Academic effectiveness of VISIR remote lab in analog electronics

Javier García-Zubía, Unai Hernández
University of Deusto
Bilbao, Spain
zubia@deusto.es

Ingvar Gustavsson
Blekinge Institute of Technology
Blekinge, Sweden
Ingvar.gustavsson@bth.se

Gustavo Alves
School of Engineering – Polytechnic of Porto, Portugal
gca@isep.ipp.pt

Abstract— **The effectiveness of VISIR is compared to other experimentation activities under the point of view presented by the professor Soysal in 2000. Advantages and limitations are discussed in terms of equipment availability, infrastructure cost, and contribution to various elements of experimental learning.**

Keywords-component; Engineering education, Students experiments, remote laboratories

I. Introduction

A key part of the formation of an engineer is focused on the concepts and physical basics that allow him to deal with guarantees his training in design. To develop these concepts, it is essential that the student can access to the laboratory and interact actively with the experiments and instrumentation. Regarding with this idea, the Accreditation Board for Engineering and Technology (ABET) establishes the use of the laboratories as a priority, based on the '13 ABET Objectives' [1].

Besides, teachers offer increasingly better electronic materials to develop autonomous and meaningful learning by the students, as slides, simulators, videos, etc. But this innovative process usually stops in the laboratory practical lessons which are designed in a classical format and without additional support beyond the open lab in order to the student finishes their practices. Remote labs appear to solve this problem, complementing the classic or hands-on laboratory with one accessible only by Internet.

This situation begins to change at the end of the 90s with the development of hardware and software equipments that allow access to experiments through Internet. It can be considered the year 2000 as the year where the remote labs are beginning to be a real tool, and the year in which Prof. Soysal carried out his job related with practical exercises using traditional and remote labs [2]. The main conclusion on his reflections is that the remote lab is a useful tool, especially in distance learning, but it is poorly effective tool in academic terms.

In 2010, 'The national engineering laboratory survey' was published as an output of the LabShared project, coordinated by the University of Technology, Sydney [3]. The goal of this survey is to describe the situation and possibilities of the remote labs in Australia. The report summarizes in its 68 pages, the results obtained from the research questions conducted in 34 Australian universities. The academic, executive, and technical staff groups were asked regarding these issues. One of the first conclusions of this report is that it will be really important to share the labs infrastructures through Internet. At page 5 of this report, it can be read:

'Remote laboratories are widely deemed to offer convincing benefits in terms of flexible access, student convenience and efficient use of equipment, but still need to ascertain their pedagogic effectiveness and financial viability to be regarded a regular supplement of hands-on laboratories'.

Section 'Remote Labs' of this report establish two ideas that are especially important in this paper. On the one hand about 40% of the academic staff (25 persons) knows what a remote lab is and what are its pedagogical uses, but only one person is a senior user of remote labs and only 4 of them are involved in the design and development of a remote lab. The report identifies several conclusions in this section, where the most important are the following ones (at page 54 of this report):

- Remote and hands-on labs should coexist, valued in their own right;
- The effectiveness of remote labs still needs to be proven;
- Remote labs could be used to complement, replace and supplement hands-on labs due to their special properties and advantages.

Again, the obtained conclusion is that remote laboratories are seen as useful and necessary tools, but they have not shown their academic effectiveness.

This paper focuses mainly on demonstrate the academic effectiveness of remote laboratories and thus going deep in the deployment and adoption of this solution in the academic world. The work focuses on the area of analog electronics and in the VISIR remote laboratory and it is organized into four sections, in addition to this introduction. Section 2 describes the VISIR system, and then work of Soysal is addressed. This work is completed with results corresponding to the VISIR platform. Academic outcomes for the VISIR in ISEP (Portugal) are shown in section IV. The work ends with conclusions and future work.

II. VISIR Remote Laboratory

The VISIR Open Lab Platform designed at the Department of Electrical Engineering (AET), the Blekinge Institute of Technology (BTH), Sweden, is an architecture for opening existing types of hands-on laboratories for remote access with preserved context in order to in the first place supplement and increase the accessibility and the capacity of them. A unique interface gives the student a feeling of being in the hands-on laboratory [4]. Some types of laboratories are easier to open for remote access than others are. So far, the current VISIR platform (4.1) supports laboratories for electrical experiments and for mechanical vibration experiments.

