Chapter 1

International Cooperation for Remote Lab use

Gustavo R. Alves[1], André V. Fidalgo, Maria A. Marques, Maria C. Viegas, Manuel C. Felgueiras, Ricardo J. Costa, Natércia Lima, Manuel Castro, Gabriel Díaz-Orueta, Elio SanCristobal-Ruiz, Felix García-Loro, Javier García-Zubía, Unai Hernández-Jayo, Wlodek Kulesza, Ingvar Gustavsson, Kristian Nilsson, Johan Zackrisson, Andreas Pester, Danilo Zutin, Luis Schlichting, Golberi Ferreira, Daniel de Bona, Fernando Santana Pacheco, Juarez B. Silva, João B. Alves, Simone Biléssimo, Ana Pavani, Delberis Lima, Guilherme Temporão, Susana Marchisio, Sonia Concari, Federico Lerro, Gaston S. de Arregui, Claudio Merendino, Miguel Plano, Rubén Fernández, Héctor Paz, Fernando Soria, Mario J. Gómez, Nival de Almeida, Vanderli de Oliveira, María I. Pozzo, Elsa Dobboletta, Brenda Bertramo

Abstract Experimenting is fundamental to the training process of all scientists and engineers. While experiments have been traditionally done inside laboratories, the emergence of Information and Communication Technologies added two alternatives accessible anytime, anywhere. These two alternatives are known as virtual and remote labs, and are sometimes indistinguishably referred as online labs. Similarly to other instructional technologies, virtual and remote labs require some effort from teachers in integrating them into curricula, taking into consideration several factors that affect their adoption (i.e. cost) and their educational effectiveness (i.e. benefit). This chapter analyses these two dimensions and sustains the case where only through international cooperation it is possible to serve the large number of teachers and students involved in engineering education. It presents an example in the area of Electrical and Electronics Engineering, based on a remote lab named Virtual Instruments System in Reality, and it then describes how a number

---

[1]The VISIR+ Project
Polytechnic of Porto, School of Engineering, Centre for Innovation in Engineering and Industrial Technology
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, PORTUGAL
visirplus@isep.ipp.pt
+351 228340532

of European and Latin-American institutions have been cooperating under the scope of an Erasmus+ project[2], for spreading its use in Brazil and Argentina.

Keywords—engineering education; remote labs; VISIR; community of practice; online labs federation

1. Introduction

Remote labs stand for physical apparatus connected to computer-controlled instruments able to be remotely accessed for carrying out real-world experiments. This definition leads to the expression "remote experimentation" which denotes the type of experiments that can be done in remote labs, in opposition to "virtual experiments", or "simulations", which can be done in "virtual labs". For a complete understanding, hands-on labs refer to physical spaces where users perform experiments by directly manipulating the instruments and/or apparatus under experimentation. The more recent expression "hybrid labs" refers to a sort of environment where parts of the apparatus under experimentation and/or the instruments connected to those apparatus are real, and other parts are modeled, i.e. correspond to mathematical and data models running on a computer. These two parts interact during the course of an experiment, hence the word "hybrid".

In historical terms, the value of experimentation in Science has long been recognized. For instance, the oldest Scientific Society in the world, the Royal Society, adopted the motto 'Nullius in verba' to "... *express the determination of its Fellows ... to verify all statements by an appeal to facts determined by experiment*." [1]. This spirit has also long been part of the training process of both scientists and engineers, as reported by Feisel and Rosa (2005) in [2]. In particular, these authors trace back the value of combining theory and practice to the very first engineering school in the United States, the US Military Academy, founded at West Point, NY in 1802 [2, p. 122]. Although majorly focusing on the role of hands-on laboratories in undergraduate engineering education, Feisel and Rosa (2005) also account for the provisions of both virtual and remote laboratories to that role.

The particular aspects of combining hands-on, simulated and remote laboratories into Science, Engineering, Technology and Mathematics (STEM) education are well discussed in [3] [4] [5]. These papers also acknowledge virtual and remote labs to be the two most recent environments where students may acquire and practice some of their experimental competences. Froyd et al. (2012) corroborate

[2] "*This project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein*"

this statement by rightfully classifying simulations and remote labs as part of one of the five major shifts in 100 years of engineering education, in particular of its 5th major shift, i.e. the influence of Information and Communication Technologies (ICT) in engineering education [6].

But while the generalized use of simulations in engineering education followed the widespread use of computers (70's), remote labs have a more recent history, mainly powered by the emergence of the World Wide Web (WWW) (90's) [7]. Other aspects impairing the large adoption of remote labs, when compared to virtual labs, are the associated development and maintenance costs, and scalability constraints [8]. In this chapter, we first briefly expand on this problematic and then present one strategy for spreading the use of remote labs in Brazil and Argentina, through an international cooperation project. This project involves a number of European and Latin-American higher education institutions, and is supported by the Erasmus+ program, under the Capacity Building in Higher Education action.

The remainder of the chapter is structured as follows: section 2 provides some background on the use of virtual versus remote labs, while also defining one particular application domain – experiments with electrical and electronic circuits; section 3 focus on one particular remote lab serving this domain; sections 4 and 5 deal with two crucial aspects for spreading the use of remote labs, i.e. nurturing a strong Community of Practice (CoP) and federating existing remote labs; section 6 presents two ongoing international projects around one particular remote lab: one project aiming to spread its community of practice in Brazil and Argentina and the other aiming to federate a number of existing nodes in Europe; and, finally, section 7 presents the conclusions and future perspectives.

2. Background

2.1. Scalability constraints

One possible direction for analyzing the scalability problem of virtual versus remote labs is to look into the dimension and hierarchical structure of an Engineering School or Faculty, while focusing on the practical educational component. At the very basis one has a single experiment. The dimensional aspect can be reduced to 1:n for simplicity purposes. Regarding hierarchy, one can consider: experiment – laboratory – course – degree – school – institution. Typically, n experiments are done in a laboratory, usually within a specific scientific domain or sub-domain, e.g. an electrical machines lab may accommodate basic electromagnetic experiments to demonstrate the basic principles of electrical machines, such as generators / motors (machines with rotating or moving parts) and transformers (non-rotating machine) to more specific experiments such as the electric efficiency of a motor coupled to a generator, or linear induction motors. A laboratory can then support one course or several courses. Those courses can be part of a single degree or belong to different degrees. An engineering school usually offers several degrees, e.g. Mechanical Engineering, Electrical Engineering, Civil Engineering, or Chemical Engineering, among other engineering degrees. Finally, one institution may have one single engineering school or several ones, depending on its dimension. An example could be a traditional university in Europe, located in a single city, with a single campus, or –in opposition– a federal university, in Brazil, with campuses located in different cities pertaining to the same state. Table 1.1 summarizes this simple overview.

Another dimensional aspect concerns the size of each heading, e.g. the student population attending one degree. One engineering school may offer more traditional degrees, e.g. electrical engineering with a numerus clausus of 1-2 hundred, alongside with more specific degrees, e.g. mechatronics or engineering cybernetics, which may just admit 20-30 new students every year. An example of this heterogeneous scenario is described in Marques et al. (2014), which analyzes application case studies of a particular remote lab [11]. In specific, the topic covered by that remote lab lasts from a minimum of 3 to a maximum of 14 weeks, while the number of students enrolled in the different courses ranges from 47 to 574 [11, p. 153].

This brief analysis paves the way to the scalability problem of virtual versus remote labs. While, for instance, one of the most widely known virtual labs in the whole world, i.e. the PhET Interactive Simulations, from the University of Colorado - US, reports (in 2013) over one hundred million (100,000,000) simulations done, after a period of approximately 10 years [12][3], a particular remote-controlled laboratory, considered the best one in its category[4], registered thirteen thousand accesses (13,000) in 2015, for a period of approximately 8 years [13]. To make it comparable, one user access to the Virtual Instruments System in Reality (VISIR) usually accounts for 1 to 10 experiments, i.e. every time a user clicks on the "Perform Experiment" button, one real, remote-experiment is done, hence the total number of experiments may be around 100,000 for the recorded number of accesses. Additionally, the numbers reported in [13] refer to 4 different VISIR nodes (i.e. servers), while the PhET Interactive Simulations are delivered through a single web location. Finally, VISIR supports remote experiments with electrical and electronic circuits (one specific topic, within electrical and electronics engineering), while PhET Interactive Simulations cover several scientific domains like Physics, Chemistry Biology, and Mathematics, among others.

---

[3] The PhET Interactive Simulations website, located at https://phet.colorado.edu, reports 360 million accesses in 06.06.2016.

[4] According to the Global Online Laboratory Consortium (GOLC), which granted this award, on its 1st edition (2015), to VISIR.

