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The Use of Virtual Laboratories for Teaching in Higher Education: An Applied Study on the Electrical Engineering Departments in Technical Institutes and Colleges in Libya

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استخدام المختبرات الافتراضية للتدريس في التعليم العالي: دراسة تطبيقية على أقسام الهندسة الكهربائية في المعاهد والكليات التقنية في ليبيا

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Abstract:

The objective of this study is to identify the feasibility of using virtual laboratories to develop technical higher education in Libya. It investigates the availability of the necessary requirements for their implementation in higher institutes and technical colleges, as well as the obstacles hindering their adoption. The researchers employed a descriptive-analytical methodology, using questionnaires and personal interviews as data collection tools. The study sample included a number of technical higher education institutions, namely: the Faculty of Engineering Technology in Janzour, the Faculty of Civil Aviation and Meteorology Technology in Asabaa, and the Higher Institutes of Science and Technology in Qasr Ben Ghashir, Souk El Khamis Amsihil, Awlad Ali, and Gharyan.The study concluded with several key findings. The requirements for implementing virtual laboratories in the targeted colleges and institutes were found to be available at a "moderate" level. Similarly, the obstacles to using virtual labs for teaching electrical engineering subjects were also assessed as "moderate". A significant finding was that the use of virtual laboratories enhances the quality of outcomes in technical higher education. Accordingly, the study recommends a set of measures to facilitate the use of virtual labs in teaching, chief among them being the provision of virtual laboratories for all technical institutes and colleges. It also recommends providing training courses for faculty members, teaching assistants, and students on their use. Crucially, the study advocates for using virtual laboratories **in conjunction with, not as a replacement for, traditional laboratories** to achieve the optimal development of student skills.

Keywords: Virtual Laboratories, Electrical Engineering, Higher Education, Higher Institutes, Technical Colleges.

الملخص:

تهدف هذه الدراسة إلى تحديد جدوى استخدام المختبرات الافتراضية لتطوير التعليم العالي التقني في ليبيا. وتبحث في مدى توفر المتطلبات اللازمة لتطبيقها في المعاهد العليا والكليات التقنية، بالإضافة إلى المعوقات التي تحول دون تطبيقها.

استخدم الباحثون المنهج الوصفي التحليلي، مستخدمين الاستبيانات والمقابلات الشخصية كأدوات لجمع البيانات. شملت عينة الدراسة عددًا من مؤسسات التعليم العالي التقني، وهي: كلية تكنولوجيا الهندسة بجنزور، وكلية تكنولوجيا الطيران المدني والأرصاد الجوية بأصابعة، والمعاهد العليا للعلوم والتكنولوجيا بقصر بن غشير، وسوق الخميس، وأمسيحيل، وأولاد علي، وغريان. وخلصت الدراسة إلى عدة نتائج رئيسية، منها أن متطلبات تطبيق المختبرات الافتراضية في الكليات والمعاهد المستهدفة كانت "متوسطة". وبالمثل، قُيّمت معوقات استخدام المختبرات الافتراضية لتدريس مواد الهندسة الكهربائية بأنها "متوسطة". من النتائج المهمة أن استخدام المختبرات الافتراضية يُحسّن جودة مخرجات التعليم العالي التقني. وبناءً على ذلك، تُوصي الدراسة بمجموعة من الإجراءات لتسهيل استخدام المختبرات الافتراضية في التدريس، من أبرزها توفير مختبرات افتراضية لجميع المعاهد والكليات التقنية. كما تُوصي بتوفير دورات تدريبية لأعضاء هيئة التدريس ومساعدي التدريس والطلاب حول استخدامها. والأهم من ذلك، تُوصي الدراسة باستخدام المختبرات الافتراضية بالتزامن مع المختبرات التقليدية، وليس كبديل عنها، لتحقيق التطوير الأمثل لمهارات الطلاب.

الكلمات المفتاحية: المختبرات الافتراضية، الهندسة الكهربائية، التعليم العالي، المعاهد العليا، الكليات التقنية.

Introduction

The tremendous development in information technology and communication systems has led many institutions to adopt technology in various aspects of their operations, including e-learning. Higher education institutions play a pivotal role in disseminating these technologies through their curricula. Numerous teaching strategies have emerged that align with contemporary learning theories, including the use of virtual laboratories, which are considered a cornerstone of e-learning. Stemming from this premise, this study aims to identify the necessary requirements for the adoption of virtual laboratories and to investigate the existing obstacles that limit their use in technical higher education in Libya.