Most instruments in an electronics laboratory have a remote control option but the breadboard has not. To open a workbench for remote access a wiring manipulator possible to control remotely is required. A switching matrix equipped with electro-mechanical relays can serve as such a device [5][6]. The switching matrix for remote wiring of electrical circuits is shown in the upper side of the photograph in Fig. 1. It is the card stack on the top of the PXI chassis that contains the instruments. VISIR platform has been described in many works [7][8][9], but here we only want to remark here the most important parts of it.

- **Web interface**: it makes possible that the user can perform the same actions as he were in the traditional lab. Its powerful interface developed in Adobe Flash represents realistic front panels of the equipment used by the students to test the circuits developed in the virtual breadboard.

- **Measurement server**: it acts as a virtual instructor that controls the commands passing from the web interface to the equipment server to prevent hazard circuit designs and protect the instruments. It is programmed by 'max list' files which contains the maximum component values and instruments adjustments for each experiment and describes the allowed circuits in the platform.

- **Equipment server**: the PXI platform connected to the relay switching matrix, both are controlled by this server written in LabVIEW. It receives the commands from the measurement server over TCP/IP to be executed on the real instruments. A 'component list' file is inserted to the equipment server to define the components installed on the matrix.

- **The switching matrix**: it is the matrix especially developed for this remote lab that performs the connections between the components and instruments that the user has carried out in the web interface.

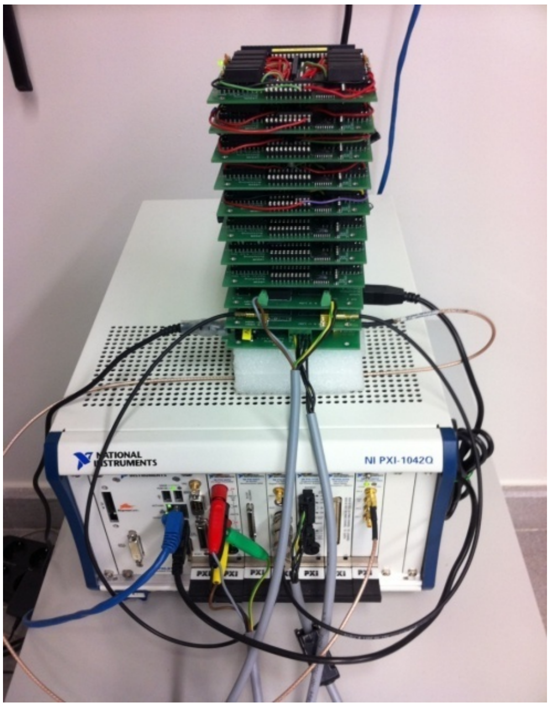

Figure 1. VISIR hardware platform at University of Deusto

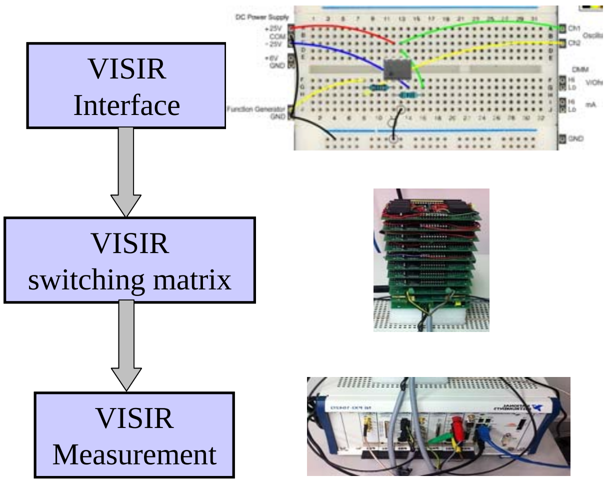

Figure 2. Practical session work flow using VISIR lab

Fig. 2 represents graphically the work flow at a VISIR practical session: the web interface allows the student to create the circuit in a virtual way through a web browser while the measurement and equipment server both are in charge of making this circuit real on the switching matrix and provided the user with the measurements obtained from the previously created circuit. This work flow described in these simple steps is represented graphically at Table II.

