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Virtual and remote laboratories in electronic and telecommunications: a technical review in education

Laboratorios virtuales y remotos en electrónica y telecomunicaciones: una revisión técnica en educación

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ABSTRACT

Training in electrical and electronic circuit analysis is a fundamental area within the learning process of future bachelors in electronics and telecommunication related fields, therefore, developing Know-How is a stage that must be part of the process where the evolution of engineering and the fourth industrial revolution have changed not only technology but also the career path of education. In this sense, this article conducts a systematic search of different success stories published to establish current trends in the design of virtual environments based on the teaching of circuit analysis.

RESUMEN

La formación en análisis de circuitos eléctricos y electrónicos es un área fundamental en el proceso de aprendizaje de los futuros profesionales de áreas relacionadas con la electrónica y las telecomunicaciones, por lo tanto, la preparación en el saber hacer es una etapa que hace parte en el proceso de aprendizaje donde la evolución de la ingeniería y la cuarta revolución industrial han cambiado no solo la tecnología sino también la forma de enseñar. En ese sentido este artículo contempla la revisión bibliográfica sobre laboratorios virtuales y remotos a través del uso de las Tecnologías de la Información y comunicación aplicadas al área de electrónica y telecomunicaciones para establecer las tendencias actuales en diseño de ambientes virtuales en función a la enseñanza del análisis de circuitos.

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1. Introduction

Global Education has been undergoing a deep transformation, leaving behind traditional systems and classrooms to give way to digital platforms with the support of Internet, and giving access to an indeterminate number of information sources that strengthen academic processes. However, one of the challenges, ever since distance education began, is the practice, which should not be stopped because it allows students to apply gained knowledge in real situations and acquire new skills in the use of tools, for this reason, both the productive sector and the universities are working on different alternatives to guarantee that students acquire skills in the management of instrumentation and equipment necessary for their professional performance.

On the other hand, according to what was analyzed in the Universidad Nacional a Distancia de Costa Rica – UNED [1], it is evidenced that disciplines such as Telecommunications Engineering can be offered virtually 100% through the incorporation of simulators and virtual technologies, increasingly strengthening virtual education around the world.

In this sense, this article searches for some success stories that exist today around the world for the development of laboratory practices in different areas, emphasizing disciplines of electronics and telecommunications, giving an account of the Results based on the academic training of future graduates of the Electronic Engineering and Telecommunication programs of the National Open and Distance University of Colombia - UNAD.

2. Problem

Currently, different alternatives have been sought through the use of Information and Communication Technologies - ICT to face the pandemic caused by SARS-CoV-2, and in education specifically, to continue with the development of curricular activities normally; The topic of this article is not new, yet it aims to strengthen the teaching and learning process in different areas of knowledge and at various levels of training.

It is important to highlight that education through virtual and distance modality has extraordinary benefits for autonomous, collaborative, and meaningful learning, for which laboratories constitute an essential support factor in engineering training, promoting new approaches and expanding possibilities to unify knowledge and train upright professionals.

Particularly, in the area of electronics and telecommunications, students who begin their academic training in virtual / distance mediation arrive at the laboratory without prior knowledge, since it is their first experience with these equipment, therefore, laboratory time must be dedicated so that the students become familiar with the instrumentation and learn how to use it quickly, instead of developing the exercises that have been designed for this practices, therefore this article aims to establish the importance of familiarizing students with laboratory instruments virtually, before the development of face-to-face practices.

Taking this situation into account, different alternatives have been sought to allow students recognize these equipment by identifying their characteristics, usage, configuration, limitations and recommendations before the development of the first face-to-face laboratory session, so as not to have the time of the face-to-face sessions on the connection and proper handling of instruments, and can also complement the work to be carried out since the objective is not to replace the practical component but to have a tool that complements this exercise.

Given the above, the existing alternatives for the development of Circuit Analysis practices were sought, and as a result two types of scenarios were established that fulfil this purpose and provide an approach to elements and measurement instruments. In the first place, remote laboratories that are a hybrid between software and hardware were found, to give access to a workbench that has the necessary equipment for a practice and interconnected each other so that the user has remote control, therefore, it requires a stable connection either internal or external.

In second place, there are virtual laboratories that improve the self-learning process by developing, as their name indicates, in virtual learning environments through the use of simulators and the internet that offer enriching and complementary experiences for the development of the practical component face-to-face or on-site.

For [2], virtual laboratories allow simulating many physical phenomena and modelling systems, abstract concepts, hypothetical situations; controlling time scale, frequency, etc., thus hiding the mathematical model if required, and showing only the simulated phenomenon, and even interactively, bringing the laboratory to student's homes. The virtual laboratories have several advantages, one of the main ones being that it allows to reach a greater number of students simultaneously in a flexible schedule, it also strengthens the development of on-site practices by providing a preview of the components and use of instruments in the laboratory.

3. Alternatives for in-situ practical component

3.1. Remote laboratories

There are remote laboratory alternatives for different disciplines worldwide, providing users with an experience close to reality in a controlled environment, through devices connected there to reach expected results and thus acquire the skills proposed by practice. In this sense, there are remote laboratory applications in different areas of knowledge such as medicine, civil works, metrology, logistics, basic sciences, among others; However, the implementation of virtual laboratories for the teaching of electronics, telecommunications and their related areas stands out above any discipline.

