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# DESIRABLE FEATURES IN A PHYSICS REMOTE LABORATORY: USERS' OPINIONS

***Carlos Arguedas-Matarrita[I], Sonia Beatriz Concari[II],***

*[I]Universidad Estatal a Distancia, San José, Costa Rica (carguedas@uned.ac.cr)*
*[II]Universidad Nacional de Rosario, Rosario, Argentina (sconcari@gmail.com)*

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**ABSTRACT*:* By acknowledging experimentation as an essential activity in the physics educational field and the potential of Remote Labs (RL) to encourage learnings, the present work shows a study to determine the technical and educational requirements that RLs to be developed at Universidad Estatal a Distancia in Costa Rica (UNED) should be provided with from the point of view of the potential users. Therefore, UNED students who would use RL to be designed at the university were inquired through a questionnaire. The replies of students taking part lead to recommend that RLs to be developed must meet, among others, the following requirements: to be reachable from mobile devices, with clear instructions, and supported by video tutorials and instructional materials in a way that the use and exploitation of the resource leads to an accurate learning process.**

**KEYWORDS*:* Remote laboratories, experimentation, distance learning.**

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**1. INTRODUCTION:** The Universidad Estatal a Distancia in Costa Rica (UNED) is distinguished by its pioneering in Distance Learning in Latin America. Since its foundation in 1977 the university has used different means of communication to assist the teaching and learning processes; however, despite the existence of resources for the distance teaching of physics as the so called Remote Labs (RL), so far, the institution does not have a RL of its own.

With the aim of developing a RL of its own, a several-phased research process has been carried out at UNED: firstly, projects which have an experiment of remote access in the teaching of physics have been shown [(1), (2)], following the description of the technological and instructional features of these projects (3) and the present work shows a study to determine the technical and educational requirements RLs should be provided with from the point of view of the potential users. Therefore, students at UNED who would use RLs designed by the institution have been interviewed.

**2. RESEARCH AREA:** The research belongs to the field of knowledge of the teaching of Physics through technologies. Particularly, the use of RLs as educational resources through which students can access real equipment and carry out online experiments via Internet by using a computer or, in some cases, a mobile device. Due to the nature of UNED, this resource based on Information and Communications Technologies (ICT), is shown as a complement of classroom and virtual laboratories used in the teaching of Physics in this institution. The possibility of extending access to laboratory work for students who are unable to attend a conventional laboratory for a variety of reasons is a research area of interest (4).

**2.1. EXPERIMENTATION:** Experimental work in the teaching of physics is an unavoidable activity which fosters in the student several abilities, which contribute to the development of the competences required by a professional of sciences and engineering: ability to measure, control variables and modelling; conceptual understanding and interpretation of different ways of representation, in such a way that they can merge the conceptual and the phenomenological aspects (5).

Although in experimental work different goals are kept, Franco, Beléndez and Ablanque (6) point out the following: (…) a) to offer a wide and general experimental training, introducing students to lab work with important matters to any experimental subject such as the acquisition of measures, the treatment of experimental data, error calculation, graphic representations, data acquisition and report writing and b) to serve as "display" of the topics of Physics studied during the lecture as well as of problems (p.51).

Nowadays ICTs offer a wide range of tools that, integrated into several teaching activities, ease learning; two of these technologies are virtual as well as remote labs. The latter allow for real experimentation by using a computer with Internet connection, thus completing the experimental work of physics.

**2.2 REMOTE LABORATORIES:** The virtual lab consists of (7) "an interactive multimedia tool which is useful to improve and to complement the learning process" (p.63). It deals with software which simulate the behavior of a hypothetical or a real system; in the virtual lab the user can control variables and analyse what is going on with the phenomenon under study when carrying out these changes. At UNED it is suggested that virtual labs (8) "(…) must have theoretical, procedural, experimental and tasks-to-do assignments components. Besides, they must favour exploration, correlation and comparison of phenomena and principles" (p.110).

For their part, RLs are technological tools that integrate software and hardware in order to shape a real experiment remotely available through Internet or through academic networks (9). The student can use the RL to carry out laboratory activities similar to the ones developed in a classroom (hands on) laboratory, but with the distinction that these are carried out remotely.

The impact of RLs has been so important that they have been considered as part of the five important changes over the 100 years of Engineering Education (10), due to the positive contribution they are having in the educational field.