Table 1 A simple overview of the dimension and hierarchy levels related to engineering schools

	1	*n*
Experiment	May range from a few minutes to a complete class. Usually the number of experiments done in a single class depends on the degree year. Initial years may accommodate more experiments due to their relative simplicity and more advanced years may imply experiments that take more time to complete. The situation of experiments taking more than one class to complete is rare.	A set of experiments may form one class (one lab script), span over two or more classes, or form one comprehensive module about a specific topic (e.g. "Introduction to DC circuits" may have 10-15 experiments that will take approximately 2-4 weeks to complete). One module may take more or less time depending of being part of the core scientific degree area or not.
Laboratory	A laboratory may serve one course or several courses depending on its level (basic, intermediate, advanced). An example of a basic laboratory could be one allowing introductory experiments with electric circuits. An example of an advanced laboratory could be an "OptoElectronic Lab".	Although sometimes several laboratories are needed to support one single course (large number of classes, classes from different courses requiring the same laboratory, etc.), the usual situation is that a single degree often requires the support of several unique laboratories.
Course	The basic "educational unit" in many educational institutions. Each course typically comprises a number of contact hours, divided into theoretical and practical ones, and non-contact hours.	In a typical semester scenario, each degree usually comprises 4 to 6 courses, depending on the number of European Credit Transfer System (ECTS) units.
Degree	One degree may range from 6 semesters (180 ECTS) to 4 semesters (120 ECTS) depending on its level: undergraduate (BSc) or graduate (MSc). The number of students attending one degree varies quite much, depending on its scope (general, specific) and its level. Taking the example of the Polytechnic of Porto – School of Engineering, one degree may admit 20 new students (e.g. MSc in Computing Engineering and Medical Instrumentation) or 210 (e.g. BSc on Informatics Engineering).	The number of degrees offered, in simultaneous, by a single school depends upon several factors: geographical location, institutional history, type of institution (e.g. university / polytechnic), etc. Taking the same example, the Polytechnic of Porto – School of Engineering offers 14 degrees (undergraduate) and 12 masters (graduate). It is the number of degrees running at the same time that provides an idea of the school size, i.e. number of students, teachers, staff, laboratories, etc.
School	A school's size varies quite significantly. Taking the total graduate engineering enrollment numbers published in [9], it may range from 88 (Baylor University, Waco, TX, ranked #118) to 7,504 (Georgia Institute of Technology, Pasadena, CA, ranked #7), which means a scale factor of 85.	One institution may have one or more Engineering and/or Technological schools. One possible example comes from the Polytechnic University of Catalonia (UPC), Spain, which aggregates 12 STEM-related schools [10].

Although the observable simulated-to-remote experiment ratio of this example (in the range of 1:1,000) may be considered as just one possible case, non-representative of all possible comparative cases, the fact is that one simulation corresponds to running a given number of code lines, which can either occur at the server or client-side, depending on the technology used. A server with a processing power of hundreds to thousands of Millions of Instructions Per Second (MIPS) can thus deliver many simulations per second, whereas the time duration of a remote experiment is dictated by its physical nature. In the electrical and electronic domain, these experiments may typically take less than a second to complete [14]. However, one may quickly think of other experiments that may take several minutes to complete in the real world (e.g. check relationships between volume and amount of solute to solution concentration) and only a few seconds to simulate (e.g. https://phet.colorado.edu/en/simulation/concentration).

A final note on this topic concerns the access/delivery type of a remote versus a virtual lab. A remote lab can either work interactively or in a batch mode [15]. In the batch mode, a remote lab receives a request from a user, setups the experiment, runs it, and then sends the result(s) to the user. In the interactive mode, one single user is in control of the entire lab for the duration of a pre-defined time slot. There are remote labs that work on the batch mode, interactive mode, or both. An example would be a remote telescope. In the batch mode, a user defines a particular set of coordinates and filter lens and submits the request to the lab. The lab will accommodate the request on the first possible time frame and then send the result(s) to the user. In the interactive mode, a user will remotely control the telescope for e.g. one hour, changing its parameters in real-time, and obtaining the results in real-time.

2.2. Development and maintenance costs

The topic of development and maintenance costs, applied to virtual and remote labs, may be divided into its software and hardware components. While a virtual lab typically consists of a server (the hardware component) running the simulations (the software component), a remote lab may include more than one server, as illustrated in [16], the whole experimental apparatus –these two parts forming the hardware component–, and the several software layers that form the interface between the remote user and the apparatus under experimentation. The larger number of parts forming the hardware and software components of a remote lab, and the possible existence of consumables, are just two supporting evidences that remote labs present higher development and maintenance costs than virtual labs.

These higher costs, however, sustain the advantages of using remote experiments, in opposition to just using simulations, in the following cases:

- Simulation results may be quite different from the results of real physical experiments, for instance in mechanical engineering influences like vibration, torque, and friction cannot be studied and understood so well.
- In order to approach simulation results to real physical experiment results, developers try to improve the accuracy of mathematical and data models. However, this effort has two main drawbacks: (i) it implies higher development costs and (ii) higher computational power, either from the server or the client side. Concerning (i) one could consider the cost of placing online a simple real experiment of a driving motor coupled to a load, versus the cost of developing the most accurate model accounting for all physical variables present in this system and its environment (temperature, humidity, etc.). Respecting (ii), present m-learning scenarios, i.e. the use of mobile hand-held devices for teaching and learning purposes, still do not account for the possibility to run highly demanding applications, for two main reasons: a) very large applications require too much memory and time to download, and b) hand-held devices often present less computational power than portable computers.

On the other side, there are areas where the whole development is based on simulations (e.g. Systems-on-a-Chip), and the real experiments are the way to test, but not to develop. So in any case, both methods are needed in any solid engineering training.

3. The VISIR system

VISIR is a remote laboratory for wiring and performing experiments with electrical and electronic circuits. Basically, it replicates a laboratory workbench equipped with a digital multimeter, a triple DC power supply, a two-channel oscilloscope, a signal generator, and a solderless breadboard, similar to the one illustrated in Figure 1. This sort of workbench is similar in all engineering schools and faculties, for experimenting electrical and electronic circuits. A stack of boards acting simultaneously as a component store and a reconfigurable matrix, able to interconnect the components and the test & measurement instruments, emulates the solderless breadboard. Figure 2 depicts a VISIR system based on PXI-instruments. The basic characteristics of the VISIR platform were initially described by Gustavsson (2001) in [17] and then further explained in [18] [19] [20] [21] [22] [23] [24].

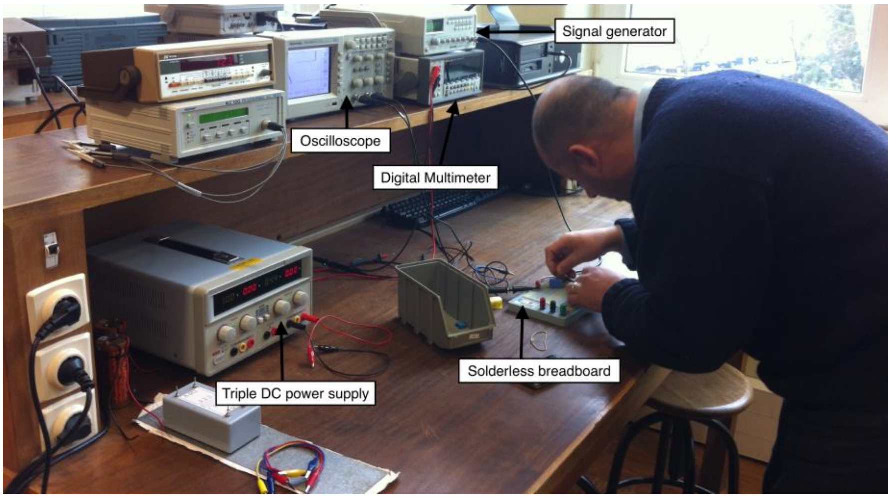

Fig. 1 A typical laboratory workbench for performing experiments with electrical and electronic circuits

If we consider the remote lab itself we can highlight some innovative aspects. Based on the interaction of a simulation of real equipment and real instruments at distance, VISIR creates a real electronic lab environment to the student, which can be accessed at any time and from anywhere as long as the student has a PC connected to Internet [25]. Within such environment, students interact with real instruments and electric / electronic components. They adjust the instruments and wire the circuits with their PC-mouse; then, the lab sends the measurement results to them, on their PC-screen. Students can also control stimulus (e.g. power supply voltages and input signals), using the PC-mouse.

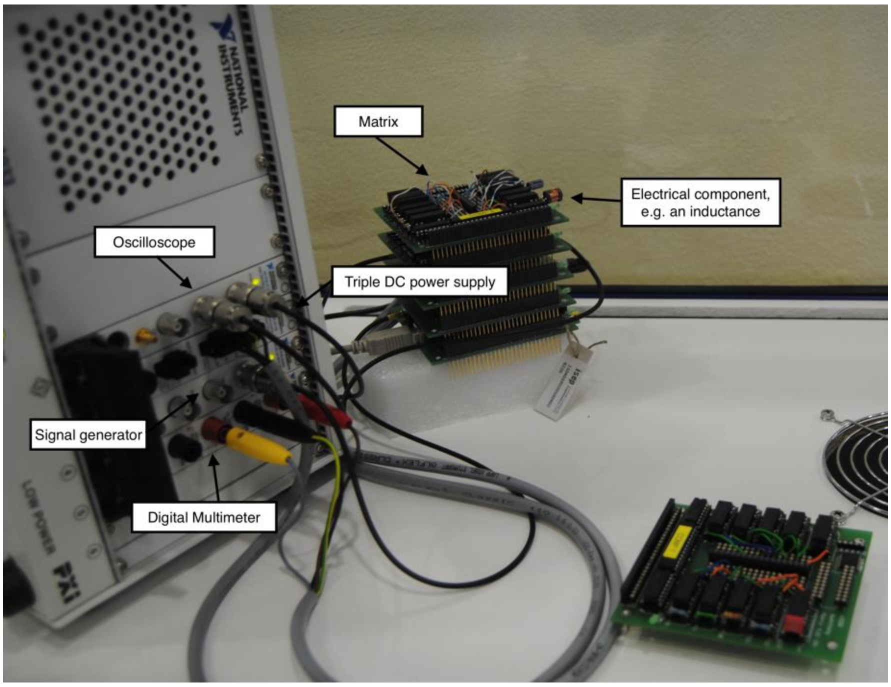

Fig. 2 Hardware component of the VISIR system – version based on PXI instruments

As a platform system, VISIR has its own web interface in which the lab contents are arranged and through which they are accessed. It contains many access and administration features such as: registration, log-in, booking, account types, etc. The availability of the lab contents depends on the user account type. Each user account type has its own features, privileges and limits. Some universities have integrated VISIR into their own Learning Management System (LMS), and/or their Remote Lab Management System (RLMS), allowing the use of the provided LMS services besides the lab work to create a rich integrated online educational platform. So, VISIR may be considered as a remote workbench, equipped with the same instruments that exist in a hands-on laboratory for conducting experiments with electric and electronic circuits. These workbenches are similar to each other, no matter of what part of the world they are being used for supporting lab classes with such circuits. This means VISIR has a universal and familiar interface that facilitates its usage. Its limited scope comes as an advantage, because all users immediately know what they are interacting with, either being students, teachers, or project partners.