In this context, solutions have been found such as the one proposed by the Pontifical Catholic University of Rio de Janeiro (PUC-Rio) [3-4], where the remote laboratory for the development of circuit analysis practices is presented, including the required instrumentation such as digital multimeters, an oscilloscope and connection elements according to previously established configurations. As conclusions this group, in the different articles published has shown that universities must have a robust infrastructure to offer this type of situation, nonetheless, the acceptance of students is initially not what was expected, but this perception changes as more possibilities are incorporated in said laboratory [5].

Along the same lines, is the case [6], where a remote laboratory was implemented for the development of amplifier practices and the respective instrumentation, through Scripts developed with Python programming language, as a conclusion, it was established that the tool is a complement to laboratory practices but will not replace the competences gained in a face-to-face laboratory.

Likewise, in Latin America different cases of success were found, such as those developed in Colombia, where a virtual laboratory was implemented for the development of IoT practices at the National Open and Distance University – UNAD [7], or the case of the Corporación Universitaria Minuto de Dios - UNIMINUTO [8], for the development of practices of the different courses related to the area of electronics and telecommunications, as well as in other parts of the Latin American continent, where they focus on the development of practical activities remotely, where students have control of the different devices, however investment is required to implement them [9-10].

Like the aforementioned cases, there are many others in different parts of the world, such as Algeria, Morocco, and Tunisia, among others [11-15], or universities in Spain [16-17], Germany [18], and in general throughout Europe [19-20], all of them aimed at the development of competencies focused on knowledge of electronic engineering and telecommunications, however, despite the fact that these solutions, and in addition to promoting the competencies of each design, require management to guarantee students access in an orderly manner, therefore it will be possible that on some dates there is high demand and it will not be possible for all users to get such access [21-26].

Another important aspect found in these solutions is related to the operation of the laboratory instrumentation since the users do not have the real handling of the devices since this is previously configured [27-28], in such a way that the operator only activates or deactivates them, leaving out the experience of connecting, calibrating, and using a measuring instrument.

3.2. Virtual laboratories

The curricular integration of Information and Communication Technologies (ICT) through virtual laboratories fosters new learning environments, strengthening pedagogy and didactics in engineering and different areas of knowledge [29-30]. Specifically in electronics and telecommunications area, there are several outstanding examples of laboratories, where they make a compilation of different laboratories and their characteristics [31], which are shown in Table 1.

Table 1. Virtual instruments (VI), Virtual Laboratories (VL) and, Virtual and Remote Laboratories, [31].

Laboratory	Type	Language	Web interface	Scope
eMersion	LVR	LabView	Java	Control
Connexions	IV	LabView	HTML	Digital filter, Signals
MeRLab	LVR	LabView	HTML	Mechatronics
UNED	LVR	Ejs, LabView	HTML	Control
WebLab	LVR	Java	AJAX	Electronic
Aurova	LVR	Ejs, Java 3D	HTML	Artificial vision, Networks
Chattannoga	LV	Matlab, LabView	HTML	Control, Dynamic
LER	LVR	LabView	HTML, PHP	Robotic

In this collection of information, the integration of Virtual and Remote Laboratories predominates in which practices are carried out using multipurpose virtual platforms and applications connected to real laboratory systems.

A successful case in the application of virtuality in the teaching of telecommunications engineering occurred in UNED, Costa Rica, in which all the academic training on this modality is offered [1], and in which EMONA TIMS and LabView have been integrated. On the other hand, the National University of Colombia - Manizales Campus, built a Laboratory of Electricity and Electronics - LEE, and through its platform it teaches on the basic handling of equipment such as multimeters, DC sources, protoboards, and parameter meters, among others, in this virtual laboratory, students have the possibility of downloading the guide and knowing about equipment characteristics and operation without the need for students and teachers to attend the lab premises before carrying out the face-to-face practice, this has become a pioneering idea in the department of Caldas, Colombia [32].

Unlike the previous cases, the University of Guayaquil does not have the infrastructure for the development of specialized practice in the areas of robotics and although the students have the theoretical knowledge, they cannot put it into practice due to limitation in the physical space of the institution, for this reason [33], based on graduate thesis, they sought to implement a Virtual Robotics Laboratory for the Engineering Career in Networking and Telecommunications, which was carried out using the free tool V-REP; professors and students can interact within this virtual laboratory, and it has been very well welcomed by the students who had the opportunity to work in it.

In the area of telecommunications, at the Technological University of Ciudad Juárez, Mexico [34-35], they implemented a virtual laboratory for Telecommunication practices making use of Information and Communication Technologies in order to overcome the lack of personnel, equipment, and classrooms, and thus enable the practice of students from the program, they also mention the importance of ICT use in the training of Telecommunications and Networking Engineers.