In the syllabuses of remote technological and scientific training, such as the ones offered by UNED, the time to carry out lab practices is now reduced to face-to-face instances; students must move to UNED University facilities, on dates and timetables established beforehand, generally at weekends, which implies costs and other inconveniences faced by those who choose a distance learning programme. In this context, it is necessary to find options in order to strengthen experimental work with this modality. In this regard, researchers at Singapore University predicted, twenty years ago, that remote labs would mean an important step in distance education (11).

**3. METHODOLOGY:** In order to comply with the aim of the present research, students at UNED who have physics courses in their curriculum were given a questionnaire. These students belong to the careers of Natural Sciences Teaching (N=509) and Industrial Engineering (N=83). The questionnaire was carried out in a self-administered way by using the *Google Drive Questionnaires* tool. The questionnaire was sent through the virtual platform of the course and via e-mail, asking for the reply as collaboration for the present study. Data collection was done between May and July 2017.

**3.1. INSTRUMENTS:** The questionnaire consisted of 13 questions, grouped in three parts: General information, Connectivity and Remote Laboratory. The instrument was submitted to a validation process through expert judgement, which is defined (12) "as an informed opinion of people with background in the field, renowned by others as qualified experts in it, and who can supply information, evidence, judgement and ratings" (p.29). In order to be selected, experts were considered to meet some of the following requirements:

- To be linked to educational research.
- To be experts in the teaching or Physics and/or Engineering.
- To be experts in the teaching of sciences.
- To be linked to the development or use of a RL.

In this process eleven experts from: Argentina, Brazil, Costa Rica, Cuba, Spain and Mexico took part.

The analysis of multiple choice answers to the questionnaire was carried out with the SPSS-17 programme, whereas open compulsory questions were analysed with the ATLAS.ti-8 programme, for which entry categories were defined in such a way that they would allow for the grouping of students' replies.

In order to establish the independence among statistically significant variables a $p \leq 0.05$ value was used by using the Chi-square test or the Fisher's exact accordingly (13).

**4. RESULTS:** A statistically significant sample of the population (N=592) was obtained, since 172 students took part, with 95% level of confidence and 7% level of uncertainty.

**4.1. GENERAL INFORMATION:** Students are registered in 31 University facilities, out of the 37 facilities UNED has all over the country. The students from the sample come from the UNED university facilities spread all over the country, however, except for the tutorships offered at the San Isidro facility, in the south of the country, the other facilities which offer tutorships are concentrated in the central region of Costa Rica and many students from the sample have to travel long distances in order to attend classroom tutorships.

According to the career the students from the sample are enrolled in, 89.5% (n=154) belong to the Teaching of Natural Sciences career and 10.5% (n=18) belong to Industrial Engineering.

According to the data obtained in the Admissions Statistics System of the UNED, the ratio of students enrolled in each career is proportional to our sample. Teaching of Natural Sciences has 509 students enrolled, while Industrial Engineering has 83 students. This corresponds to 86.0% and 14.0% respectively.

**4.2. DEVICES TO ACCESS THE VIRTUAL ENVIRONMENT:** In order to establish the different devices students have, a multiple choice question in which students had to choose the devices they use to access the learning management system of the course was put forward; the result obtained was that 85.5% (n= 147) use a laptop and 70.9% (n= 122) use a smart mobile phone or Smartphone and, a lower percentage, use a desktop computer (25%) and tablets (9.9%). It should be noted that most students have more than one device to access the course: 130 students have more than one device and only 8 students have only a PC desktop for Internet connection. These results are shown in Figure I.