4. Community of practice (CoP)

In brief, a CoP is a group of people informally bound together by shared expertise, a set of problems, or interest in a topic or fulfillment of goals [26]. In addition, a CoP focuses on sharing best practices and creating new knowledge to advance a domain of professional practice.

The formation of a CoP around VISIR was inspired by general discussions around the following question: “What is the added value of Remote Experimentation to Education?”. This question arose in a former collaborative research project named Remote Experimentation Network – Yielding an Inter-university Peer-to-Peer e-service (RexNet-yippee), which involved several Higher Education Institutions (HEI) from Europe and Latin America (LA) [27]. Although not completely answered, this question was partially addressed by the simple equation presented on Figure 3. In face of the difficulty in reaching a precise quantitative formula able to compute such added value, the proposed qualitative formula was simple enough to point directions on how to increase it. In simple terms, if one increases the educational value of a given remote experiment and, simultaneously, decreases its development and maintenance costs, then the resulting added value will increase.

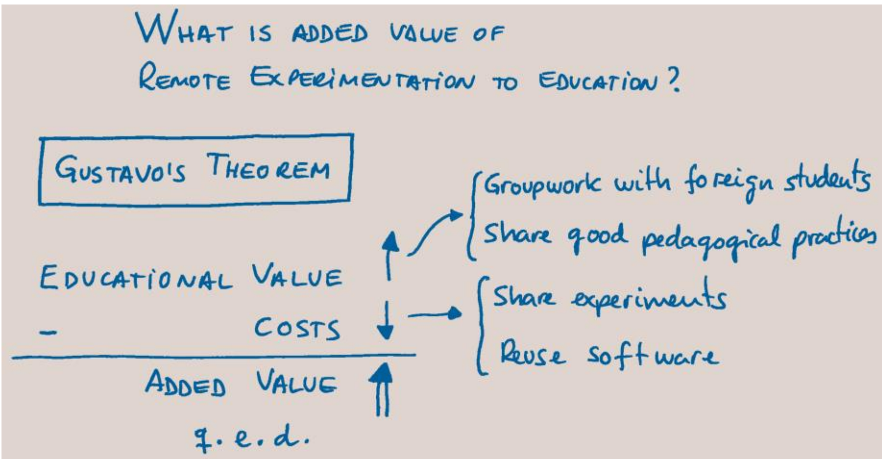

Fig. 3 A simple formula for evaluating the added value of remote experimentation to education [15]

The two guidelines suggested in the formula for increasing the educational value are in line with the objectives of a CoP. These same guidelines form part of a project proposal (VISIR+) submitted to the Erasmus+ program, for enlarging a CoP around VISIR with European HEI that already have this system and a number of Latin American HEI, which have a rich experience on the use of remote experimentation, but do not have VISIR. An important aspect that needs to be highlighted at this stage is that such collaboration implies a shared knowledge and interest in a given scientific area. In the case of VISIR+, this concerns the teaching and learning of electric / electronic circuits' theory and practice.

The CoP around VISIR actually started as a Special Interest Group (SIG) of the International Association for Online Engineering (IAOE), circa 2006. While initially gathering researchers interested in enhancing and spreading the VISIR system [18], it soon started to benefit from the input of a larger number of users, i.e. from teachers and students, and effectively growing into a CoP. The following list presents some of the results achieved by this CoP, in the past 10 years:

- A number of technical improvements in the VISIR hardware (the relay matrix) and software (the user interface) directly resulting from the received user feedback [11] [28].
- Developing a cheaper and equally reliable platform based on LXI-compatible instruments [29] [30].
- Outreaching a larger number of students and teachers, effectively helping in expanding the existing CoP. So far, approximately 50 teachers and 5,000 students have used VISIR, in particular considering its use in a Massively Open Online Course (MOOC) developed by the Spanish National Distance Education University (UNED) [31].
- Evidence of collaborative episodes involving teachers and students from different world regions, namely from Europe, Latin America, Middle East, and Australia [32] [33] [34] [35] [36].

But, in order to effectively support an even larger community, the simple existence of several VISIR nodes is not enough. The reasoning is simple and implies two directions: number of available experiments and number of students and teachers served in simultaneous. Considering all the experiments done with electrical and electronic circuits, in a single semester, it is clear that, even with a large relay matrix, one single VISIR system is unable to serve one single school. Considering a simple, yet widely performed experiment like an RC low-pass filter, it is obvious that one single VISIR system is unable to serve all engineering schools. The solution to this scalability problem is presented in the next section.

5. A federation of VISIR nodes

The two other guidelines suggested in the formula for decreasing the development and maintenance costs of remote labs are better understood within the conceptual definition of a federation. When sharing experiments, institutions may choose to: (i) simply open their access to anyone hitting the webpage where they are located; (ii) disseminate their existence (and access to) through a repository; or (iii) join a federation that allows some sort of Single Sign-on (SSO) facility. Examples of (i) are the Control System Online Lab, developed by Jim Henry and hosted by the University of Tennessee at Chattanooga, US [37], or any VISIR system, when accessing the demo page and using the guest login [38]. Examples of (ii) are the European Go-Lab portal, which provides access to hundreds of online labs [39], or the Lab2Go portal [40]. Finally, examples of (iii) are the Labshare institute [41], or the iLab Service Broker [42]. Unfortunately, option (i) does not really provide any sort of rewarding mechanism, as there is no structured way to access other remote experiments. Although the possibility to search the web for any particular, open, remote experiment still exists, it is a random, time-consuming process, where the guarantee of a quality-of-service (e.g. the remote experiment remains open for an entire course duration) is virtually zero. Option (ii) is more structured and facilitates the task of searching and using a given remote experiment. However, it is up to the owner of the repository to set up the rules defining how a given remote experiment is made publicly available and what sort of service level must be provided. Usually, by joining such a repository, a given institution will have to provide but also be allowed to use remote experiments provided by other institutions. In some cases, the repository is completely open, i.e. all the remote experiments listed in the repository are open, often with some sort of restriction (limited access time, diminished complexity, etc.). Again, this sort of sharing presents more advantages to users rather than to providers, i.e. the two directions (provider-client and client-provider) are not balanced in terms of benefits.

A federation implies a different quality of service level, in relation to a repository. It offers a server or now often cloud based user and lab management in one system. Administrators can define lab and user groups, and their roles, and offer pre-defined access types to the online labs and remote experiments. Via special web-services (smart gateways [43]) these systems can be connected to an LMS by single-sign-on, if the LMS supports the Learning Tools Interoperability (LTI) protocol. The lab owner in every case defines the use policy (time-frames, actual number of users etc.) of his lab. But he accepts that all (usually identified) users, who are registered into the lab group of the federation to which his lab is connected to, have access to his experiments.

Orduña et al. (2015) expose the advantages of a federated system [43] concerning the experiments shareability: "*once students of a particular institution can ac-*

cess through the Internet to a particular laboratory, it can also be accessed by students of other universities”. This advantage is bidirectional through RLMSs in which a federation is established: two institutions providing the same remote lab – or the same practical experiment from a specific remote lab– can balance their clients/users load. This feature, inherit to RLMSs, improves the users’ immersion in the remote lab environment due to the improved time response.

Laboratory time response depends on several factors: circuit, frequency, number of measuring requests, etc. In any case, there is a physical constraint to the number of concurrent users performing measurements; threshold limit value is 60 in VISIR [44]. Even though it is unlikely that all connected users perform measurements simultaneously –laboratory time is mostly allocated to circuit assembling and configuring the equipment– much more than for measuring, a balanced users’ load for some particular experiments in strong demand, would provide a better time-response, and hence a better immersion.

This particular aspect is visible through the following sequence of experiments, done with a single VISIR node (Figures 4, 5, and 6).

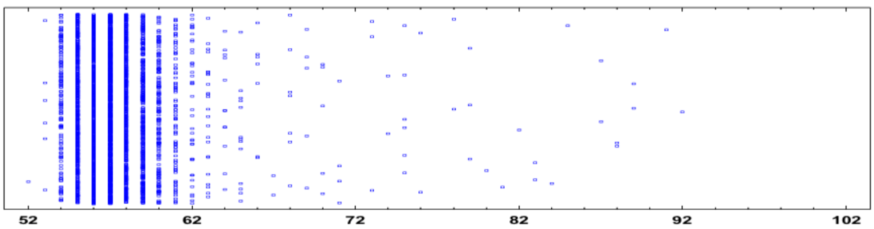

Fig. 4 Unique user, time response in milliseconds; 5 minutes in continuous mode

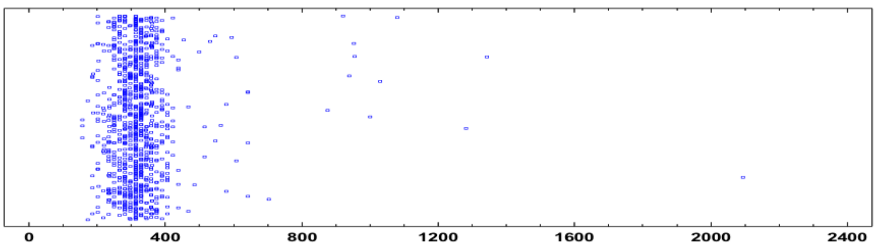

Fig. 5 Five users simultaneously measuring, sample time response in milliseconds; 5 minutes in continuous mode

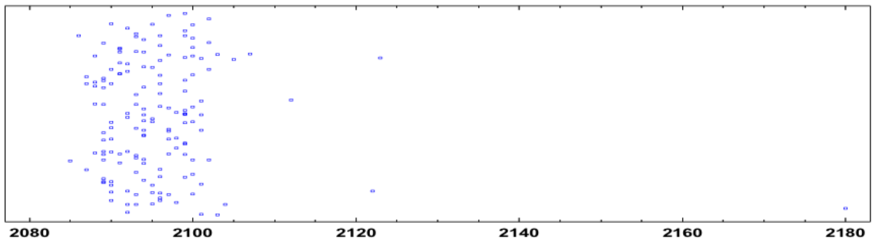

Fig. 6 Over 20 users simultaneously measuring, sample time response in milliseconds; 5 minutes in continuous mode

The sequence shows the increasing delay in serving an increasing number of simultaneous users, based on the batch operation mode of VISIR. The number of potential users, in a single engineering school, presented in section II, helps to understand the limitations of having a VISIR node operating in an isolated fashion.