Problem Statement

The engineering education, in general, and technical education, in particular, relies on practical and laboratory applications to understand concepts and their applications. However, due to the increasing number of engineering and technical education institutes and the high cost of establishing physical laboratories, makes the Ministry of Technical Education unable to provide these facilities for all its affiliated institutes and colleges. Consequently, students in

most of these institutions currently receive a predominantly theoretical education, resulting in a professional application deficit among most graduates. Therefore, it must imperative to develop the laboratory and technical skills of engineering students. The electrical engineering departments in technical colleges and institutes were selected as a case study to develop a framework that allows for the graduation of highly skilled and competent professionals. The research problem can be summarized in the following questions:

Q1. Can we use of virtual laboratories feasible in higher institutes and technical colleges in Libya? This main question branches into the following sub-questions:

•a. What are the obstacles of using virtual laboratories for teaching in technical higher education in Libya?

•b. To what extent are the requirements for using virtual laboratories available in technical higher education in Libya?

Q2. Is the use of virtual laboratories effective in developing the technical skills of students?

Study Objectives

This study aims to:

1.Define the concept of virtual laboratories, their components, and the types used in electrical engineering education.

2.Ascertain the feasibility of using virtual laboratories to develop higher education in Libya and to reduce the gap between the labor market and educational outcomes.

3.Identify the requirements for using virtual laboratories and assess their availability in higher institutes and technical colleges in Libya.

4.Identify the obstacles to the implementation of virtual laboratories in higher institutes and technical colleges in Libya.

Significance of the Study

This study serves as an important resource for understanding the concept of virtual laboratories, their components, types, implementation requirements, and the obstacles to their use in the context of the studied higher education institutions. It clarifies the potential of using virtual labs for teaching electrical engineering courses in technical higher education and demonstrates their effectiveness in developing students' technical skills.

Research Methodology

The researchers employed a descriptive-analytical method to achieve the study's objectives, following these steps:

1.**Literature Review**: Reviewing books and previous studies as a source of secondary data.

2.**Primary Data Collection**: Using the following tools for primary data collection:

1.**Questionnaire:** The researchers used a questionnaire to collect data. The study population consisted of faculty members in the electrical engineering departments at technical colleges (College of Engineering Technology in Janzour; College of Civil Aviation and Meteorology Technology in Asbi'a) and higher institutes (Higher Institute of Science and Technology in Qasr Bin Ghashir; Higher Institute of Science and Technology in Souq Al-Khamis Amseyhel; Higher Institute of Science and Technology in Awlad Ali; Higher Institute of Science and Technology in Gharyan). Due to the limited size of the population, a comprehensive census approach was adopted. Questionnaires were distributed to all members of the population, and after follow-up, 40 were returned. Of these, 4 were deemed invalid for statistical analysis, resulting in 36 valid questionnaires, representing a 90% response rate.

2.**Personal Interviews**: An interview protocol was designed, and interviews were conducted with several faculty members from the electrical engineering departments in technical higher education.

Scope of the Study

The research was conducted in the electrical engineering departments of the following technical colleges (College of Engineering Technology in Janzour; College of Civil Aviation and Meteorology Technology in Asbi'a) and higher institutes (Higher Institute of Science and Technology in Qasr Bin Ghashir; Higher Institute of Science and Technology in Souq Al-Khamis Amseyhel; Higher Institute of Science and Technology in Awlad Ali; Higher Institute of Science and Technology in Gharyan).

Theoretical Framework and Literature Review

I. Theoretical Framework

This study seeks to define the concept of virtual laboratories, their components, and their advantages, and to illustrate some of the virtual labs used in the field.

1. The Concept of Virtual Laboratories Virtual labs. are considered one of the most important scientific technologies contributing to the advancement of science by presenting practical aspects to students in a simplified and cost-effective manner. They allow students to conduct experiments without the need for expensive equipment and without exposure to physical risks.

Virtual laboratories are defined as programmed environments that simulate real laboratories, through which learners can perform lab experiments remotely as many times as needed. They compensate for the absence of physical lab equipment and allow for the coverage of most course concepts with virtual experiments, which is often difficult to achieve in reality due to the limited time and number of physical labs.

