Impact of the electric field and equipotential lines remote laboratory as a tool to support inclusive education

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Abstract

The technological advances in recent years have allowed generating new elements and tools that make the teaching-learning process at any educational level, more dynamic, functional, and purposeful; it is at this point that remote laboratories contribute to the use of new information and communication technologies. This article has been developed within the framework of the research project "design and implementation of a platform for virtual and remote laboratories, *case study of electric field and equipotential lines laboratory*". The design and testing of such laboratory allowed researchers to evaluate the incidence of these resources as support tools for inclusive education; they were also applied and validated with the students of the faculty of engineering at Universidad Libre, Bosque Popular branch in Bogotá. Thus, the remote laboratories started to be implemented in Universidad Libre as tools without any of the restrictions of the real laboratories, and it was possible to evidence the same development and to a great extent of the competencies that are sought to be developed with them.

Keywords: remote laboratories, inclusive education, technologies in education, competence development.

1. Introduction

The information and communication technologies (ICT) respond to the standard that was proposed by the United Nations (UN, 2018) in 1993, which declared as its instrumental basis the decision to provide opportunities for people with disabilities, the Information and Communication Technologies (ICT), are simply tools for social inclusion, not surprisingly, UNESCO has formulated the GIFIICT (Global Initiative For Inclusive Information and Communication Technology) as a sustaining platform for change for the disabled population [1].

Likewise, the development of the ICTs has facilitated the population with disabilities to be able to reach the services and aids that are minded for this purpose [2].

Nowadays, it is necessary for the students to have technology studies integrated in the curriculum, so that the individual can face and solve the problems coming in the future; their learning must be framed in the management and construction of their own knowledge. This is how variables to the detail of the classroom itself take place, such as the establishment of flexible study schedules and the fact that there is a provision of time and space for a favorable exercise of practices and/or laboratories [3].

There are several projects of remote laboratories in different places and universities in the world, that are available to develop guides for different curriculum subjects that help to obtain results in real time. In the Colombian context, some universities have developed laboratories, but there is no evidence whatsoever showing the incidence of their use [4].

This article seeks to show the impact caused by the use of the remote laboratory of electric field and equipotential lines, designed and developed at Universidad Libre as a tool to support the teaching-learning process in inclusive education [5], and to analyze how technology can help people with special needs [6]; For its better understanding, it has been organized as following: section 1 presents the theoretical framework and the state of the art; section 2 (Materials and Methods) explains how the impact has been studied, and the analysis process is described; after that, section 3 (Results) shows the results of the study; section 4 (Discussion) presents the discussion and contributions of the findings; and finally, the conclusions are established.

Disability in Colombia

Taking a demographic space as reference, according to the DANE figure 1, out of 2.9 million people that segment:

- Visual impairment: 1.2 million.
- Speech and hearing disability: 500 thousand.
- Cognitive disability: 340 thousand.
- Motor disability: 280 thousand.
- Other manifestations: 580 thousand.

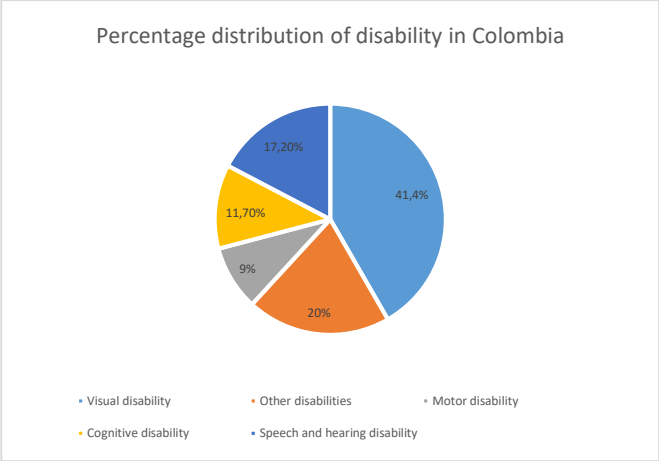

Figure 1. Percentage distribution of disability in Colombia

Source: Data from DANE / Minsalud 2018.