Another approach to build a VISIR federation is to carry it out following a strategical design of the practical experiments offered by the different VISIR nodes. Every VISIR node of the community could share a "percentage" of its matrix to the VISIR federation. If every VISIR node offers a rich and broad specialized block of experimental practices (i.e. Node 1: Basic circuits and electrical laws; Node 2: Diodes experimentation; Node 3: transistors experimentation; Node 4: OpAmp experimentation; etc.) the overall VISIR nodes would share a huge and plentiful electronics practices repository, enriching exponentially the availability and quality of practical experiments. This repository could also be extended to practical guides and additional documentation, forming a VISIR community not only for sharing resources but also for a continuous improvement at all levels.

Finally, this whole notion of building a federation of individual nodes is not unique to remote labs; rather there are also examples of proposals emerging from the area of simulations, as presented in [45].

6. Ongoing projects around VISIR

6.1. VISIR+

The history of collaboration around VISIR among a number of European and LA HEI; the current demand for an increased use of instructional technologies in Science and Engineering Education, in both Brazil and Argentina, able to supply these two countries with a better skilled workforce; and the opportunity presented by the Erasmus+ program, favoring joint projects between these two world regions, under the scope of the Capacity Building in Higher Education (CBHE) measure, provided the motivation to submit a project proposal for installing new VISIR nodes in the two aforementioned countries. Under this scope, the Polytechnic of Porto (IPP), from Portugal, the National Distance Education University (UNED) and the University of Deusto (UD), both from Spain, the Carinthia University of Applied Sciences (CUAS), from Austria, the Blekinge Institute of Technology (BTH), from Sweden, the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), the Federal University of Santa Catarina (UFSC), the Federal Institute of Santa Catarina (IFSC), the Brazilian Association for Engineering Education (ABENGE), all the previous 4 institutions from Brazil, the National University of Rosario (UNR), the National University of Santiago del Estero (UNSE), and the Research Institute of Rosario for Educational Sciences (IRICE-CONICET), all the previous 3 institutions from Argentina, joined forces together and submitted a project proposal to the very first call of Erasmus+ program, on 10 February 2015. The project proposal, entitled "Educational Modules for Electric and Electronic Circuits Theory and Practice following an Enquiry-based Teaching and Learning Methodology supported by VISIR", and shortly referred as VISIR+, was positively evaluated in July 2015 and had its Kick-Off-Meeting (KOM) in Karlskrona, Sweden on 1-3 February 2016.

In brief, VISIR+ is installing 5 new VISIR nodes in the Brazilian and Argentinean HEI, i.e. PUC-Rio, UFSC, IFSC, UNR, and UNSE, with the assistance of the European HEI who already have one or more VISIR systems installed, i.e. BTH, IPP, UNED, UD, and CUAS. IRICE-CONICET is responsible for quality monitoring the didactical implementation of the new VISIR nodes and ABENGE will support the dissemination and impact evaluation of the VISIR+ project. Figure 7 provides an idea of the geographical distribution of the VISIR+ consortium.

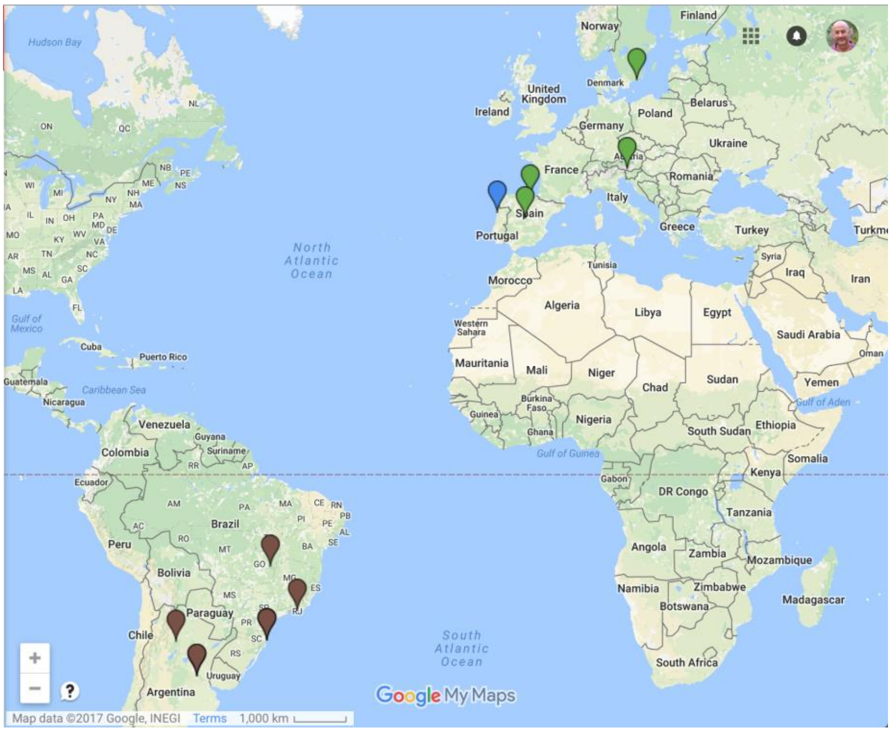

Fig. 7 Geographical distribution of the VISIR+ consortium

In order to effectively grow the CoP around VISIR, the project includes the following three training actions (TA):

- A 1st one held at BTH, with presentations done by all European partners. Two representatives from the Argentinean and Brazilian HEI participated locally, while an additional number of teachers participated remotely. At the end of this activity, participants were expected to know what VISIR is, what experiments it can support, how it can be incorporated into a course curricula, what learning outcomes does it enable, etc. A snapshot of TA1, delivered at BTH, is shown in Figure 8.
- A 2nd TA delivered at each LA HEI. Although the initial plan was to deliver this TA after the local installation of a VISIR node, bureaucratic problems impairing the timely acquisition of the necessary equipment, by these institutions, led to the situation where only PUC-Rio used its newly installed VISIR node to support the local TA. However, this constraint did not prevent the delivery of the TA because of the remote nature of VISIR. Instead of using a local system, the trainers remotely used the system installed at their home institution in Eu-

rope. The target audience of TA2 were the two local representatives who attended TA1 plus all interested teachers from the same institution and also, at least, one representative from the associated partners. These associated partners –two per LA HEI– are nearby educational institutions also interested in using VISIR. Figures 9, 10, 11, 12, and 13 provide snapshots of TA2 delivered at PUC-Rio, UFSC, UNR, UNSE, and IFSC respectively. The results of TA2 were reported in [46] [47] [48].

- Finally, a 3rd TA to be held at each associated partner. This last TA, jointly delivered by one LA partner and one European partner, will test the capacity to aggregate other institutions around the use of VISIR. This TA will include application examples from courses delivered at the LA HEI, to prove the adaptability of VISIR to different institutional cultures and its universality in terms of experiments with electric and electronic circuits.

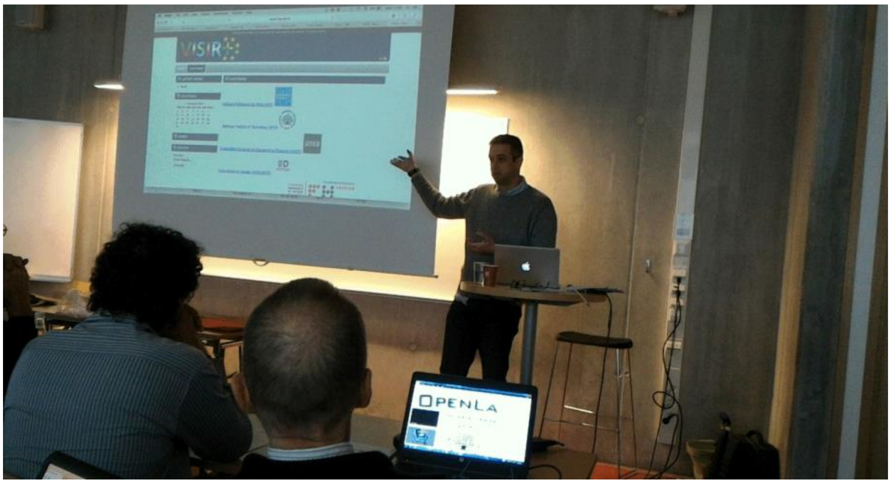

Fig. 8 Snapshot of TA1 delivered at BTH (1-2 February 2016)

Fig. 9 Snapshot of TA2 delivered at PUC-Rio (5-6 September 2016)

Fig. 10 Snapshot of TA2 delivered at UFSC (22-23 August 2016)

Fig. 11 Snapshot of TA2 delivered at UNR (12-16 September 2016)