III. Academic Requirements of an Experiment and Remote Laboratories

In an experiment of basic analog electronics the main objective is to show the students a physical phenomenon and enable them to interact with it in order to understand the concepts and rules of the theoretical model. During this work the students acquire knowledge and also become familiar with the engineer's abilities. The 13 ABET objectives describe what are expected from the work in the laboratory:

1. …apply appropriate sensors, instrumentation and/or software tools to make measurements of physical quantities.
2. …identify the strengths and limitations of theoretical models as predictors of real world behaviours. This may include evaluating whether a theory adequately describes a physical event and establishing or validating a relationship between measured data and underlying physical principles.
3. …devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the resulting data to characterise an engineering material, component or system.
4. …demonstrate the ability to collect, analyse and interpret data, and to form and support conclusions. Make order of magnitude judgements and use measurement unit systems and conversions.
5. …design, build or assemble a part, product or system, including using specific methodologies, equipment or materials; meeting client requirements; developing system specifications from requirements; and testing and debugging a prototype, system or process using appropriate tools to satisfy requirements.
6. …identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process or design, and then re-engineer effective solutions.
7. …demonstrate appropriate levels of independent thought, creativity and capability in real-world problem solving.
8. …demonstrate competence in selection, modification and operation of appropriate engineering tools and resources.
9. …identify health, safety and environmental issues related to technological processes and activities, and deal with them responsibly.
10. …communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports.
11. …work effectively in teams, including structure individual and joint accountability; assign roles,
12. …behave with highest ethical standards, including reporting information objectively and interacting with integrity.
13. …use the human senses to gather information and to make sound engineering judgements in formulating conclusions about real-world problems, responsibilities and tasks; monitor progress; meet deadlines; and integrate individual contributions into a final deliverable.

The six first objectives are related to the practical experience in the lab while the other 7 objectives describe the general or traverse skills. Soysal work establishes 11 basic elements in a practice of laboratory and scores them by asterisks in a subjective and well founded way.

TABLE I summarizes the original one obtained from Soysal work, completed (by us) with a specific column concerning the VISIR remote lab (S1, S2, S3, and S4 are explained in TABLE II). The maximum is **** and the minimum is *. In principle a column is better than another one if it has more *, and although each reader can analyze/create TABLE I in a different way, the * assigned to VISIR should not be very different as VISIR merges the characteristics of CIE-os and CIE-ol. Anyway, each reader can fill his own table, and he can establish what laboratory is the best solution for his academic requirements. Some of the * assigned are explained in the next pages, but other can be seen more subjective.

To complete the table reading to VISIR lab a few remarks should make. The VISIR laboratory reproduced the working conditions of two of the types of lab work described by Soysal: Individual design projects and Computer integrated experiments On Site.

With respect to the first type of laboratory, VISIR interfaces provides the student with the same situation as in a classical lab session, where the student he should select and mount his own electronic circuit without any help from the VISIR platform. The same can be said about the start-up and adjustment of the instruments, because the instruments are displayed without any preset.

Regarding with the second type of experimentation, the VISIR is based on the same technology or similar: GPIB in the case of Soysal lab and PXI at the VISIR lab. Both choices are justified by the year of development of both remote labs. In this topic, the LXI technology is currently emerging. In this second comparison, VISIR lab does not offer any possibility of saving information about the experiment, and therefore it does not provide an analysis of the obtained results by a computer. In this way, the user hast to save his own data and analyze them after the practice.

In this sense the VISIR lab reproduces a classical instrumentation session, where the information was obtained visually and the user wrote it by hand in a paper. Currently most of the instruments provide facilities and services to obtain and save measured data in electronic format for future electronic analysis. This drawback can be solved by the VISIR because PXI technology makes it possible (like the GPIB).

The four stages of a practical session have been grouped at TABLE II. Only four scenarios have been analyzed: two in a classical lab (hands-on and computer assisted session), and two in the remote lab (CIE-os and VISIR). TABLE I and TABLE II both are related through the S1, S2, S3 and S4 annotations at TABLE I that represent the stages of a practical exercise in the laboratory.

