



Design of Virtual and Real Teaching Laboratory with On-Site and Remote Access to Exercises

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1. Introduction

Virtual laboratory exercises allow the academy to apply new educational models. In such models, students can perform teaching experiments in real laboratories, as well as remotely. These educational models offer a number of advantages to the students and academy in comparison with the traditional real laboratory format [1-5]. Virtual laboratories are expected to grow in number together with progress in technology and development of specialized hardware and software.

Virtual laboratories, in particular, allow the students to perform experiments with dangerous and toxic materials, train in working with complex devices, equipment and instruments, and reduce the time that the students spend on campus premises. Also, virtual laboratories promote self-learning and increase responsibility of the students for their own learning. From educational point of view, such laboratories are extremely useful and have immense potential.

At our Department of Telecommunications Engineering of the National Autonomous University of Mexico (UNAM) we were concerned by the lack of a teaching laboratory concurrent with or complimentary to a theoretical Optical Devices course. This optional course is taught at the 8th, next to the last, 9th semester of the undergraduate studies. The need for a teaching laboratory complementary to the specified course was recognized by faculty members, but there was neither floor space and equipment, nor staff available for traditional real laboratory with sets of equipment for each experiment. Such situation is typical for a number of other teaching subjects at our Faculty. In total, only 57 % of theoretical subjects that we teach at our Department of Telecommunications

Engineering have a concurrent teaching laboratory. On the other hand, there is an urgent need in integrating the theoretical knowledge with practical experience, so that our graduates meet the highest professional standards. While looking for a solution to this problem, we conducted a survey that was focused on the programming skills, computer infrastructure, and remote web-access capability of our students. The survey revealed that more than 95% of the students had a computer and connection to Internet at home (Fig 1), and almost 100% of our students knew the basics of Matlab and Java.

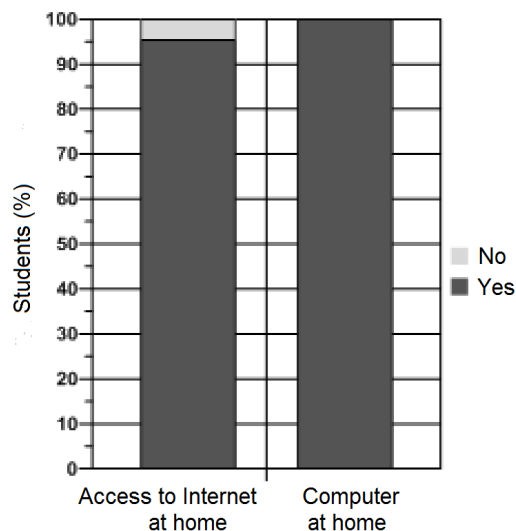


Fig 1. Remote access capability of the students.

Such conditions were very favourable for implementation of a virtual laboratory. At the same time, we wanted to have some degree of physical interaction of the students with real laboratory equipment, materials, and their direct interaction with teaching staff. Therefore, we decided to combine the virtual and real exercises in each and every laboratory experiment. We defined our objectives as follows:



1. To design a laboratory with virtual and real exercises that would allow the students to integrate the theoretical knowledge with practical experience in working with real materials, elements, devices, and measurement instruments;
2. To provide the students with learning environment that would enable them to handle real devices and equipment, perform experiments in the correct way, identify possible errors and faults in experimental setups, and adequately perform analyses and interpretation of experimental data;
3. To stimulate self-learning and responsibility of the students for their own learning by means of the new laboratory.

2. Design of new laboratory exercises

We elaborated new laboratory exercises by means of an iterative procedure comprising design, analysis, and optimization of the content. We defined the following features of each new exercise: 1. Objective; 2. Content; 3. Extension; 4. Originality; 5. Subjects to evaluate; 6. Time required for virtual and real part of each exercise. We followed the following principal steps in the process of elaboration of the experiments (Fig 2):

1. Selection of the objective, content and extension, considering the course teaching programme and career curricula;
2. Choice of computer interface content and development of such interface;
3. Publication of content on the laboratory webpage;
4. Testing, verification and evaluation of new exercises;
5. Making corrections and improvements in the new tools.

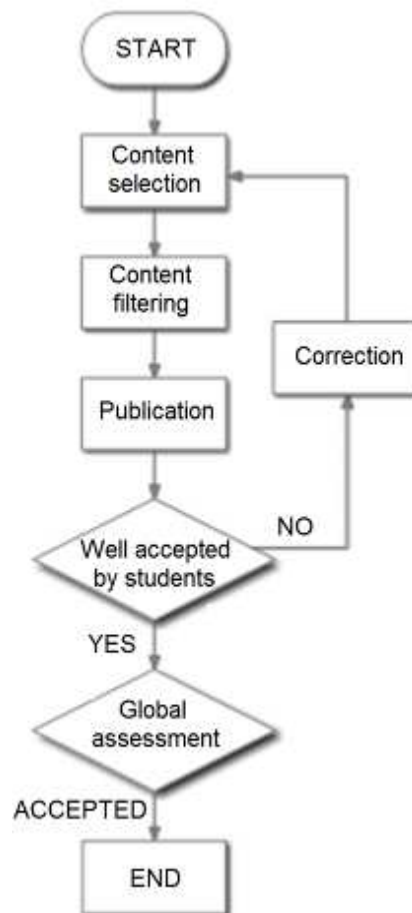


Fig 2. Design procedure flowchart.

Following is a brief description of virtual and real exercises on Optical Spectroscopy. The objective of these exercises consisted in learning the methods employed in optical spectroscopy, learning the constitution of laboratory spectrometers, such as used in optical communication technology, and obtaining experience in accessing optical emission spectra of semiconductor light sources and transmission spectra of solid and liquid substances.