The appropriation of the advantages of the information and communication technologies by the disabled population, dimensions the impact or the weighted transformation of the level and quality of life, and even better, the access to education.

State of the art

In order to identify some of the existing remote laboratories [7] developed for different purposes, we carried out an analysis of the state of the art, finding the following:

- e-Laboratory Project: one of the pedagogical characteristics of this project is the developed portal; each remote experiment is accompanied by a series of supports, namely motivation, physical background, an experiment guide, a description of experimental arrangement, and access to the remote experience.
- WebLab-Deusto: among the educational supports, it offers user guides, technical manuals, description of each experiment, and videos that show the execution of the experiences.
- Physil@b: as a pedagogical support in this project, they developed a book called PHYSYLAB. It includes concepts and exercises that integrate the theoretical foundation, conventional practices, virtual laboratory, and remote access practices, which is a very interesting pedagogical complement in the teaching of physics.
- Remote Laboratory from the UNR: in this remote laboratory, one can make measurements of electrical parameters, and it allows the analysis of real semiconductor devices by curves.
- UNEDLabs: this portal from the Universidad de Educación a Distancia (UNED) in Spain, uses the notification of services by email, instant messaging, news, and forums, as an educational support, allowing

interaction and collaboration between students and teachers.

There are a large number of remote laboratories developed throughout the world, focused only on didactic-pedagogical issues, but not with inclusion; it should be noted that most of these laboratories already offer educational guides and diverse support material for the students to carry out the experiences. In this case, it is relatively important to manage it, although there has been an important advance, we still consider it insufficient, so that these resources are used to promote relevant and inclusive learning.

2. Materials and methods

The systems engineering program of Universidad Libre - Bosque Popular branch in Bogotá, designed and developed the remote laboratory of electric field and equipotential lines, which is used as a tool in the course of Electricity and Magnetism of basic sciences in the Systems, Industrial, Environmental, and Mechanical programs.

The objective of the remote laboratory of electric field and equipotential lines is to experimentally determine the electric field lines for a particular configuration of electrode and verify the dependence of the shape of the electric field lines.

Given a configuration of electrical charges distributed on a conductor, there are sets of points that are at the same potential and that if the equipotential surfaces of a given configuration of charges are known, it is possible to find, out of them, the electric field lines that are generated by the configuration.

This control over the laboratory is done through the Internet [8]. Currently, users can experiment on: determining the electric field lines, maximum potential difference.

The architecture of the laboratory follows the client/server model, as shown in figure. 2. The web server is supported by the services provided by Universidad Libre, which is connected, on the one hand, to the network so that it can serve the students, and on the other, to the laboratories.

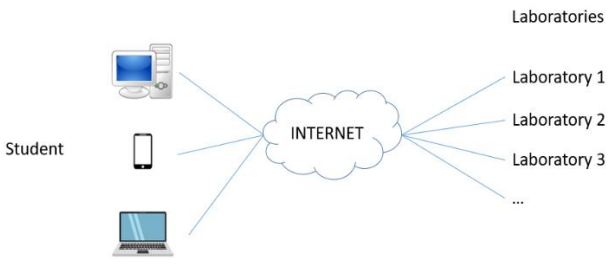

Figure 2. System architecture.

The electronic device (Lab) was designed and implemented as follows:

- It is capable of moving the tip of a multimeter on a conducting paper in two horizontal and one vertical axes.
- The data are generated and displayed in real time, according to user's requests.
- It is able to interpret user's orders and move the tip of the multimeter to the desired coordinate (position).
- It has a camera for live transmission of its movement.
- The conductive paper on which one works has certain points to which the tip of the multimeter must be transferred, its accuracy is vital for the correct development of the laboratory.
- Every time a student finishes his laboratory, the tip of the multimeter returns to its initial position, and the generator voltage returns to zero.
- The voltage generator of the electronic device is capable of varying its voltage (from 0 volts to 24 volts) according to the instructions given by the user.
- All the data that is generated by the electronic device is stored in a database.