Mona Al-Zahrani defined virtual laboratories as an electronic environment that helps the learner to think and acquire practical and technological skills(منى الزهراني, 2022). It simulates a real science laboratory by linking the theoretical

side with the practical side, using special applications and programs to simulate reality, with the ability to add new components and innovative experiments to save time and effort.

2. Types of Virtual Labs Used in Electrical Engineering Education Virtual labs used in electrical engineering can be classified based on their operational method and student interaction into three main types:

- **a. Simulation-Based Labs:** This is the most widespread type used within engineering education institutions in Libya. In these labs, equipment and electrical machines are represented as mathematical and software models. The student interacts with a graphical user interface (GUI) to build circuits and conduct experiments entirely within a software environment, with no connection to real hardware. The student "drags and drops" various electrical components, connects them with virtual wires, and uses virtual measurement instruments to see the results. The displayed results are the mathematical solution to the models representing these components. The most famous examples include:
    - **MATLAB/Simulink:** Considered the gold standard in academia. It provides a powerful environment for modeling and simulating power systems, electrical machines, power electronics, and control systems.
    - **Multisim & LTspice:** Excellent software for simulating and analyzing electronic circuits (analog and digital). They are widely used in teaching courses on electrical circuits and electronics.
    - **ETAP/PowerWorld Simulator:** Specialized software for large-scale power system analysis (load flow, short-circuit studies, stability).
    - **Advantages:** Absolute safety, low cost, flexibility, and the ability to safely explore hazardous conditions (e.g., faults, overloads).
    - **Disadvantages:** Their sole use can lead to a lack of hands-on experience, weakness in using real measurement devices, and a deficiency in safety skills for handling real electrical equipment.

- **b. Remote-Triggered Labs:** In this type, the student interacts via the internet with real laboratory equipment located somewhere in the world. The student sends commands through a web interface, which trigger real devices, and the real measurements and results are sent back to the student. Popular technologies include:
    - **LabVIEW Remote Panels:** Allow the creation of web-accessible GUIs to control hardware.
    - **Custom Platforms:** Often built using web servers and communication protocols to control devices like relays and variable speed drives.
    - **Advantages:** Realism (results from real hardware) and resource sharing.
    - **Disadvantages:** High cost of building and maintaining the hardware, limited access (scheduling required), and a limited set of pre-programmed experiments.
- **c. Augmented/Mixed Reality & Hybrid Labs:** This is the latest trend, merging the real and virtual worlds.
    - **Augmented Reality (AR):** A student points their phone's camera at a table, and a 3D model of a transformer appears on the screen, allowing them to connect virtual wires and see data overlays.
    - **Virtual Reality (VR):** A student wears a VR headset and finds themselves inside a 3D virtual lab environment, able to move, "grab" components, and operate them.
    - **Hybrid Labs:** Combine simulation and remote experiments.
    - **Advantages:** High level of engagement and interaction, and safe training on safety procedures.
    - **Disadvantages:** High development cost and complexity, and the need for special hardware (VR headsets, AR-compatible devices).

3. Components of Virtual Laboratories (الحازمي, 2010), (المغربي, 2017),(Fatima Abdullah Bujaily, 2021), (المغربي, 2017), and (أيمان الشهراني, 2022) identified the basic components for setting up virtual laboratories as follows:

1. **Laboratory Devices and Equipment:** Sensors linked to the experiment's tools to transmit commands, control signals, and change input values, and through which results and readings are extracted.
2. **Computer Hardware:** Each student needs a computer to access and work within the virtual lab.
3. **Communication Network and Devices:** A secure network that connects the user's device to the local or global network.
4. **Virtual Laboratory Software:** Special programs for managing the labs and students in terms of tasks, permissions, and activity monitoring.
5. **Collaboration and Management Software:** Programs related to managing the lab and its users in performing experiments.

4. Advantages of Virtual Laboratories (الجعفري, 2022) highlighted the advantages of using virtual labs that are not found in traditional labs, including:

1. Flexibility of use.
2. Reducing the learning time spent in a real lab.
3. Making laboratory teaching more engaging and exciting.
4. Reducing material costs.
5. Ease of monitoring and guiding learners' progress.
6. Enhanced safety and reduced risks during experiments.
7. Enabling students to identify and correct errors.
8. Allowing students to visually comprehend scientific concepts through animated representations of processes invisible to the naked eye.
9. Reducing the time teachers spend setting up experiments.
10. Helping teachers demonstrate multiple experiments simultaneously.

