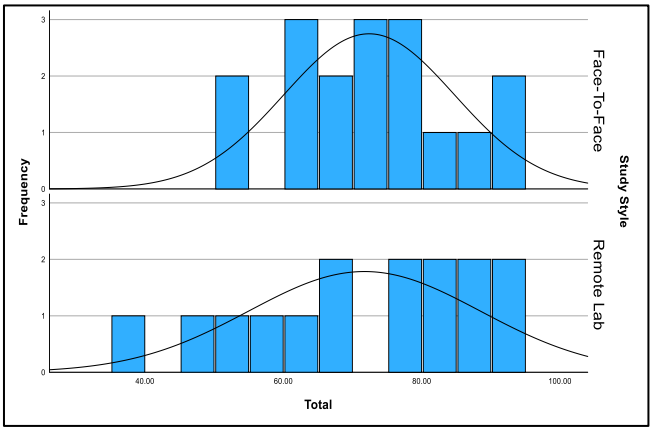

Figure 4: Normality Test Using Histogram graph

Table 4 shows the initial results of statistics analyses, it indicates that the Mean value of students' academic performance for Face-To-Face Lab group is 72.29%, while the Mean of students' academic performance for Remote Lab group is 71.62%.

Table 4: Mean and standard deviation for each group

Study Style	*N*	*Mean*	*Std. Deviation*
Face-To-Face	17	72.2941	12.34002
Remote Lab	15	71.6222	16.76773

The comparative analysis between two means using two-sided t-test analysis found that the p-value of the t-test is > 0.005, suggesting a failure to reject the null hypothesis, as showed in Table 5a, Table 5b. This means that the mean difference between students' academic performance scores of both groups is not significantly different.

Table 5a: Two-Sided t-test Analysis-Part1

Independent Samples Test				
	Levene's Test for Equality of Variances		*t-test for Equality of Means*	
	F	*Sig.*	*t*	*df*
Equal variances assumed	2.203	.148	.130	30
Equal variances not assumed			.128	25.485

Table 5b: Two-Sided t-test Analysis-Part2

Independent Samples Test				
	t-test for Equality of Means			
	Significance			
	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference
Equal variances assumed	.449	.897	.67190	5.16301
Equal variances not assumed	.450	.899	.67190	5.26319

5. Discussion

The statistics results indicates that the remote laboratory study style has succeeded in being an alternative solution to the traditional laboratory study style if face-to-face study stops or in the case of distance laboratory education programs. As a result, this study validated the researchers' hypothesis H0: there is no significant difference between the

effect of remote laboratory and traditional lab study styles on students' academic performance.

6. Conclusion

Continuous progress in modern technologies has provided successful solutions and effective technical alternatives in various fields. To address the cessation of face-to-face studies in educational institutions for any emergency reason, this article presented an alternative technical solution to the face-to-face laboratory for the Embedded Systems course. The proposed solution allows students to conduct their experiments remotely. The RLS was used in an experimental study at the College of Electronic Technologies in Tripoli, Libya, during the fall semester of 2023-2024.
The research results showed that the remote laboratory method has a positive effect on students similar to the effect of face-to-face laboratory on students' academic performance. This confirms the validity of the hypothesis of this study, which states that there is no significant difference between the effect of the two study methods on students' academic performance.

Proving the validity of the hypothesis of this study prompts the search for integrated and alternative solutions ready in the event that face-to-face study stops, especially in countries and regions suffering from natural disasters, wars, and security instability.

References

[1] Miladi, Jalal & Akyüz, Halil İbrahim. (2024) Design and implementation of a Web-Based Remote laboratory for Embedded Systems Course Experiments. Journal of Sustainable Engineering Applications and Technological Developments. 10.51764/smutgd.1499299
[2] de Lima, João Paulo & Mellos Carlos, Lucas & Schardosim Simão, José & Pereira, Josiel & Mafra, Paulo & Silva, Juarez. (2016). Design and implementation of a remote lab for teaching programming and robotics. IFAC-PapersOnLine. 49. 10.1016/j.ifacol.2016.11.133.
[3] Chen, Xuemin & Song, Gangbing & Zhang, Yongpeng. (2010). Virtual and Remote Laboratory Development: A Review. 10.1061/41096(366)368.
[4] Karadimas, Dimitris & Kostas, Efstathiou. (2007). An Integrated Educational Platform Implementing Real, Remote Lab-Experiments for Electrical Engineering Courses. Journal of Computers. 2. 10.4304/jcp.2.2.3744.
[5] Kozič, Antoni & Macerauskas, Eugenijus & Sakalys, Paulius. (2016). Remote Laboratory As Conceptual Model Of Blended Learning. Society. Integration. Education. Proceedings of the International Scientific Conference. 2. 549. 10.17770/sie2016vol2.1421.
[6] Bayer, Sonja & Klieme, Eckhard & Jude, Nina. (2016). Assessment and Evaluation in Educational Contexts. 10.1007/978-3-319-45357-6_19.
[7] Zhou, Ming. (2023). Significante of Assessment in Learning: The Role of Educational Assessment Tools. Science Insights Education Frontiers. 18. 2881-2883. 10.15354/sief.23.co215.
[8] Fuentealba, Carmen. (2011). The Role of Assessment in the Student Learning Process. Journal of veterinary medical education. 38. 157-62. 10.3138/jvme.38.2.157.
[9] Costa, Joana & Araújo, Sónia & Soliman, Mohammad & Sousa, Maria. (2022). Assessment Methods Determining the Higher Education Students' Academic Success. Communications in Computer and Information Science. 1425. 10.1007/978-3-031-07018-1_7.
[10] Born, A. D. (2003). Web-Based Student Assessment. In A. Aggarwal (Ed.), Web-Based Education: Learning from Experience (pp. 165-188). IGI Global. 10.4018/978-1-59140-102-5.ch011

Author Profile

Jalal Miladi Lecturer at the Faculty of Electronic Technologies, and currently obtaining his PhD at Kastamonu University, Türkiye. He received a bachelor's degree. Bachelor's degree in computer engineering from the University of Tripoli in 1997, and a master's degree in engineering management in 2009. Miladi is interested in different research fields, such as: embedded systems design, the Internet of Things, and computer networks.