As a complement to the management of the remote laboratory [8] some tools are developed and implemented, as following:

Backend, MySQL, VNC Viewer, DNS Raspberry Pi 3 Model B - Motherboard. While online, the server is responsible for managing remote requests and administrate the laboratories in real time. The server has the possibility to monitor the running laboratories in real time, and to monitor the students that are connected, their connection point (IP address), Frontend. Languages such as HTML5, PHP, JavaScript, and CSS were used.

Operation: for the use of the laboratory, the user guide that is provided states the following:

- The principal registers the teachers.
- The teacher registers his course on the website and uploads the list of students to the course.
- The student logs on the website with his username and password, all the information corresponding to the electric field and equipotential lines laboratory is presented here, practice guide.
- The student schedules the time and date to use the laboratory.
- The student performs the practice, through the website, which connects to the laboratory device and can provide the data in order to perform the process, the device delivers results, digital and visual, in real time.
- The student does the analysis of the data and keeps the guide that has been developed within session.

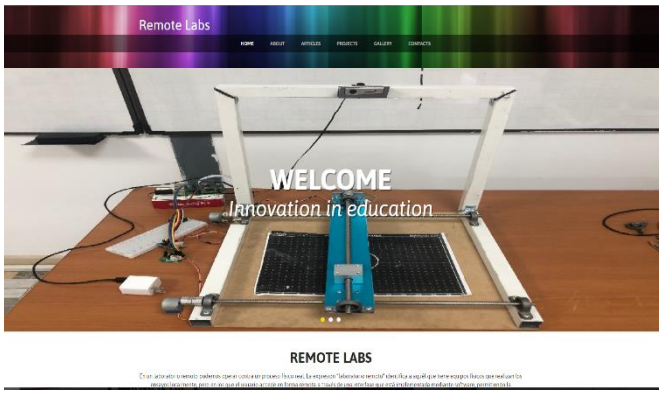

Figure 3. Main screen of the laboratory of electric field.

Evaluation of the Laboratory

The collection of the data was obtained by means of a survey with five specific questions and was carried out at the end of each of the day and night groups in the Electricity and Magnetism course, during the semesters 2018/1, 2018/2, 2019/1.

It was also applied to students with physical diversity in lower limbs who are enrolled in the engineering faculty.

A comparison between current grades and the grades from the semesters prior to the use of the remote laboratory was made.

The rating value was scored from 1 to 5, the questions that were used are shown in table 1.

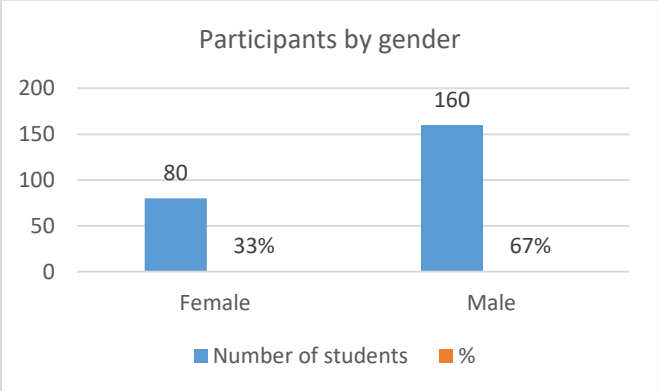

Figure 4. Number of Participants by gender.

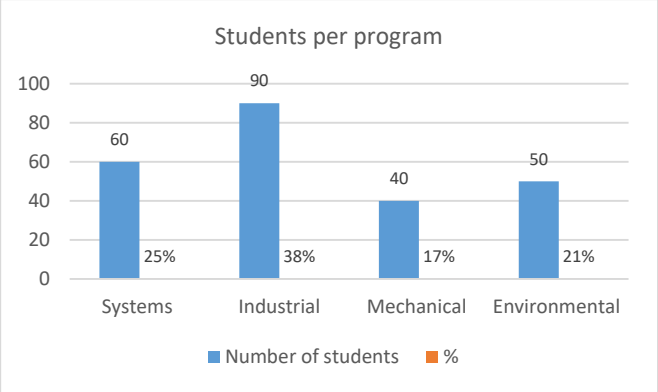

Figure 5. Number of students per program.