11. Satisfying the learner's curiosity and desire for discovery and experimentation.

12. Providing opportunities to practice skills that are difficult to implement in reality.

II. Previous Studies

Given the importance of this topic, many studies have been conducted on the use of virtual laboratories for education.

- **Jamal Abd Rabbo Al-Zaanin** studied the "Effectiveness of Teaching a Mobile Electricity Unit Using CD-based Educational Programs on Achievement, Critical Thinking Skills, and Motivation of Ninth-Grade Students in Gaza." The study found that using computer-based programs was effective for the experimental group, improving their critical thinking skills and motivation(الزعانين, 2009).

- **Abdullah bin Abdulkarim Al-Harbi** presented a study on a "Proposed Vision to Activate the Use of Virtual Laboratories in Teaching Science from the Perspective of Faculty Members at Qassim University." The study concluded that it is necessary to provide an infrastructure that supports the activation of virtual labs and to raise awareness among students and faculty(الحربي, 2023).

- **Samah Naji** conducted a study on "Designing an Enrichment Program Based on Virtual Lab. to Develop Electronic Circuit Composition Skills for Industrial Secondary School Students"(ناجي, 2019).

- **Nyan-Myau Lyau & Edi Sarwono** reviewed the advantages and challenges of implementing virtual labs in electrical engineering education, especially during the COVID-19 pandemic, concluding that they are a highly useful tool(Sarwono & Lyau, 2023).

- **Travassos Valdez, Maria João, & Maciel** studied the "VEMA environment" for virtual labs in electrical engineering education, finding it to be an effective and engaging platform that helps students "think like engineers"(Travassos Valdez et al., 2014).

- **Juan, Pedro, and Arturo** studied a "Real-Time Power Electronics Laboratory to Enhance Remote Engineering Education in the Field of Grids and Smart Microgrids," concluding that converting labs to real-time virtual labs is an effective strategy but requires significant technical investment(Gutiérrez et al., 2021).

This study is similar to previous studies in that it examines the use of virtual laboratories in education and aligns with the latter three studies by focusing on teaching electricity courses. However, this study differs by addressing aspects not covered by previous research, such as the feasibility of using virtual labs to teach electrical engineering courses in the specific context of technical higher education in Libya.

Analysis of the Current Study

Characteristics of the Study Sample: The study targeted faculty members in the electrical engineering departments of technical colleges and higher institutes. Figure (1) shows the graphical representation of the study sample by gender.

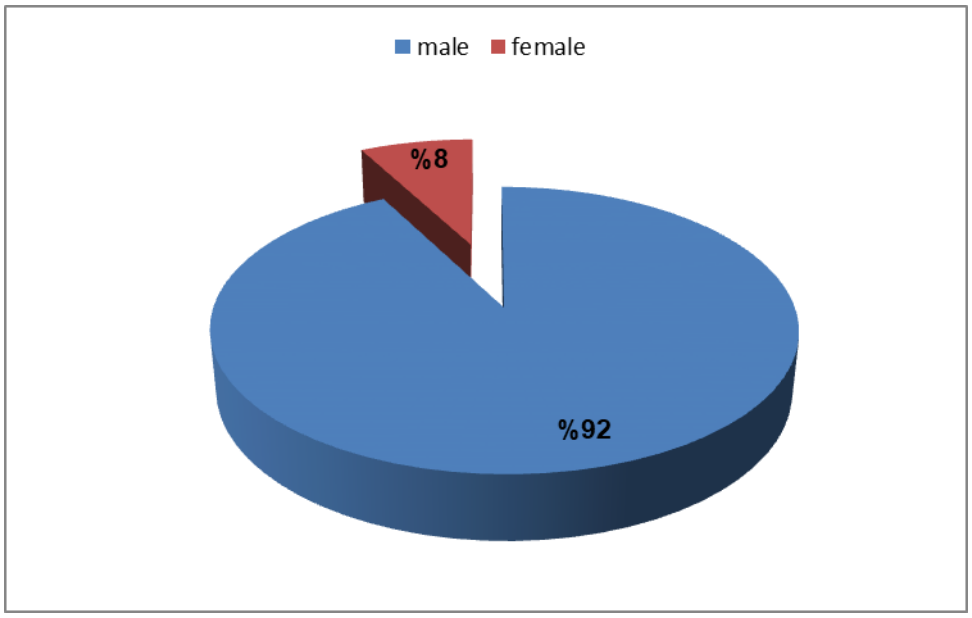

Figure (1) Graphical Representation of Study Sample Items by Gender

And Figure (2) shows the graphical representation of the study sample items by age.