TABLE I. TABLE I SOYSAL TABLE COMPLETED WITH VISIR REMOTE LAB CONTROL

	Individual design projects	**Guided lab experiments with conventional instruments**	**Computer simulations**	**Classroom demonstrations**	**Computer integrated experiments: on site**	**Computer integrated experiments: on line**	**VISIR**
1. Selection of instruments (S1)	****	**	-	-	**	-	***
2. Selection of components and material (S1)	****	***	**	-	***	-	***
3. Building of experimental setup (S1)	***	****	***	-	****	-	****
4. Debugging (S2)	****	****	****	-	****	-	****
5. Dealing with environmental conditions and disturbances (S2)	****	****	-	-	****	-	****
6. Instrument setting and adjustment (S3)	****	****	*	-	****	**	****
7. Data collection (S3)	**	**	****	**	****	***	**
8. Numerical processing of obtained data (S4)	**	**	****	**	****	****	**
9. Analysis and interpretation of the results (S4)	**	**	****	***	****	****	**
10. Understanding of physical concepts	*	*	****	***	****	****	****
11. Presentation of experiment results (S4)	*	*	****	*	****	****	****
	31	**29**	**30**	**11**	**41**	**21**	**36**

TABLE II. TABLE II DESCRIPTION OF THE DIFFERENT TYPES OF LABORATORY BASED ON THE PHASES OF THE EXPERIMENT

	Hands-on lab with conventional instruments	**Computer integrated experiments on site (CIE-os)**	**Computer integrated experiments: on line (CIE-ol)**	**VISIR**
S1. Selection and Assembly of the under test (Interface)	****	***	-	***
S2. Experiment Implementation (switching matrix)	****	***	-	***
S3. Measurement of the signals on the circuit (measurement)	***	****	***	***
S4. Presentation and analysis of results	**	****	****	***
	13	**14**	**7**	**12**

TABLE III. TABLE III ORGANIZATIONAL CHARACTERISTICS OF EACH TYPE OF LABORATORY

	Hands-on lab with conventional instruments	**Computer integrated experiments: on site (CIE-os)**	**Computer integrated experiments: on line (CIE-ol)**	**VISIR**
Opening hours. Timetable	**	**	****	****
Lab management and organization	**	*	****	***
Student per workbench	*	*	*	****
Price per student	**	*	****	***
	7	5	13	14

The goal of Stage 1 (S1) is to build an electronic circuit to test. It is divided in three steps: selection of the circuit elements (given at the practice script), selection of the measurement instruments (this information should not be reported in the script) and finally, the performance of the practice in the breadboard. As the VISIR is a copy of a hand/on lab session, the user can perform the same steps in both scenarios. The difference is that the VISIR lab limits the number of circuits that can be created, because not all the available combinations are allowed. Regarding with the CIE-os scenario, the instruments are preselected and connected to the breadboard, so the student doesn't need to do this step. In this situation, all the work is given to the student and he cannot control it and use for its learning process.

At S2 the experiment is performed, and in this case the important issue is that the student interacts with a real situation: noise, failed connections, mistakes, etc. In other words, he has to debug the practice to obtain correct results. The hands-on scenario is the most real one, but at CIE-os and VISIR lab some circumstances are under control and cannot be handled by the student, for example the connections. At CIE-os, the student cannot control anything in the practice, because the experiment is fully prepared.

In Stages 3 and 4 students must measure, represent and manipulate information to analyze the experiment and get the relevant conclusions. In this situation VISIR offers the same information as a hands-on lab, but it makes it through a computer, which enhances its use.

But VISIR is less powerful than CIE because in both situations the numeric information is collected to be analyzed later using specific software as Excel, Matlab, etc.

The conclusion is that VISIR lab is very close to offer to students equal opportunities which they can take on a classic or computerized laboratory. VISIR need only implement procedures to capture and send the student files with the numerical evolution of the experiment. This improvement is technically easy, and only depends on the design of the interface, and not on the capacity of the VISIR to collect that information.

From an organizational point of view the TABLE III shows the different possibilities offered by each type of laboratory to exploit it in the subjects.

Beyond the number of assigned bullets, the most notable conclusion is that a remote laboratory is always available to the student (24 hours a day, 7 days a week), and it happens although the teacher in charge of the lab is not worry so much about the lab, because in the case of the VISIR and CIE-os, both are only one equipment (VISIR is more complex than CIE-os).

The price of the VISIR is high, but it should be split between the number of students, which may well be hundreds or thousands of them.