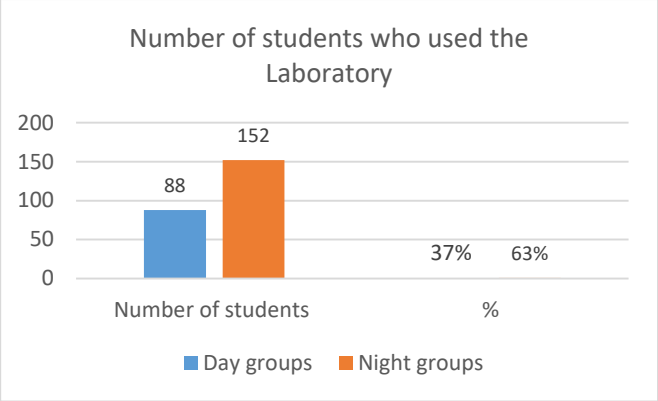

Figure 6. Number of students who used the Laboratory.

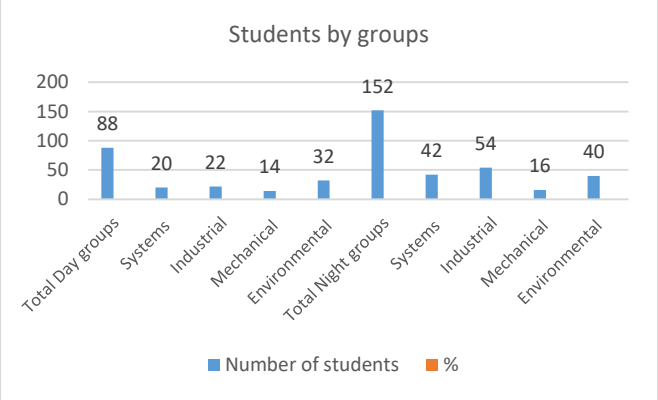

Figure 7. Number of students by groups.

Table 1. Questions that were used.

Electrical Physical Subject	
1	Is it easy to use?
2	Has it helped you with the course?
3	What do you think about the management of data?
4	What is your level of satisfaction?
5	Would you like to have more laboratories available?

3. Results

Figure 8 shows the global position of the answers that were obtained in the three academic periods, distributed by groups.

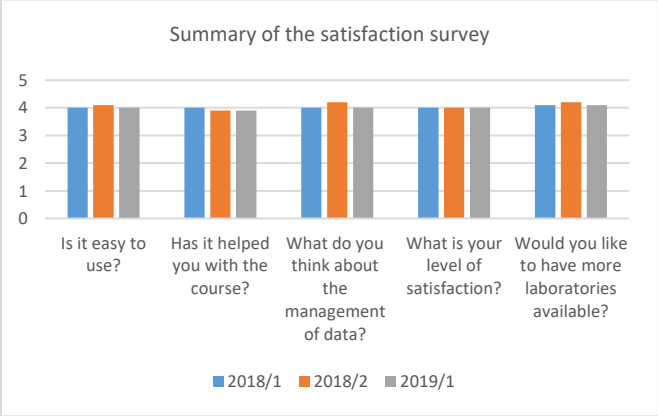

Figure 8. Summary of the satisfaction survey.

The answers of the students in the day group and the night group are similar in the three academic periods. Students evaluate the laboratory with a value greater than 4.0, which is constant in all semesters and groups. It is observed that the night groups believe the laboratory has helped them with the course; while there is a smaller proportion in the day groups expressing the same. For the management of the data, the students find that it is positive (4.0); it is indicated that the laboratory handles variables of positive and negative charges, voltages, amperages, and AC power.