The first stage consists in virtual pre-practice. The students access remotely the laboratory webpage with the following content:

- List of exercises with respective links
- Exercise protocols
- Complementary resources
- Exercise questionnaires
- Links to virtual and real exercise steps
- Link to Notes and Reports
- Link to Help and On-line Assistance.

The complimentary resources comprise images of diverse emission, absorption, and transmission spectra, light source datasheets, manuals and diagrams of spectrometers, etc.

The students that successfully pass the first virtual stage proceed to the real laboratory experiment. They employ the optical spectrum analyzer, optical circulator, optical attenuator, optical directional couplers, as well as some other measurement instruments and accessories (Fig 3). The students access the optical emission spectra of light emitting diodes and transmission and reflection spectra of optical devices, such as different filters (Fig 4).



Fig 3. Real experiment layout: Light source (1), Device under Test, DUT (2), (3) Optical Spectrum Analyzer, OSA (3), Computer (4), and Internet (5).

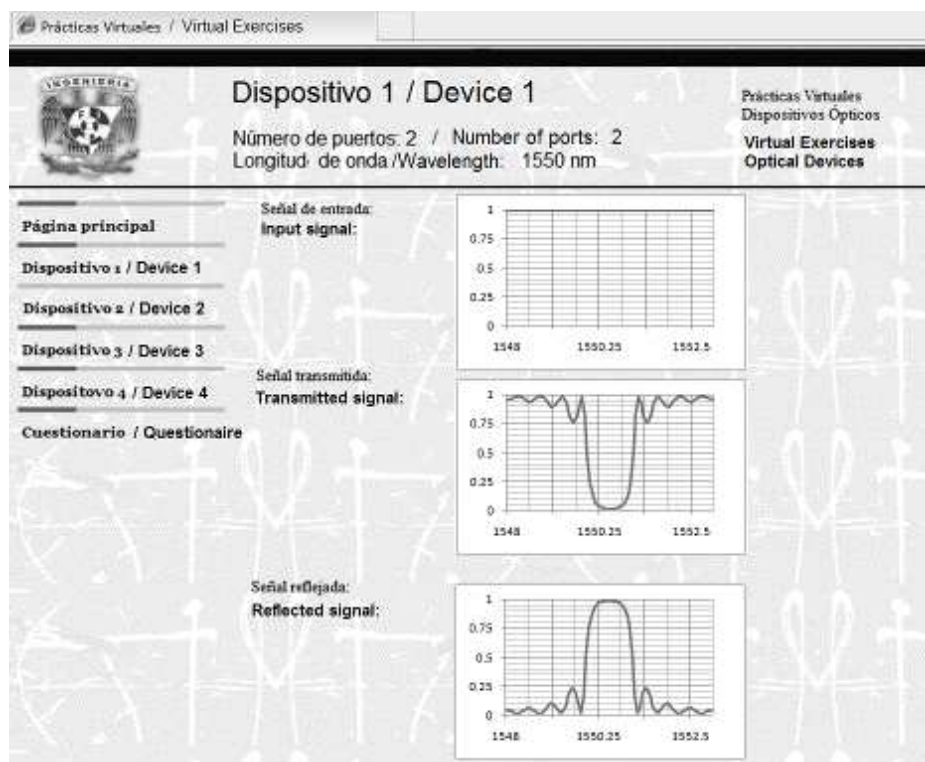


Fig 4. Virtual exercise interface: Investigation of transmission and reflection spectra of a Fiber Bragg Grating (FBG).

The third, final stage is post-practice with virtual and real elements. At this stage, the students can access some elements of the real experimental facility via Internet and repeat or perform more detailed experiments from home.

3. Educational outcome

All students enlisted in the Optical Devices course performed the new exercises without significant difficulties. According to our survey, the students highly appreciated the experience related to the characterization of modern optical elements, such as semiconductor light sources and Fiber Bragg Gratings, and in working with complex measurement instruments. Also, the students highly appraised more efficient use of their time in campus: 77 % of students performed virtual pre- and post-practices during free time and breaks between the lectures (Fig 5). Also, despite our intentions to promote self-learning and autonomy of the students, more than 80 % of them indicated that professor's close assistance was crucial for successful completion of the exercises. Under this condition, the virtual and real teaching laboratory with on-site and remote access to exercises had a significant positive educational outcome.

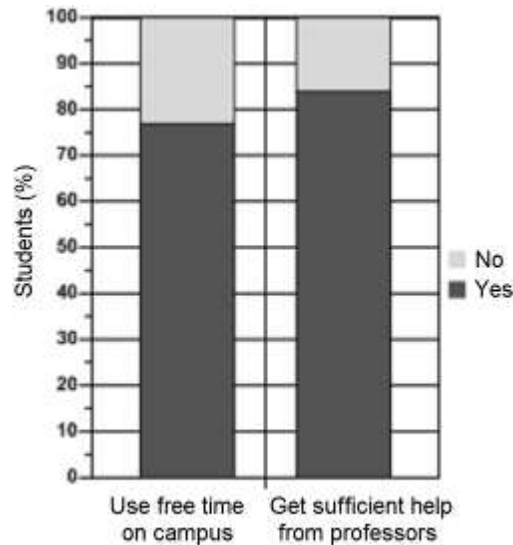


Fig 5. Final survey results.

4. Conclusions

We established a virtual and real teaching laboratory with on-site and remote access to exercises. The students performed virtual pre-laboratory exercises, real on-site work and remote post-laboratory experiments, data processing and interpretation, and elaboration of final reports. Such a laboratory can serve a large number of students. At the same time, the students learn how to characterize complex elements and devices, and how to use sophisticated laboratory equipment and measurement instruments rarely available in traditional undergraduate teaching laboratories.

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