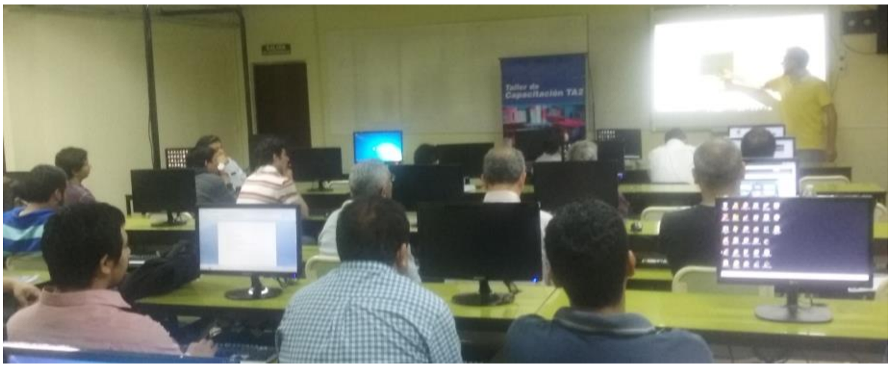

Fig. 12 Snapshot of TA2 delivered at UNSE (12-16 September 2016)

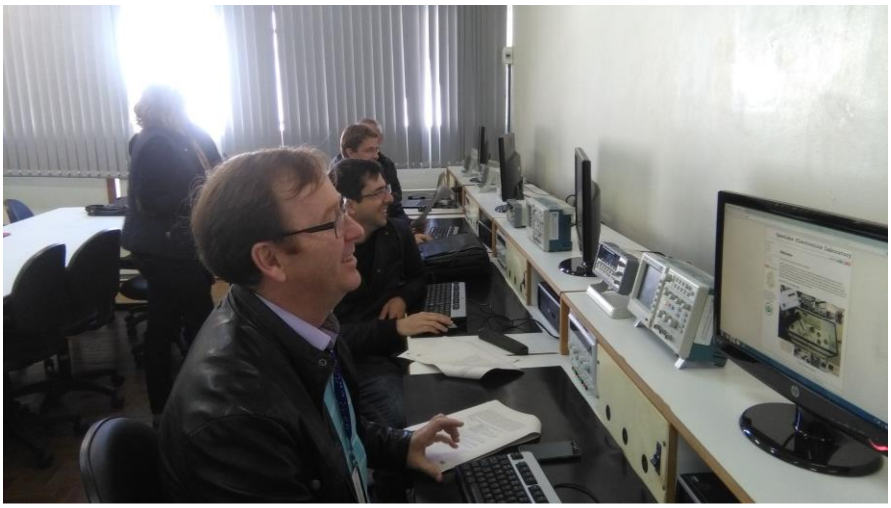

Fig. 13 Snapshot of TA2 delivered at IFSC (25-26 August 2016)

An underlying common aspect to all TA is the proposed instructional design of all target courses. In particular, VISIR+ aims to develop a set of educational modules comprising the use of hands-on, simulated and remote labs, following an enquiry-based methodology explained in [49] [50] [51]. The combination of these three different lab environments provides additional opportunities for students to acquire higher-order experimental skills and hence be better prepared to face the labor market [52]. In addition, teachers may use two supplementary tools (simulations and remote labs) for enriching theoretical classes, in particular for proving or demonstrating a given model or formula, which is thought to favor students' motivation and, hence, increase their knowledge retention level [53][54].

6.2. PILAR

Regarding PILAR, an acronym that stands for "Platform Integration of Laboratories based on the Architecture of visiR", there are still few results. The project proposal was submitted in February 2016 and positively evaluated in July 2016. The project KOM was held in Madrid, Spain, on November 2016 and the initial activities are now being implemented, in particular a thorough analysis of the characteristics associated with the VISIR systems installed in the consortium partners, i.e. BTH, CUAS, UNED, UD, and IPP. In addition to these partners, the project consortium also includes the International Association for Online Engineering (IAOE), a Small and Medium Enterprise (SME) named EVM Project Management Experts SL, and Omnia, the Joint Authority of Education in Spoo Region, Finland. At the end of the project, it is expected that the first federation of VISIR nodes will be effective and able to provide the services mentioned in section 5.

7. CONCLUSION AND FUTURE PERSPECTIVES

Although the two previous projects are still ongoing, some aspects that arise from analyzing the constant growing of the VISIR community should be remarked. The possibility that emerges from a federation of remote labs allows sharing resources and widens opportunities for remote experimentation. This means that whereas at a first moment each partner has its own VISIR system, to be used by teachers and students, and shared with other institutions, the next step will be to federate the VISIR systems of the various institutions. What could be achieved from this federation can be described with an example. If the VISIR system of one participating engineering school, located in Argentina, and the VISIR system of another participating engineering school, located in Spain, are integrated into a federation, the students and teachers of those two institutions will have a seamless access to both systems. This is much more than what each institution has developed individually and is able to offer to its teachers and students, alone.

In this way, VISIR+ can be considered the first necessary step to have a federation of VISIR nodes, in which each partner is a supplier and a user at the same time. On its turn, PILAR is the vehicle to implement the first federation of VISIR nodes, in Europe.

Acknowledgments

The authors would like to acknowledge the support given by the European Commission through grant 561735-EPP-1-2015-1-PT-EPPKA2-CBHE-JP and also by the Spanish Office for Education Internationalization (Servicio Español para la Internacionalización de la Educación, SEPIE), through grant 2016-1-ES01-KA203-025327, both under the scope of the Erasmus+ program.

REFERENCES

[1] The Royal Society (2016) History. https://royalsociety.org/about-us/history/. Accessed 2 Jun 2016.

[2] Feisel LD, Rosa AJ (2005) The Role of the Laboratory in Undergraduate Engineering Education. Journal of Engineering Education 94:121-130. doi:10.1002/j.2168-9830.2005.tb00833.x

[3] Ma J, Nickerson JV (2006) Hands-on, simulated, and remote laboratories: A comparative literature review. ACM Computing Surveys 38(3):1-24. doi:10.1145/1132960.1132961

[4] Corter JE, Nickerson JV, Esche SK, Chassapis C, Im S, Ma J (2007) Constructing reality: A study of remote, hands-on and simulated laboratories. ACM Transactions on Computer-Human Interaction 14(2):1-27. doi:10.1145/1275511.1275513

[5] Brinson JR (2015) Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories. Computers in Education 87(C):218-237. doi:10.1016/j.compedu.2015.07.003

[6] Froyd JE, Wankat PC, Smith KA (2012) Five major shifts in 100 years of engineering education. Proceedings of the IEEE 100(Special Centennial Issue):1344–1360. doi: 10.1109/JPROC.2012.2190167

[7] Alves GR, Gericota MG, Silva JB, Alves JB (2007) Large and Small Scale Networks of Remote Labs: a Survey. In: Gomes L, García-Zubía J (eds) Advances on remote laboratories and e-learning experiences, 1st edn. Universidad de Deusto Press, Bilbao, p 15-34

[8] Orduña P, Rodriguez-Gil L, García-Zubía J, Dziabenko O, Angulo I, Hernández-Jayo U, Azcuenaga E (2016) Classifying online laboratories: Reality, simulation, user perception and potential overlaps. In: Proceedings of 13th International Conference on Remote Engineering and Virtual Instrumentation, Madrid, Spain, 24-26 February 2016

[9] US News & World Report (2016) Education Ranks & Advice, US Best Engineering Schools. http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-engineering-schools/eng-rankings. Accessed 1 Jul 2016

[10] Universitat Politècnica de Catalunya (2016) Own schools. http://www.upc.edu/the-upc/the-institution/schools. Accessed 1 Jul 2016

[11] Marques MA, Viegas MC, Costa-Lobo MC, Fidalgo AV, Alves GR, Rocha JS, Gustavsson I (2014) How Remote Labs Impact on Course Outcomes: Various Practices Using VISIR. IEEE Transactions on Education 57(3):151-159. doi:10.1109/TE.2013.2284156

[12] Khatri R, Henderson C, Cole R, Froyd JE (2013) Over One Hundred Million Simulations Delivered: A Case Study of the PhET Interactive Simulations. In: Proceedings of the 2013 Physics Education Research Conference, Portland, OR, US, 17-18 July 2013

[13] Salah R, Alves GR, Abdulazeez D, Guerreiro P, Gustavsson I (2015) Why VISIR? Proliferative Activities and Collaborative Work of VISIR System. In: Proceedings of the 7th International Conference on Education and New Learning Technologies, Barcelona, Spain, 6-8 July 2015
[14] Swartling M, Bartůněk JS, Nilsson K, Gustavsson I, Fiedler M (2012) Simulations of the VISIR Open Lab Platform. In: Proceedings of the 9th Remote Engineering and Virtual Instrumentation Conference, Bilbao, Spain, 4-6 July 2012
[15] Gomes L, García-Zubía (eds) (2007) Advances on remote laboratories and e-learning experiences. Universidad de Deusto Press, Bilbao
[16] Schmid C (2000) Remote Experimentation in Control Engineering. Paper presented at the 45th International Scientific Colloquium, Ilmenau Technical University, Germany, 4-6 October 2000
[17] Gustavsson I (2001) Laboratory Experiments in Distance Learning. Paper presented at the International Conference on Engineering Education, Oslo, Norway, 6-10 August 2001
[18] Gustavsson I (2003) User Defined Electrical Experiments In A Remote Laboratory. Paper presented at 2003 Annual Conference of the American Society for Engineering Education, Nashville, Tennessee, 22-25 June 2003
[19] Gustavsson I, Zackrisson J, Håkansson L, Claesson I, Lagö T (2007) The VISIR project - an Open Source Software Initiative for Distributed Online Laboratories. In: Proceedings of the 4th Remote Engineering and Virtual Instrumentation Conference, Porto, Portugal, 25-27 June, 2007
[20] Zackrisson J, Gustavsson I, Håkansson L (2007) An Overview of the VISIR Open Source Software Distribution 2007. In: Proceedings of the 4th Remote Engineering and Virtual Instrumentation Conference, Porto, Portugal, 25-27 June, 2007
[21] Gustavsson I, Zackrisson J, Ström-Bartunek J, Nilsson K, Håkansson L, Claesson I, Lagö T (2008) Telemanipulator for Remote Wiring of Electrical Circuits. In: Proceedings of the 5th Remote Engineering and Virtual Instrumentation Conference, Düsseldorf, Germany, 22-25 June, 2008
[22] Gustavsson I, Zackrisson J, Nilsson K, García-Zubía J, Håkansson L, Claesson I, Lagö T (2008) A Flexible Instructional Electronics Laboratory with Local and Remote Lab Workbenches in a Grid. International Journal of Online Engineering 4(2):12-16
[23] Gustavsson I (2011) On Remote Electronics Experiments. In García-Zubía J, Alves GR (eds) Using Remote Labs in Education – Two Little Ducks in Remote Experimentation, University of Deusto Press, Bilbao, p 157-176
[24] Salah RM, Alves GR, Guerreiro P, Gustavsson I (2016) Using UML Models to Describe the VISIR System, International Journal of Online Engineering 12(6):34-42. doi: 10.3991/ijoe.v12i06.5707
[25] Tawfik M, Sancristobal-Ruiz E, Martin S, Gil M, Pesquera A, Losada P, Diaz-Orueta G, Peire J, Castro M, García-Zubía J, Hernández-Jayo U, Orduña P, Angulo I, Costa-Lobo MC, Marques MA, Viegas MC, Alves GR (2012) VISIR: Experiences and Challenges. International Journal of Online Engineering 8(1):25-32. doi:10.3991/ijoe.v8i1.1879
[26] Couros A (2003) Communities of Practice: A Literature Review. Available via http://www.tcd.ie/CAPSL/_academic_practice/pdfdocs/Couros_2003.pdf. Accessed 23 Jan 2017
[27] Alves GR, Ferreira JM, Müller D, Erbe H-H, Alves JB, Pereira CE, Sucar E, Herrera O, Chiang L, Hine N (2005) Remote Experimentation Network – Yielding an Inter-university Peer-to-Peer e-service. In: Proceedings of the 10th IEEE International Conference on Emerging Technologies and Factory Automation, Catania, Italy, 19-22 September 2005
[28] Fidalgo A, Costa-Lobo MC, Marques MA, Viegas MC, Alves GR, García-Zubía J, Hernández-Jayo U, Gustavsson I (2012) Using Remote Labs to serve different teacher's needs - A case study with VISIR and RemotElectLab. In: Proceedings of the 9th Remote Engineering and Virtual Instrumentation Conference, Bilbao, Spain, 4-7 July 2012