Virtual laboratories as support for the development of the face-to-face practical component have been used in several fields, as stated [36], students can access the Virtual Laboratory of Induction Machines - VLIM to reduce damage to equipment and risks in its handling, in turn [37], they designed a simulator used as support to train up-to-date professionals in the subject of control and process simulation, in these cases face-to-face education is complemented through virtual labs by means of practices in controlled environments to procure basic knowledge to handle real equipment.

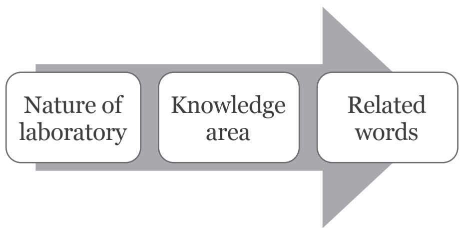
Authors such as [38-39], went beyond virtual laboratories and integrated them with video games in teaching / learning, on the one hand, they state that virtual laboratories deliver the opportunity to train students and provide them with confidence for future interactions with real laboratories environments, with advantages such as: cost, portability, concurrency and security; and that video games also provide them with skills such as: mental speed, reaction, connection between thoughts and movements and concentration.

From the above it can be deduced that virtual / remote laboratories and gamification are currently a trend in education, as deduced [40], in the master's thesis, the use of Information and Communication Technologies is a common factor in the classroom, allowing students to strengthen their learning and teachers to energize classes through the integration of different pedagogical and didactic strategies.

4. Methodology used in the search for information.

To establish a clear context on the current situation of the alternatives for the development of practical components, a systematic search of information was carried out in databases related to the field of electronics and telecommunications. In this sense, it was found that databases such as IEEE Xplore, Scopus and Google Scholar have documented information on remote and virtual laboratories, for which it was necessary to perform a search equation according to the criteria established in Figure 1.

Figure 1. Information search scheme in databases.



Source: own.

In this respect, and in accordance with the search criteria, the process was undertaken in the database mentioned, based on the needs of the search for this article, that is, the nature of the laboratory (virtual or remote); Subsequently, the area of knowledge was delimited towards electronics and telecommunications and finally keywords were established so that the search process is centralized in laboratories developed for the practices of areas typical of the discipline. Besides that, the search time was limited to the last ten (10) years to obtain updated answers, involved in the learning processes from different universities in the world.

As a result of the searches carried out, Table 2 defines the keywords used as an alternative search in each criterion:

Table 2. Keywords by criterion.

1st Criteria	2nd Criteria	3rd Criteria
Laboratories (type)	Electronic	Oscilloscope
(nature) labs	Telecommunications	Multimeter
(nature) laboratories	Circuit analysis	Power supply
	Ohm law	Breadboard

Source: own.

With these criterions, we proceeded to build the equation considering that the word nature in first one is replaced either by the word virtual or remote. With these keywords we proceeded to search the database.

5. Discussion

Currently there are several points of view on the topics addressed in this article for the use of remote and virtual laboratories in the teaching and learning process of students, although these offer a unique opportunity to impart and strengthen knowledge, from the curricular scope, it must find a point of equilibrium where the virtual and the real world complement each other in the development of engineering courses, in this case for electronics and telecommunications areas [41].

As stated [42-43], there are several works oriented to the development of virtual and remote laboratories to support learning in engineering and the possibilities are opened for many other areas of knowledge; In all cases, the aim is to motivate learning through dynamics, models and mechanisms that strengthen students' abilities in specific topics and that require support for the appropriation of knowledge.

Beyond that, it was found that the experience of remote laboratories offers the development of exercises using real devices, however, the students do not have real control over the elements since they are previously connected, in such a way that the experience is something similar to a simulation software. In this regard, virtual laboratories offer an advantage given that they are developed in a scenario like that found in the presence, where the student not only do their exercises, but also interacts with the instruments involved in the session, from the connection, putting running and subsequent disconnection.

Finally, it is important to remember that professors are also involved in the teaching / learning process, who worry every day about innovating in the curricular contents that are taught to students, authors such as [44-50], rely on Virtual and remote laboratories making use of Information and Communication Technologies to deliver knowledge to students about electronics and telecommunications at different levels of training (secondary and undergraduate), giving their students the possibility of applying theoretical knowledge through integration of virtual practices strengthening self-learning.

6. Conclusions

In recent years, and specifically in this pandemic due to SARS-CoV-2, where things have taken an unexpected turn towards virtuality, proposals for the development of online activities (academic, work and personal) have increased and people get used to technology.

In the educational field, virtual laboratories have been strengthened to support the development of practice in all areas of knowledge, however it is important to remember that virtual practices feature results obtained in real laboratories, through interactive elements and activities that allow students acquire skills to face intellectual challenges that their learning process may demands from them.

Provided that these laboratories are not intended to replace the face-to-face practical component, students need to use physical elements that allow then to validate knowledge reached through simulated environments, that is, developing the session in person, where they must already have skills to use both, the devices, and instruments of the laboratory, strengthening their skills in the area of knowledge.

In the area of engineering by means of virtual or distance education, in-situ laboratories are proposed to allow students, not only to interact with elements, but also with their academic peers to create networks and work teams, since teamwork strengthens critical thinking and analysis in the troubleshooting process.

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