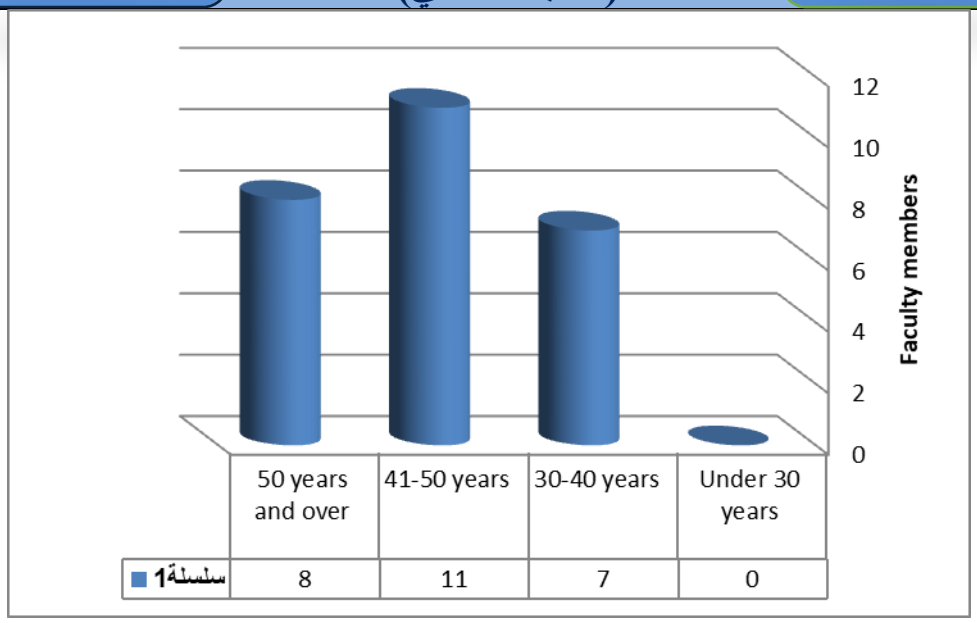

Figure (2) Graphical Representation of Study Sample Items by Age.

And Figure (3) shows the graphical representation of the study sample items by academic qualification

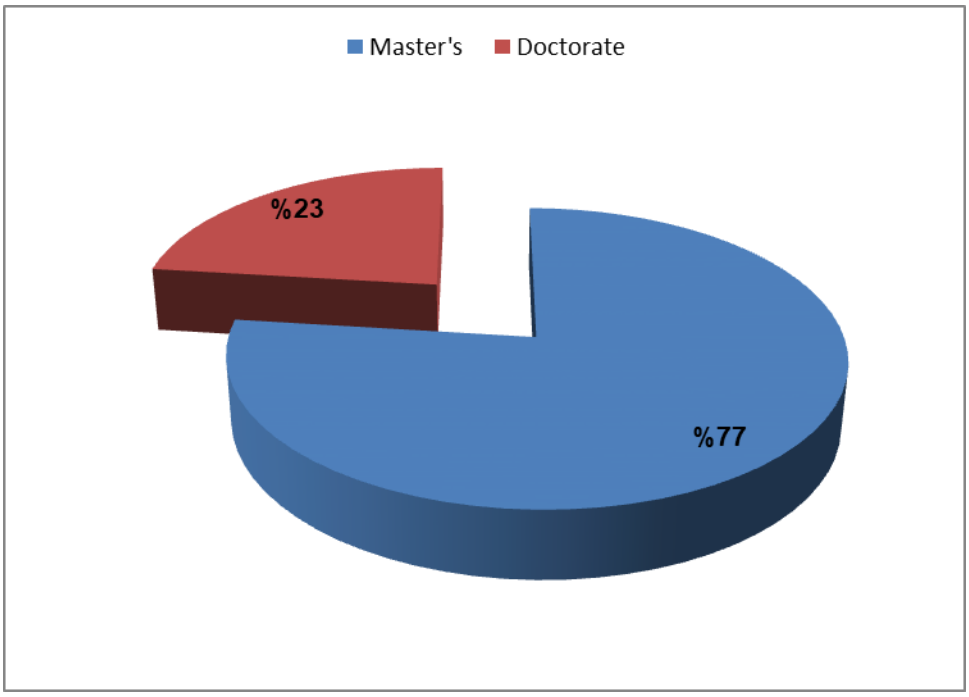

Figure (3) Graphical Representation of Study Sample Items by Academic Qualification