[29] Hernández-Jayo U, García-Zubía J, Angulo I, Lopez-de-Ipiña D, Orduña P, Irurzun J, Dziabenko O (2010) LXI Technologies for Remote Labs: An Extension of the VISIR Project. International Journal of Online Engineering 6(SI 1):25-35. doi:10.3991/ijoe.v6s1.1385

[30] Hernández-Jayo U, García-Zubía J (2011) A Remote and Reconfigurable Analog Electronics Laboratory based on IVI an LXI Technologies. In: Proceedings of the 8th Remote Engineering and Virtual Instrumentation Conference, Brasov, Romania, 29 June - 2 July 2011

[31] García F, Díaz-Orueta G, Tawfik M, Martín S, Sancristobal-Ruiz E, Castro M (2014) A practice-based MOOC for learning electronics. In Proceedings of the IEEE Global Engineering Education Conference, Istanbul, Turkey, 3-5 April 2014

[32] Ferreira G, Lacerda J, Schlichting L, Alves GR (2014) Enriched scenarios for Teaching and Learning Electronics. In: Atas del XI Congreso de Tecnologías, Aprendizage y Enseñanza de la Electrónica, Bilbao, Spain, 11-13 June 2014

[33] Schlichting L, Anderson JA,Faveri F, Bona D, Ferreira G, Alves GR, Liz MB (2016) Remote Laboratory: application and usability. In: Atas del XII Congreso de Tecnologías, Aprendizage y Enseñanza de la Electrónica, Seville, Spain, 22-24 June 2016

[34] Odeh S, Anabtawi M, Alves GR, Gustavsson I, Arafeh L (2015) Assessing the Remote Engineering Lab VISIR at Al-Quds University in Palestine. International Journal of Online Engineering 11(1):35-38

[35] Odeh S, Alves J, Alves GR, Gustavsson I, Anabtawi M, Arafeh L, Jazi M, Arekat M (2015) A Two-Stage Assessment of the Remote Engineering Lab VISIR at Al-Quds University in Palestine. IEEE Revista Iberoamericana de Tecnologias del Aprendizaje 10(3):175-185. doi: 10.1109/RITA.2015.2452752

[36] Nafalski A, Göl Ö, Nedić Z, Machotka J, Ferreira JM, Gustavsson I (2010) Experiences with Remote Laboratories. In: Proceedings of the 7th Remote Engineering and Virtual Instrumentation Conference, Stockholm, Sweden, 29 June - 2 July 2010

[37] Laboratories without Borders (2017) Control Systems, http://weblab.utc.edu/Weblab/Stations/controlslab.html. Accessed 24 Jan 2017

[38] OpenLabs Electronics Laboratory (2017) Guest login. https://openlabs.bth.se/electronics/index.php/en?sel=guestlogin. Accessed 24 Jan 2017.

[39] The Go-Lab Project (2016). Global Online Science Labs for Inquiry Learning at School. http://go-lab-project.eu. Accessed 1 Jul 2016

[40] Zutin DG, Auer ME, Maier C, Niederstätter M (2010) Lab2go - A repository to locate educational online laboratories. In: Proceedings of the 1st IEEE Global Engineering Education Conference, Madrid, Spain, 14-16 April 2010

[41] The Labshare Institute (2016). About. http://www.labshare.edu.au/about/institute. Accessed 1 Jul 2016

[42] iLab Service Broker (2016) Welcome to iLab. http://ilab.mit.edu/iLabServiceBroker/. Accessed 1 Jul 2016

[43] Orduña P, Zutin DG, Govaerts S, Lequerica-Zorrozua I, Bailey P, Sancristobal-Ruiz E, Salzmann C, Rodriguez-Gil L, DeLong K, Gillet D, Castro M, López-de-Ipiña D, García-Zubía J (2015) An Extensible Architecture for the Integration of Remote and Virtual Laboratories in Public Learning Tools. Revista Iberoamericana de Tecnologias del Aprendizaje 10(4):223-233. doi: 10.1109/RITA.2015.2486338

[44] Orduña P (2013) Transitive and Scalable Federation Model for Remote Laboratories. PhD Dissertation, University of Deusto

[45] U.S. Department of Defense (DoD) Modeling and Simulation Coordination Office (M&SCO) (2016) White paper. M&S VV&A RPG Core Document: VV&A of Federations. http://www.msco.mil/documents/Core_Federation01_Federation.pdf. Accessed 11 Jul 2016

[46] Alves GR, Fidalgo A, Marques, MA Viegas MC, Felgueiras MC, Costa RJ, Lima N, Pozzo I, Dobboletta E, García-Zubía J, Hernández-Jayo U, Castro M, García-Loro F, Zutin DG, Christian K (2017) VISIR+ Project – Preliminary results of the training actions. In:

Proceedings of the 14th Remote Engineering and Virtual Instrumentation Conference, New York, NY, USA, 15-17 March 2011 (in press)
[47] Hernández-Jayo U, García-Zubía J, Colombo AF, Marchisio S, Concari SB, Lerro F, Pozzo MI, Dobboletta E, Alves GR (2017) Spreading the VISIR remote lab along Argentina - The experience in Patagonia. In: Proceedings of the 14th Remote Engineering and Virtual Instrumentation Conference, New York, NY, USA, 15-17 March 2011 (in press)
[48] García-Loro F, Fernandez R, Gomez M, Paz H, Soria F, Pozzo MI, Dobboletta E, Fidalgo A, Alves GR, Sancristobal-Ruiz E, Diaz-Orueta G, Castro M (2017) Educational Scenarios Using Remote Laboratory VISIR for Electrical/Electronic Experimentation. In: Proceedings of the 14th Remote Engineering and Virtual Instrumentation Conference, New York, NY, USA, 15-17 March 2011 (in press)
[49] Lima N, Alves GR, Viegas MC, Gustavsson I (2015) Combined efforts to develop students experimental competences. In: Proceedings of the exp.at'15 conference, Ponta Delgada, Azores, Portugal, 2-4 June 2015
[50] Viegas MC, Lima N, Alves GR, Gustavsson I (2014) Improving Students Experimental Competences Using Simultaneous Methods in Class and in Assessments. In Proceedings of the Technological Ecosystems for Enhancing Multiculturality Conference, Salamanca, Spain, 1-3 October 2014
[51] Alves GR, Viegas MC, Lima N, Gustavsson I. (2016). Simultaneous Usage of Methods for the Development of Experimental Competences. International Journal of Human Capital and Information Technology Professionals 7(1):54-73. doi:10.4018/IJHCITP.2016010104
[52] Restivo T, Alves GR (2013) Acquisition of higher-order experimental skills through remote and virtual laboratories. In Dziabenko O, García-Zubía (eds) IT Innovative Practices in Secondary Schools: Remote Experiments, Universidad de Deusto, Bilbao, p 321-347
[53] Cooper M, Ferreira JM (2009) Remote laboratories extending access to science and engineering curricular. IEEE Transactions on Learning Technologies 2(4):342-353. doi:10.1109/TLT.2009.43
[54] García-Zubía J, Cuadros J, Romero S, Hernández-Jayo U, Orduña P, Guenaga M, Gonzalez-Sabate L, Gustavsson I (2016) Empirical Analysis of the Use of the VISIR Remote Lab in Teaching Analog Electronics. IEEE Transactions on Education PP(99):1-8 doi:10.1109/TE.2016.2608790 (in press)

Authors' short biographic notes

Gustavo R. Alves graduated in 1991 and obtained an MSc and a PhD in Computers and Electrical Engineering in 1995 and 1999, respectively, from the University of Porto, Portugal. He is with the Polytechnic of Porto - School of Engineering, since 1994. He was involved in several national and international R&D projects and has authored or co-authored +200 publications, including book chapters, and conference and journal papers with a referee process. His research interests include engineering education, remote labs, and design for debug&test (e-mail: gca@isep.ipp.pt).