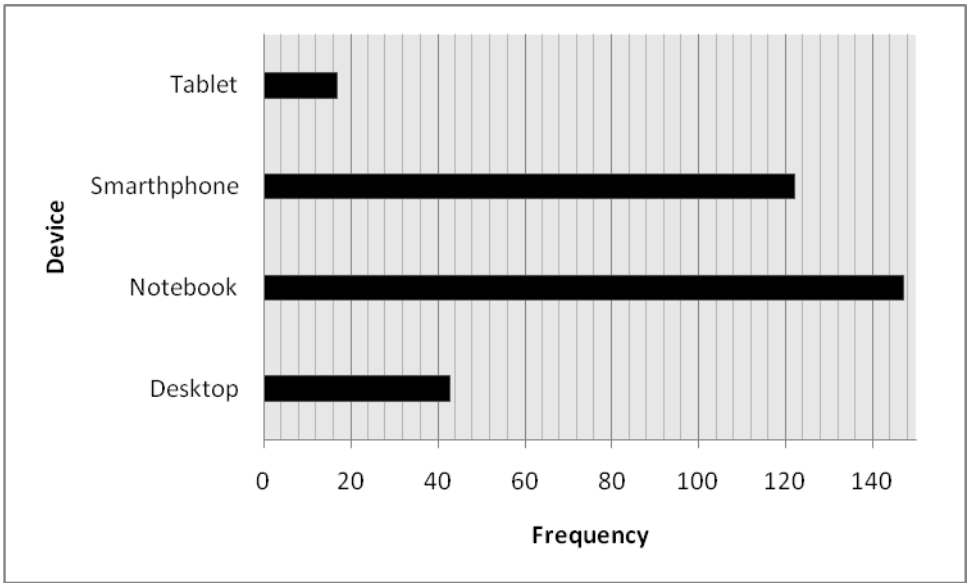


Fig I: Devices students use to access the environment of the course

It can be inferred from Figure I that students from the sample who have a desktop computer are just a few in relation to the ones who have a laptop or a Smartphone. This is a growing trend among young people to have mobile devices.

**4.3. REMOTE LABORATORY:** Before answering the questions put forward about RLs, the people surveyed were asked to watch a video that explains what a RL is, with the aim of avoiding confusing this resource and a virtual laboratory**.**

Among the results it is pointed out that 57.0% (n= 98) did not know anything about these resources whereas 43.0% (n= 74) did know; however, only 34.9% (n= 60) had used a RL at some time before.

About the career in which students from the sample who have used a RL are enrolled, the result was that 98.3% (n=59) belong to the Teaching of Natural Sciences. Results are shown in Table I.

| **Question** | | **Career students are enrolled in** | | |
|---|---|---|---|---|
| | | **Teaching of Natural Sciences** | **Industrial Engineering** | **Total** |
| Have you ever used a Remote Laboratory? | No | 95 | 17 | 112 |
| | Yes | 59 | 1 | 60 |
| Total | | 154 | 18 | 172 |

Table I: Use of RL according to the career they are attending.

It was obtained that the use of RL is connected to the career in which the student is enrolled ($p$=0.006); this finding might be due to the fact that in the Teaching of Natural Sciences career RLs have been used since 2014 in two different courses while in the Industrial Engineering career it was used for the first time in 2016, so it is expected that the fact of having used a remote experiment is associated with the career: over one third of the students attending the

Teaching of Natural Sciences career (38.3%) have used a RL before, whereas only one student attending Industrial Engineering (5.5%) has.

Besides, each student from the sample was asked to identify three difficulties he had (or he considers he might have) when working with a RL; answers to this question are shown in Figure II.

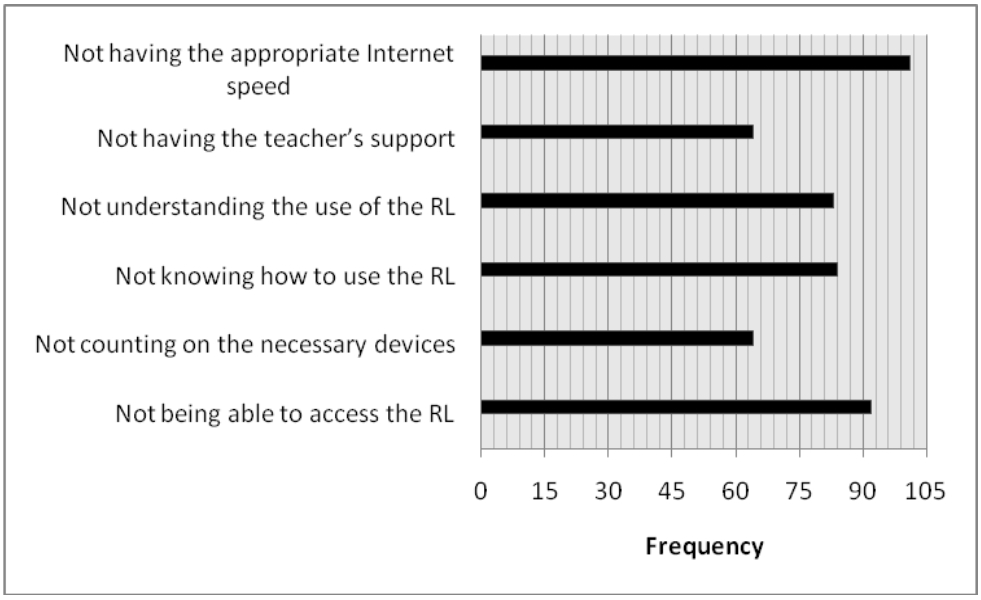


Fig II: Difficulties students had, or they consider they might have when using a RL.