And Figure (4) shows the graphical representation of the study sample items by years of experience

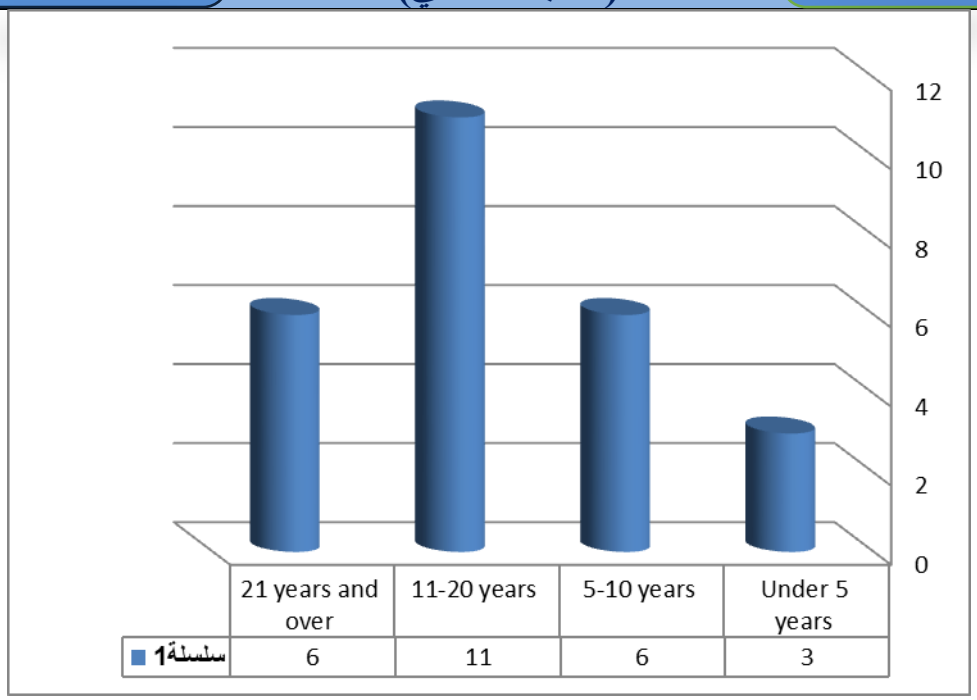

Figure (4) Graphical Representation of Study Sample Items by Years of Experience

And Figure (5) shows the graphical representation of the study sample items by academic degree

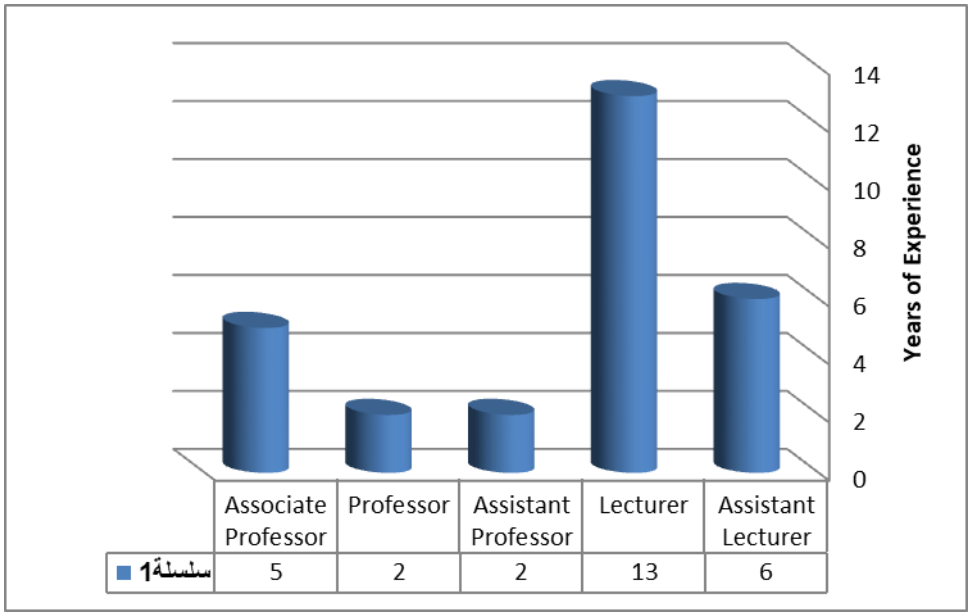

Figure (5) Graphical Representation of Study Sample Items by Academic Degree

And Figure (6) shows the graphical representation of the study sample items by academic institutions