André Fidalgo is a researcher at CIETI/LABORIS and has been a lecturer at the Polytechnic of Porto – School of Engineering (IPP/ISEP) since 1999, in Porto, Portugal, where he teaches Electronics and Test and Debug of Digital Systems. His main research interests are related to Test and Debug of Digital Systems, Remote Laboratories, as well the E-learning wider research field (e-mail: anf@isep.ipp.pt).

Arcelina Marques graduated in Physics from University of Porto, received her MSc degree in Physics of Laser Communications from University of Essex in 1992, and her PhD in Engineering Sciences from University of Porto in 2008. She is a professor at the Polytechnic of Porto - School of Engineering since 1995, where she lectures physics, electronics and biomechanics courses. She has been involved in several R&D projects and has been a member of the Physics Department Management Board, in several occasions, since 1999 till present. She is a member of the IEEE Instrumentation & Measurement Society (e-mail: mmr@isep.ipp.pt).

Maria C. Viegas is a researcher at CIETI-LABORIS and a professor at the Polytechnic of Porto - School of Engineering, Portugal, since 1994. She graduated in Physics/Applied Mathematics, MSc in Mechanical Engineering and PhD in Science and Technology (Physics Didactics). Her research interests include engineering education, physics didactics, professional development and remote experimentation learning outcomes (e-mail: mcm@isep.ipp.pt).

Manuel C. Felgueiras received the BSc and PhD degrees in electrical and computer engineering from the Faculty of Engineering, University of Porto, Porto, Portugal, in 1987 and 2008, respectively. He started his activity in 1994 as an assistant professor and later on as an adjunct professor and researcher with the Department of Electrical Engineering, School of Engineering, Polytechnic of Porto, Portugal. His research interests at CIETI include design for debug and test of mixed-signals, remote experimentation in e-learning and renewable energy source (e-mail: mcf@isep.ipp.pt).

Ricardo Costa has a Bachelor (1999) and an MSc (2003) degrees in Electrical and Computer Engineering from the Faculty of Engineering of the University of Porto; and a PhD (2014) from the University of Coimbra. With more than 25 publications, he has been researching in the area of remote experimentation, and he is now a teacher at the Polytechnic of Porto at the Electrical Engineering Department, teaching electrical and informatics courses, coordinating BSc and MSc degree projects and participating in some international projects (e-mail: rjc@isep.ipp.pt).

Natércia Lima is a professor at the Polytechnic of Porto - School of Engineering (ISEP) since 1993, where she teaches Physics, and a full member of the Research Group in Systems Testing, part of the Center for Innovation in Engineering and Industrial Technology, since 2014. Her research interests include engineering education, students learning with remote experimentation and professional development (e-mail: nmm@isep.ipp.pt).

Manuel Castro, Electrical and Computer Engineering educator in the Spanish University for Distance Education (UNED), has a doctoral industrial engineering degree from the ETSII/UPM. Has been Director of the Department and ViceRector at the UNED. He co-chaired the conference FIE 2014 (Frontiers in

Education Conference) in Madrid, Spain, by the IEEE and the ASEE as well as REV 2016. He is Fellow member of IEEE and Past President Sr of the IEEE Education Society. He has been awarded at the IEEE EDUCON 2011 and at the IEEE Education Society. He is co-editor of IEEE-RITA of the IEEE Education Society and member of the Board of the Spanish International Solar Energy Society (ISES) (e-mail: mcastro@ieec.uned.es).

Gabriel Díaz Orueta has a degree and a PhD in Physics by Universidad Autonoma de Madrid. He is associate professor in the Electrical and Computing Engineer department at UNED (Spanish University for Distance Education). He teaches electronics and information security for networks and his research is centered in remote laboratories, technology enhanced learning and information security. He is the director of Master Universitario de Investigación en Ingeniería Eléctrica Electrónica y Control industrial at UNED. He is IEEE senior member and past president of the Spanish Chapter of the IEEE Education Society (e-mail: gdiaz@ieec.uned.es).

Elio San Cristóbal Ruiz is an assistant professor in the electronic and computer department of the Spanish University for Distance Education (UNED). He has a doctoral engineering degree from the ETSII (Industrial Engineering School) of UNED, 2010. He also has a Computer Science Engineering degree by the Salamanca Pontifical University (UPS), Madrid 2002 and a Technical Engineering degree in computer networks (UPS), Madrid 1998. He has worked for the University Distance Education Institute (IUED) from UNED and in Computer Science Service Centre of the UNED (e-mail: elio@ieec.uned.es).

Felix García Loro is a researcher at Spanish University for Distance Education (UNED). He has an Industrial Engineering degree from the UNED and is now pursuing his PhD in Industrial Enginnering. He is Assistant teacher in Electronics for Information and Communication Technologies and Microelectronics; lecturer in Fundamentals of Electrical Engineering, Medium and Low Voltage Electrical Installations and Electric Machinery. His research interests are focused on integration of remote laboratories, control systems and big-data (e-mail: fgarcialoro@ieec.uned.es).

Javier García-Zubía has a degree and a PhD in informatics. He is a full professor in the Faculty of Engineering of the University of Deusto, Spain, where he teaches electronics and embedded systems and investigates in remote laboratories, technology enhanced learning and embedded systems. He is IEEE senior member and president of the Spanish Chapter of the IEEE Education Society (e-mail: zubia@deusto.es).

Unai Hernandez-Jayo was born in Barakaldo, Spain, in 1978. He received the MSc and PhD degrees in telecommunications engineering from the University of Deusto, Bilbao, Spain, in 2001 and 2012, respectively. In 2004, he joined the University of Deusto, where he is currently an Assistant Professor with the Telecommunications Department, teaching classes in electronic design and communications electronics. His current research interests include the use of information and communication technologies in the educational process and the application of ICT in cooperative vehicular systems (e-mail: unai.hernandez@deusto.es).

Wlodek J. Kulesza is a Professor at Blekinge Institute of Technology BTH in Sweden. He researches in a field of Wireless Multisensory System for Health and Security Applications. He teaches Sensors Signals and Systems as well as Research Methodology including Philosophy of Science for students of Engineering. He has leaded Workshops of Scientific Writing at Chinese and Polish Universities. Among others, he is a co-author of the textbooks: “Scientific Metrology” and two volumes of “Measurement Data Handling” (e-mail: wlodek.kulesza@bth.se).

Ingvar Gustavsson received the M.S.E.E. and Dr. Sc. degrees in electrical engineering from the Royal Institute of Technology (KTH), Stockholm, Sweden, in 1967 and 1974, respectively. He has been an Associate Professor of electronics and measurement technology with the Blekinge Institute of Technology (BTH), Karlskrona, Sweden, since 1994. In 1999, he started a remote lab project at BTH that today is known as VISIR (Virtual Instrument Systems in Reality). He partly retired in 2012 to concentrate on activities related to VISIR. His research interests are in the areas of instrumentation, remote labs, industrial electronics, and distance learning. He has resigned from many committees, but he is still a member of Swedish professional societies (e-mail: ingvar.gustavsson@bth.se).

Kristian Nilsson received the licentiate degree from Blekinge Institute of Technology (BTH), Karlskrona, Sweden, in 2014, where he is currently working with the VISIR Open Laboratory Platform, and has been a lecturer at BTH since 2010. His main research interests are related to distance learning, remote labs, electronics, and signal processing (e-mail: kns@bth.se).

Johan Zackrisson is currently working as a software architect, but has a fifteen years background at Blekinge Institute of Technology (BTH), where he was working as an engineer, mainly focusing on online engineering and remote laboratories. Together with Ingvar Gustavsson and Kristian Nilsson he has been one of the visionaries behind the VISIR platform at BTH. Most of his time nowadays is spent in industry, building telematics systems for Condition-Based Maintenance, Monitoring and Support (e-mail: johanz@gmail.com).

Andreas Pester has a degree in mathematics and a PhD in logic and methodology of mathematics. He is a professor for mathematics and mathematical modelling in the Faculty of Engineering and & IT of the Carinthia University of Applied Sciences, Austria, where he teaches different courses in mathematics and mathematical modelling and investigates in online simulations and online experiments, technology enhanced learning and machine learning for online environments. He is IEEE member and IAOE and treasurer of the Austrian Chapter of the IEEE Education Society (e-mail: pester@fh-kaernten.at).

Danilo Garbi Zutin is a Senior Researcher at the Carinthia University of Applied Sciences (CUAS), Villach, Austria. His research interests are in the field of remote engineering, Online Laboratories, Internet of Things, distributed software architectures applied to Online Engineering and cloud computing, particularly laboratory infrastructure as a service (LIaaS). Danilo is author or co-author of more than 30 scientific papers published in international journals, magazines and conferences. Most of these papers are in the field of online engineering, remote and virtual laboratories and issues associated with their dissemination and usage (e-mail: dgzutin@ieee.org).

Luis Carlos Martinhago Schlichting is a full professor at the Federal Institute of Education, Science and Technology of Santa Catarina - Florianópolis - Brazil. Graduated in Electrical Engineering and PhD from the Federal University of Santa Catarina - Brazil. His main interests in research are related to remote laboratories, power electronics and electromagnetic compatibility (EMC) (e-mail: schlicht@ifsc.edu.br).

Golberi Ferreira was born in Florianópolis, SC, Brazil, in 1966. He received the MSc degree in Electromagnetism in 1995, the PhD degree in Electromagnetic Compatibility in 1999, both at the Federal University of Santa Catarina, Brazil, and the Posdoctorate in Engineering Education in 2017, at the University of Nottingham, UK. He joined as a full professor the Federal Institute of Santa Catarina in 1990, where he was ViceRector from 2011 to 2016. He is now the Coordinator of the Eletronic Engieneering course, since 2017. His current research interests include the analisys of electromagnetic compatibility systems and remote laboratories (e-mail: golberi@ifsc.edu.br).