The usefulness of the laboratory is evaluated, the assessment of the students is higher than (4.0), in all the academic periods and groups. In this case, the students would be willing to use another laboratory, as the answer is positive one can observe that they would be willing to use another laboratory again.

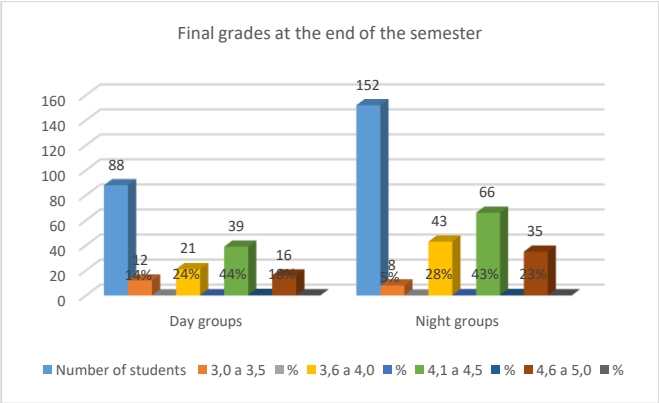

Figure 9. Final grades at the end of the semester.

In order to describe the impact caused by the use of the remote laboratory of electric field and equipotential lines in the course of Electricity and Magnetism, figure 9, we analyzed the variation of the average grade, with respect to the history of grades for the same subject in previous semesters. It was observed that the approval rate rose to a range of 3.6 to 4.5 with a percentage of 24% in the day group and 43% in the night group. Also in the range of 4.6 to 5.0, it is seen that the response was better in the night group, with 35%.

It is important to note that there is no registration of lost semesters during this time, as there were for previous semesters with a percentage of up to 10%.

4. Discussion

From the results that were obtained in the survey of the students with physical diversity in lower limbs, the results from the general survey, figure 8, and the sample of average grades in figure 9, we have:

We present the findings during the academic periods and also built an experience focused on evaluating students who present some physical diversity in lower limbs and who are enrolled in the engineering faculty; in order to evaluate the functionality of the remote laboratory through the opinion of the students about its use. This experience involved the development of the laboratory practices using the remote environment. All connections to the server were external to the campus.

In addition, to the question Is it easy to use?, 85% of the interviewees said yes; to the question Has it helped you with the course?, 95% said yes; as per What do you think about the management of data?, 81% thought it met the requirements; to What is your level of satisfaction?, 87% of the interviewees feel satisfied; and to the question Would you like to have more laboratories available?, 100% of the interviewed students

agree that it is a tool that can improve their quality of life and help their performance in the different subjects they study.

With regards to the impact, a comparisson between definitive grades and the grades from previous semesters was made.

In general, the students showed a positive attitude and have stated that the remote laboratory of electric field is very intuitive and easy to use. They highlighted the ease of working practices in the remote laboratory, and they also believe that class work should be taken out of the classroom and supported by autonomous practices as the main input to independent work. They emphasized the help obtained with the grade they achieved. Several students confessed to having had a new and also interesting experience, which has allowed them to expand their vision about the possibilities that there are in the Internet.

5. Conclusions

In each of the analyzes of data and in the article, we have seen the possibilities that remote laboratories have as support tools in the new teaching-learning and inclusion processes. As a complement, it can be said that we are still obtaining values and working over time, and the conclusions are:

- Since they are students from the engineering faculty, they see remote laboratories as a new opportunity.
- Students with Physical diversity in lower limbs believe that, for them, it is a tool that can improve their quality of life and help their performance in their different courses.
- Students would be willing to continue using other remote laboratories.
- Remote laboratories in Universidad Libre are now considered as vital tools in the teaching-learning process.
- Remote laboratories are conducive for universities to expand their inclusive education as they generate new horizons in engineering education, because it broadens opportunities and moments of experimentation.
- Maintenance costs are relatively low compared to a real laboratory.

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