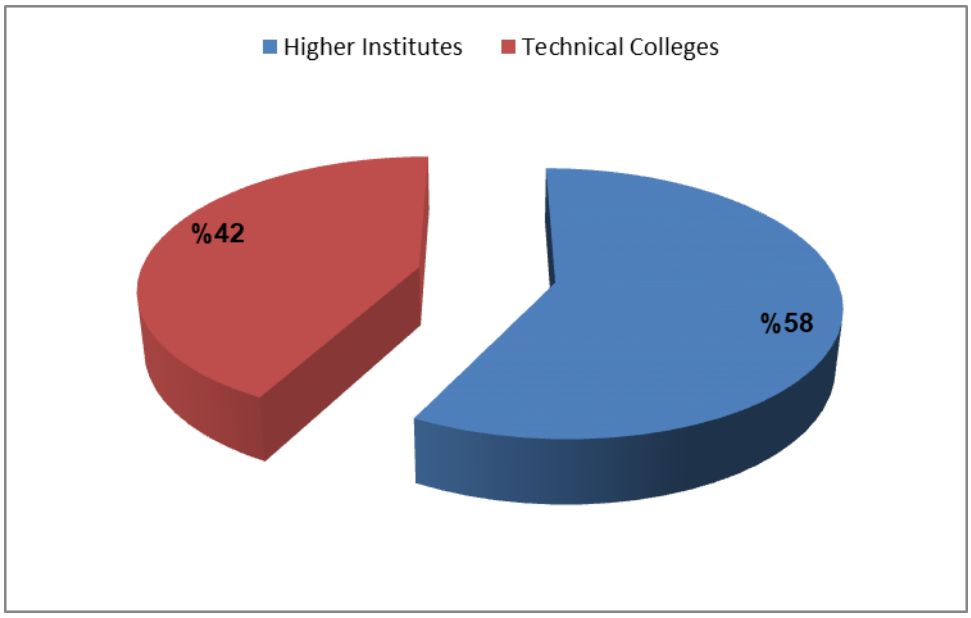

Figure (6) Graphical Representation of Study Sample Items by Academic Institutions

II. Discussion of Research Questions

Question 1: Is the use of virtual laboratories feasible in the technical institutes and colleges in Libya? This question branches into the following two sub-questions:

- **a. What are the obstacles to using virtual laboratories for teaching in technical education in Libya?**

Table (1) illustrates the obstacles to using virtual laboratories in the surveyed higher education institutions, calculated using the mean and standard deviation of the participants' responses. The statements are ranked, with rank (1) representing the greatest obstacle.

Table (1): Obstacles to the Use of Virtual Laboratories

No.	Statement	Mean	Std. Dev.	Rank
1.	Using virtual labs creates a psychological barrier between the student and the instructor.	3.4231	1.02657	14
2.	Some faculty members are unable to work with virtual labs.	3.6154	0.85215	11
3.	Lack of professional development for teaching assistants and faculty through training courses on using virtual labs.	4.3077	0.67937	**1**
4.	Slow response and delay from some students in synchronous interaction when using virtual labs.	3.9231	0.62757	7
5.	Malfunctions of hardware and the computer lab network hinder the execution of experiments.	4.1923	0.80096	**2**
6.	Lack of a user guide for faculty on how to use virtual labs.	3.9615	0.77360	6
7.	Most virtual lab software is in English, which is a barrier for students, TAs, and faculty.	3.5385	1.02882	12
8.	Inability to tier virtual labs into different levels according to student proficiency.	3.7308	0.91903	9
9.	Lack of awareness from the technical education administration regarding the importance of virtual labs.	4.0385	0.99923	4
10.	Lack of features for monitoring and evaluating students in virtual labs.	3.5000	1.14018	13
11.	Large class sizes hinder the use of virtual labs.	3.1538	1.18970	15
12.	Students' poor computer literacy skills hinder the use of virtual labs.	4.0385	0.82369	4
13.	Lack of interaction among students when conducting experiments using virtual labs.	4.0000	0.84853	5
14.	Using virtual labs leads to a deficiency in acquiring essential manual and practical skills.	4.0769	1.12865	**3**
15.	Using virtual labs leads to a deficit in students' knowledge of real equipment and how to handle it.	3.9231	1.01678	7
16.	The high degree of safety in virtual labs weakens the safety culture among students when dealing with real electrical equipment.	3.8846	1.10732	8
17.	The inability to represent personal variables like humidity, equipment quality, and aging in virtual labs leads to a misunderstanding of real-world equipment behavior.	3.6923	1.01071	10
Overall Mean for the Axis		**3.8235**	**0.43957**	