Daniel Dezan de Bona has an MSc in Electrical and Computer Engineering from the Polytechnic of Porto. He works as a technician at Federal Insitute of Science, Technology and Education at Santa Catarina/Brazil, where he works in researching on electronics, remote laboratories, EMC and embedded systems (e-mail: dezan@ifsc.edu.br).

Fernando S. Pacheco holds an undergraduate, master's and doctorate degree in Electrical Engineering from the Federal University of Santa Catarina. He is a lecturer at the Federal Institute of Santa Catarina, Florianópolis, teaching for vocational and undergraduate students in the areas of signal processing, programming, and electronics, as well as coordinating research and outreach programs (e-mail: fspacheco@ifsc.edu.br).

Juarez Bento da Silva graduated in 1991 in Business from the Pontifical Catholic University of Rio Grande do Sul, MSc in Computer Science from the Federal University of Santa Catarina (2002) and PhD in Engineering and Knowledge Management from the Federal University of Santa Catarina (2007). He is currently a Lecturer at Federal University of Santa Catarina and Remote Experimentation Lab coordinator (RExLab) (e-mail: juarez.silva@ufsc.br).

João B. Alves graduated in Electrical Engineering in 1971, at the Federal University of Pará, obtained his MSc from the Federal University of Santa Catarina, Brazil, in 1973, and his PhD from the Federal University of Rio de Janeiro, Brazil, in 1981, both in Electrical Engineering. He partly retired from his lecturing duties at the Federal University of Santa Catarina, Brazil, where he still supervises post-graduation students. His research interest include remote laboratories, robotics and general systems theory (e-mail: joao.bosco.mota.alves@ufsc.br).

Simone Bilessimo is a bachelor of Mechanic Production Engineering, MSc and PhD of Engineering Production. She is a researcher at RexLab (Remote Experimentation Laboratory) and has been a lecturer at the Federal University of Santa Catarina (UFSC) since 2012, in Araranguá/SC, Brazil. Her main research interests are related to entrepreneurship, integration of technology in education and remote experimentation (e-mail: simone.bilessimo@ufsc.br)

Ana M Pavani holds Enginering, Master and Doctoral degrees in Electrical Engineering. She has been working for the Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio) since 1976. She is a member of the Board of Directors of the Networked Digital Library of Theses and Dissertations (NDLTD) and the manager of LAMBDA, a laboratory of PUC-Rio. Her research interests are ICT supported learning, digital libraries and management of digital collections (e-mail: apavani@puc-rio.br).

Delberis A. Lima holds an MSc and a DSc in Electrical Engineering from the Universidade Estadual Paulista (UNESP), Ilha Solteira, São Paulo, Brazil. Currently, he is associate professor at Pontifical Catholic University of Rio de Janeiro (PUC-Rio). His research interests include power systems planning, operations and economics, smart-grid, electricity markets and education in Electrical Engineering (e-mail: delberis@ele.puc-rio.br).

Guilherme Temporão has a PhD in Electrical Engineering and is an assistant professor at Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio). His main research areas are quantum optical communications and metrology in optical components. Since 2013 he has been involved with introducing the blended-learning modality and remote labs in several undergraduate courses (e-mail: temporao@opto.cetuc.puc-rio.br).

Susana Marchisio is a researcher at the National University of Rosario (UNR), Argentina and has been a lecturer at UNR, since 1978, where she teaches Physics of Electronic Devices. She has a Doctoral Industrial Engineering degree from the ETSII/UNED, Spain. She has been Director of the Distance Education Department and of the Postgraduate Engineering School at the Faculty of Exact Sciences and Engineering in UNR. She also teaches Methodology of Research and Educational Technology at postgraduate programs. Her research fields are Engineering Education, Distance Education, teaching with technologies and remote labs (e-mail: smarch@fceia.unr.edu.ar).

Sonia Beatriz Concari has a Phd in Physics from the Universidad Nacional de Rosario (UNR). She has been full professor at UNR, Universidad Tecnológica Nacional and Universidad Nacional del Litoral, teaching Physics. She is lecturer of Metodology of the Investigation and Epistemology of the Technology at posgrade programs. Has been principal researcher at many projects in the fields of Solar Energy and Remote Laboratories, as well as Physics and Engineering Education. She is also mentor at the Pennsylvania State University (e-mail: sconcari@fceia.unr.edu.ar).

Federico Lerro was born in Rosario, Argentina. He has a degree in Electronic Engineering at the National University of Rosario (UNR). He is Assistant Professor at the laboratory of Physics of Electronic Devices from the Electronics Engineering career. He is the technical coordinator of the Remote Laboratory, which has been his main research interest for the last ten years (e-mail: flerro2@yahoo.com.ar).

Gastón Saez de Arregui, was born in Rosario, Argentina in 1972, graduated in Informatics System Engineer, Master degree of Renowable energy in 2015. Researcher in remote lab education system and renowable energies. Member of Rosario National University energy laboratory. Posgraduate professor of UNR. Actual engineering Doctorate degree (PhD) in process (e-mail: gsaez218@gmail.com).

Claudio Merendino was born in Rosario, Argentina in 1961, and has a degree in Electronic Engineering at the National University of Rosario (UNR) since 1987. Since 1983 he has been a professor in the Electronic Engineering career, in the Chair of Physics of Electronic Devices. Also teached in chairs such as Digital Techniques and Computer Technology. He participates in developments of remote laboratories in the University and equipment applied to teaching in the professional field (e-mail: claudiomerendino@hotmail.com).

Miguel Plano. Electronic Engineer, professor at the National University of Rosario (UNR) in the area of the science of materials and electronic devices, researcher in education of the sciences and in renewable energies where he does activities for a Masters in Energy of the same university. He participates in developments of remote laboratories linked to both fields of research (e-mail: mplanoster@gmail.com).

Rubén A. Fernandez graduated in Electronic Engineer, specialist in education of superior education. He is a Full Professor in the Faculty of Exact Sciences and Technologies of the National University of Santiago del Estero, where he teaches Power Electronic and Engineering Project. Has been Director of the Academic Department of Electronics, Director of the School of Electronic Engineering and Academic Secretary of the Faculty of Exact Sciences and Technologies. He is a researcher in teaching higher education and renewable energies (e-mail: raf@unse.edu.ar).

Hector Ruben Paz graduated in Road Engineer, specializing in Geometric Design of Road and Transport Engineering - Formation of Human Resources in Science, Technology and Regional Development - Numerical Methods and Computer Engineering. Senior Professor in Philosophy and Pedagogy. Regular Professor and Researcher. Dean of the College of Sciences and Technologies of the National University of Santiago del Estero, Argentina. Outgoing President of the Federal Council of Engineering Deans of Argentina (CONFEDI). Past President of the Ibero-American Association of Institutions of Engineering Education (ASIBEI) (e-mail: hrpazunse@unse.edu.ar).

Mario Fernando Soria is an electronic engineer, graduated from the National University of Cordoba, is also a graduate in Teacher in Secondary Education Professional Technical modality. He is the Head of Practical Work in the Electronics Department of the Electronic Engineering Career. He has been in charge of the Electronics Department of the Secondary Technical School (e-mail: fernandosoria@unse.edu.ar).

Mario José Gómez graduated in electrical engineering with orientation in electronics at the National University of Tucumán, Argentina. He is an adjunct professor at the electronics 1 and electronics 2 faculty. He currently also serves as director of the electronics career. He is also a teacher in technical high school and is currently the head of the electronics department at the school (e-mail: mariog76@hotmail.com).

Nival Nunes de Almeida holds a PhD in Electrical Engineering from the Federal University of Rio de Janeiro and he is associate professor at the State University of Rio de Janeiro (UERJ). His research areas are engineering education and intelligent systems. He held the post of Rector of the UERJ from 2004 to 2007 and he was president of the Brazilian Association of Engineering Education from 2011 to 2016 (e-mail: nivalnunes@yahoo.com.br).

Vanderli Fava de Oliveira graduated in Civil Engineering, Doctorate degree in Production Engineering and Post-doctorate in Engineering Education. He is Professor of Federal University of Juiz de Fora where he teaches Introduction and Context and Practice in Production Engineering. He is Coordinator and Researcher of the Observatory of Engineering Education, Evaluator of courses and Institutions in Brazil and in the Arcu-Sur System of Mercusul and President of the Brazilian Association of Education in Engineering (ABENGE) (e-mail: vanderli.fava@ufjf.edu.br).

María Isabel Pozzo is a researcher at National Scientific and Technical Research Council and has been an Associate Professor at the National University of Rosario (UNR) since 2000, Argentina, where she teaches Field Work for Educational Scientists. She also teaches Research Methodology Postgraduates courses at different careers and universities. Her main research interests are related to teaching at the university level, ICT in higher education and interculturality. She holds a PhD in Educational Sciences from UNR and did her postdoctoral stage at the

Katholieke Universiteit, Leuven, Belgium with a Coimbra Group scholarship (e-mail: pozzo@irice-conicet.gov.ar).

Elsa Dobboletta is an English Teacher and Translator graduated from Institute of Higher Education "Olga Cossettini", Rosario, where she teaches Research Methodology. Since 1984 she has been an English Lecturer at several Engineering careers at National Technological University, Regional Faculty of Rosario. She is a member of the Research team of Dr. María Isabel Pozzo at Rosario Institute of Research in Educational Sciences from the National Scientific and Technical Research Council (IRICE-CONICET) (e-mail: elsadobboletta@gmail.com).

Brenda Bertramo is Professor and Licenciate in Educational Sciences, graduated at the National University of Rosario (UNR) under the supervision of Dr. María Isabel Pozzo. She teaches "Professional Practice" in Higher Education Institute of Santa Fe for Technical Studies and several humanistic subjects in high schools. Her main research interests are related to Higher education teaching evaluation through surveys (e-mail: brendabertramo@gmail.com).