Figure II shows that the options offering the highest percentages are the ones related to connection speed, being this problem that arises in some areas of the country.

The other difficulties observed are related to matters of teaching and learning; different actions can settle them, such as an appropriate teacher's support in the virtual platform as well as in classroom tutorships or by planning virtual tutorships, since UNED has tools for this kind of interaction that may help strengthen the use of these resources in distance learning. In this regard, Culzoni (14) points out that a good interaction between students and tutors helps solve problems that arise during the course in these educational resources.

Table II shows the distribution of the replies shown in Figure II and the fact of having used a RL or not.

| Accounts for replies | Has used a RL before | | Total |
|---|---|---|---|
| | No | Yes | |
| Not understanding the use of a RL | 50 | 33 | 83 |
| Not being able to access the RL | 51 | 41 | 92 |
| Not knowing how to use a RL | 32 | 18 | 50 |
| Not having the teacher's support | 46 | 18 | 64 |
| Not having the appropriate Internet speed | 72 | 29 | 101 |
| Not having the necessary devices | 53 | 11 | 64 |
| Total | 304 | 150 | 454 |

Table II: Difficulties that students have or may have in connection with the previous use of a RL or not.

It has been noted that there is a statistically significant association ($p$=0.005) between the replies and the options and the fact of having used a RL before or not. Table II shows that in the replies of students who have used a RL the highest frequencies are shown for the options: Not being able to access the RL (f=41) and Not understanding the use of a RL (f=33); these are typical difficulties of the RL used, in which students had to set up complements and update the JAVA programme in order to carry out the suggested practice, which caused problems when accessing the RL environment (15).

Worries showing higher frequency among students who have not used a RL before are not having the appropriate Internet speed (f= 72), not having the necessary devices (f=53) and not being able to access the RL (f=51), aspects that are linked only to technical matters.

In the option "Others" for that question several different difficulties are mentioned. The following are some:

- *That there is not enough time to do it.*
- *It affects its development if it is in a different language.*
- *The ones I used at UNED are terrible; access is difficult.*

- *That the RL equipment does not work, e.g., the Webcam.*
- *When failing the connection during the practice, results are not saved, and it is necessary to start all over again.*
- *One problem I had when using it is that in the computers available at the facility the required complements cannot be downloaded.*
- *Not being able to develop them on the mobile phone, since where I live, there is neither Internet access nor electricity, only the mobile phone and these cannot be carried out on a mobile phone.*
- *Instructions are not clear, the RL I used is very difficult to use, I did not like it.*

In order to solve some problems that may arise when using a RL from the users' point of view, students were asked to choose three features that they would like a RL at UNED to have. Figure III shows the distribution of answers.