Finally, the VISIR allow several students to be connected at the same time, so they have the illusion that there are multiple instances of the VISIR lab, when in reality what happens is that the VISIR has a system of multiplexing, which allows up to 16 users at the same time to practice with a frequency no higher than 4 MHz. Basic exercises with signals around KHz have come to connect more than 100 students simultaneously without loss in the quality of the experiment with a latency of no more than 5 seconds.

TABLE I, TABLE II and TABLE III allow concluding that the VISIR is a tool that does not disturb at all the academic work of a student during a practical session, and therefore it should be considered as a relevant tool in the process of teaching and learning of students in analog electronics.

IV. Academic performance of VISIR at ISEP

The VISIR platform was acquired by and installed at the School of Engineering – Polytechnic of Porto (ISEP), in July 2010. During the 1st (fall) semester of 2010-2011 it was used in support of lab classes of a large undergraduate Physics course, with over 550 students enrolled. The students were naturally divided into two large groups: one group (A) doing the course for the first time, and another group (B) that had a valid lab mark from the previous year. The goal, for students belonging to group B, was to provide the conditions for recalling the lab work done and allow them to keep in pace with the course syllabus. The preliminary results regarding such a methodology were published in [10], where one of the most important aspect was the atypical (i.e. more autonomous) usage of the VISIR platform by students of group B. A possible explanation for this fact is the way students are motivated to use VISIR: i.e. if they have an intrinsic or extrinsic motivation, where in each case the learning gains may differ. To analyze this aspect, the scores obtained by students, of the two groups, in one particular question of the final exam (i.e. directly connected to the sort of competences/knowledge that could be trained with VISIR), were compared against the information if the student had used (or not) the remote lab. The results, published in [11] showed that students from group B that used VISIR performed better (i.e. they had, in general, higher scores in that particular question) than those that did not use it. This was not observable in students from group A, i.e. it was not possible to clearly distinguish, in terms of the score obtained in that question, students that used VISIR from those that did not. When comparing the two groups, it was noticed that students from group B (with prior contact with the course) did perform better, as they showed a significant lower number of 0% on that particular question.

The academic performance of VISIR at ISEP is now being evaluated under different conditions, i.e. it is being used in six different courses, of six different degrees, and results will be published soon.

V. Conclusions and Future Work

The VISIR platform is an effective tool for teaching analog electronics. VISIR is also an open consortium and actually it has six partners-universities: BTH (Sweden), UDeusto (Spain), ISEP (Portugal), FHW (Austria), UNED (Spain), CUAS (Austria) and India. The future work should be developed by this consortium:

- To federate all the VISIR systems running in a unique platform. Doing this the consortium will offer the students more experiments with the same effort.
- To allow collaboration in VISIR. For instance, some persons will be able to control the experiment at the same time.
- To integrate assessments in the VISIR system.
- To allow people with special needs to access the VISIR system.

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AUTHORS

J. García-Zubia is with University of Deusto, Electronics and Automation Department. He is with the University of Deusto, he is Head of Dpt. of Industrial Technologies of the Faculty of Engineering. He is the responsible of the remote lab at the University of Deusto (WebLab-DEUSTO: weblab.deusto.es). The WebLab-Deusto has been implemented using web 2.0 techniques (AJAX, SOAP, etc.), this approach is a novelty in Europe. Different works have been published explaining the results and the technology of this weblab and the evolution of WebLab-DEUSTO has been supported by different projects. (e-mail: zubia@ deusto.es).

U. Hernández is with the University of Deusto in the Telecommunications Department at the Faculty of Engineering. He is developer of the research group on web-based laboratories and he is in charge of the remote labs based on instruments control. He is involved too in the deployment in University of Deusto of the VISIR project leaded by the Blekinge Institute of Technology (Ronneby, Sweeden). (e-mail: unai.hernandez@ deusto.es).

I. Gustavsson, is with the Blekinge Institute of Technology, Department of Electrical Engineering, Karlskrona, 37179, Sweden, (email: ingvar.gustavsson@bth.se).

Gustavo R. Alves is with the School of Engineering – Polytechnic of Porto, in the Department of Electrical Engineering. He is involved with the Physics LabFARM project, sponsored by ISEP. His research interests include design for debug and test, reconfigurable systems, and remote experimentation in e-learning contexts. (e-mail: gca@isep.ipp.pt)