Table (1) presents 17 statements describing potential obstacles. According to the

respondents, the most significant obstacle is the **lack of professional development for teaching assistants and faculty** through training courses. This is followed by **the malfunction of hardware and computer lab networks,** which also poses a major barrier to the use of virtual labs.

- **b. To what extent are the requirements for using virtual laboratories available in technical education?**

Table (2) shows the availability of requirements for using virtual labs, ranked according to the mean and standard deviation of responses. Rank (1) represents the most essential available requirement.

Table (2): Availability of Requirements for Using Virtual Laboratories

No.	Statement	Mean	Std. Dev.	Rank
18.	A computer lab is available in the higher education institution.	3.8462	1.08415	**1**
19.	It is possible to obtain virtual laboratory software.	3.4231	1.10175	4
20.	Training opportunities are available for faculty to use virtual lab software.	3.1538	1.28662	6
21.	Features for evaluating students in virtual labs are available.	3.6154	0.75243	**2**
22.	Teaching assistants are available to help faculty teach using virtual labs.	3.4615	1.02882	3
23.	An internet network is available for use in some virtual labs.	3.2308	1.39449	5
24.	An instruction manual for the virtual labs is available.	3.4231	1.06482	4
Overall Mean for the Axis		**3.4505**	**0.85875**	

Table (2) shows that, according to the faculty, the most important available

requirement is the **presence of a computer lab**, followed by the **availability of features for student evaluation** within the virtual labs.

Answer to Question 1: Is the use of virtual laboratories feasible in the technical institutes and colleges in Libya? Based on the preceding tables and the responses from personal interviews, we can conclude that the use of virtual laboratories is currently feasible in the technical colleges and some of the higher institutes, due to the availability of computer labs. However, most higher institutes still require the establishment of computer labs.

Answer to Question 2: Is the use of virtual laboratories effective in developing the technical skills of students? Based on Table (1) and the interview responses, we can conclude that the use of virtual laboratories is indeed effective in developing students' technical skills. This is due to the absence of restrictions, allowing students to learn anytime and anywhere, protecting them from physical risks, and enabling them to enhance their skills by repeating practical applications multiple times.

Results and Recommendations

I. Study Results

1. The availability of requirements for implementing virtual labs in the surveyed institutions was found to be at **a moderate level**.
2. The obstacles to using virtual labs for teaching electricity courses were also assessed to be at a **moderate level.**

3. Some technical colleges and higher institutes have the potential to activate the use of virtual labs for teaching their electrical engineering courses.

4. According to faculty members, using virtual labs offers several advantages that enhance the quality of technical education outcomes, including:

1. It saves students time, allowing them to conduct experiments even at home.

2. It helps develop practical skills by allowing experiments to be performed in the lab and repeated at home.

3. It helps faculty members save time.

4. It protects students from physical hazards.

5. Virtual labs are beneficial in situations where access to physical labs is difficult or when there is a shortage of expensive equipment.

II. Recommendations

1. Provide training courses for faculty members, teaching assistants, and students on the use of virtual laboratories.

2. Equip all technical institutes and colleges with virtual laboratories.

3. Use virtual laboratories in conjunction with, not as a replacement for, traditional laboratories to achieve the optimal development of student skills.

4. The administration of higher institutes should design and develop programs for needed virtual labs that are not currently available.

5. Provide user guides and manuals for virtual labs and make them accessible to faculty, teaching assistants, and students.

6. Benefit from the experiences of other universities and higher institutes in this domain.

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