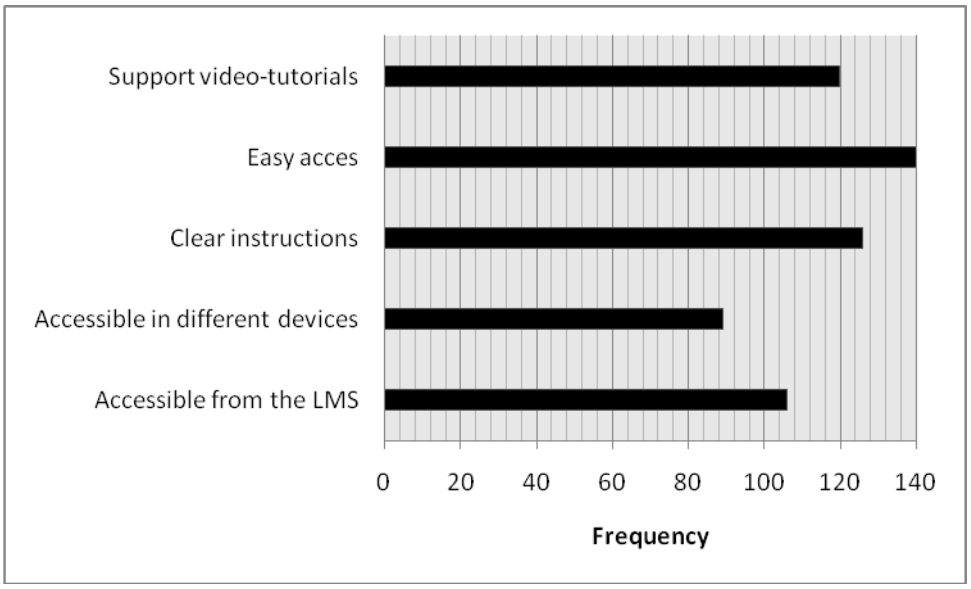


Fig III: Desirable features for the RL at UNED

The most frequently mentioned feature is the one referring to access friendliness (n=140), which equals 81.4%, followed by clear instructions with 73.3% (n= 126), containing support tutorial videos was pointed out by 120 participants (69.8%), accessible from the virtual platform and from different devices showed percentages as high as 61.6% and 51.7% respectively. Besides, other features students would like RLs to show were pointed out. The following are some of them:

- *Continued tutor's support.*
- *That it is as real as possible.*
- *That it is accessible not only on different devices, but also on different Internet search engines, and that it is also possible to see from the computer what is going on without having to fulfill difficult procedures on the computer in order to activate the remote camera (besides I have some time tried to visualize it and no matter how hard I try it never allows me to, which turns the laboratory into just a programme without real experiment).*
- *A functional webcam to observe the experiment and not only to obtain data.*
- *That instructions as well as commands inside the RL are shown in Spanish.*

Finally, it was asked: Do you consider it is important to use technological resources in experimental work during your university training? Why? The results were: 87.0% (n= 150) showed they do, whereas 12.0% (n= 20) answered only occasionally and only 1.0% (n= 2) considered it is not important.

Students, who answered "No", think it is important to use technological resources in experimental work and they put forward the following reasons:

- *Although it is good to know and to use technological resources, these are very difficult to use.*
- *They do not allow us to touch or interact with the equipment.*

In order to analyse the positive answers about the use of these resources, the ATLAS.ti programme was used. For that purpose, entry categories which are shown in Table III were defined with the corresponding results.

| Category | Frequency of appearance |
|---|---|
| They allow for the updating of the teaching and learning process. | 45 |
| They encourage learning. | 37 |
| They prepare for future professional training. | 30 |
| They are a complement. | 30 |
| They simplify experimental work. | 23 |
| They are very visual resources. | 14 |
| They enable educational innovation. | 11 |
| They enable working from home. | 8 |
| Total | 198 |

Table III: Frequency of appearance of the defined categories.

According to the categories in Table III, the main reason noticed by students from the sample to use these technologies in teaching, is that they make it possible to update the teaching and learning process (f=45), they encourage learning (f=37), they are a complement and training for future professional practice and they are a complement. (f=30). It should be noted the ICTs make it possible to strengthen and update the teaching and learning process when they are used intentionally and with an accurate planning. In the case of RLs, in a recent study, Gómez, García & Díaz (16) determined that students consider the use of these resources to be useful in their training and besides they enable them to develop professional competences for a future job placement.

One aspect to be pointed out is that although the sample is made up of students from a distance learning programme, the category "They enable working from home" is the one that showed the lowest frequency.

**5. CONCLUSIONS:** Most students taking part have mobile devices to access virtual environments and to carry out their learning activities, which in many cases means the only possibility to access the virtual environment at UNED, therefore, RLs to be developed at the institution must satisfy these current needs of the student population in this institution and of distance learning in general.

The sample taking part hopes RLs are easy to access, mainly from mobile devices, with clear instructions and with the support of tutorial videos. In this regard, it is required to fulfill coordinated work for the design and development of RLs as well as of the support materials that will be given to students in a way that the use and exploitation of the resource allow for an accurate learning process.

Finally, since distance learning refers to planned learning which normally happens in a different place from the classroom, there is no doubt that RLs allow for the strengthening of this educational system since with them it is possible to carry out real experimental work without having to attend a classroom tutorship. Distance experimenting through RL reduces the number of compulsory movements of students from UNED to University facilities.

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