Remote Lab Experiments
Preliminary Results from an Introductory Electronic Engineering Module

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Keywords: Remote Lab, Remote Experiment, Engineering Education, Web-based Education.

Abstract: A case study concerning the remote lab use in introductory module for Electronic Engineering studies is presented. During the preparation stage of a forthcoming lab session, students access remote experiments using web browser pages for each instrument which are fully controlled and acquire data in real time. Instead of using virtual instruments or performing only computer simulations students are able to accumulate experiences about the forthcoming lab session and thus prepare more efficiently for it. Preliminary research shows that there is a considerable improvement in students' performance.

1 INTRODUCTION

Facilities of the laboratories in higher educational institutions are generally insufficient when the number of students is considered. Implementation of a laboratory to meet the requirements has a very high price. For this reason there is an increasing tendency for the use of Remote as well as Virtual Laboratories. The former denotes that real lab equipment made accessible over the internet by second being virtual simulations only performed by dedicated software. Both types have advantages and drawbacks but they can be adapted to a course in order to broaden the students' perception and skills (Jeschke *et al.,* 2007; Jona *et al.,* 2011).

The use of remote experiments have received great attention during last years. Several projects have focused on the dissemination of such online experiments: The European LiLa project (Richter *et al.,* 2011), the iLabs project (Sancristobal *et al.,* 2010) of the MIT, the Australian LabShare project (Lowe *et al.,* 2008) as well as The Lab2Go project (Zutin *et al.,* 2010) aim at building an index of online labs by providing infrastructures for dedicated and specialized experiments. The use of these infrastructures for the introductory-core (first two semesters) level of an Engineering curriculum may be redundant. Based on this observation the Education Unit of Laboratory of Electric

Characterization of Materials and Electronic Devices designs and offers a web-based remote lab providing a set of basic remote experiments that support the laboratory assignments of the core module "Introduction to Electronics" at 1st semester. The main factor that motivated this work was the fact that students have been observed to lack preparation prior to lab sessions.

In previous work the theoretical part of the module was supported by using electronic examinations and assessments of undergraduate students like multiple choice tests and virtual experiments (Tsiakas *et al.,* 2007; Triantis *et al.,* 2007; Ninos *et al.,* 2010)

The current paper presents the results of a preliminary study from the application of remote experiments run at the Department of Electronics during 2012-13 fall semester.

2 DESIGN APPROACH

The proposed system based on National Instruments' (NI) LabVIEW and Texas some type of remote access (usually web pages), the Instruments' (TI) TINA software. The architecture based on client-server lightweight approach meaning that all the critical (and process demanding) elements are relying on Lab's servers while students

access their experiments through certified web browsers. The basic architecture of the system is presented on Fig.1.
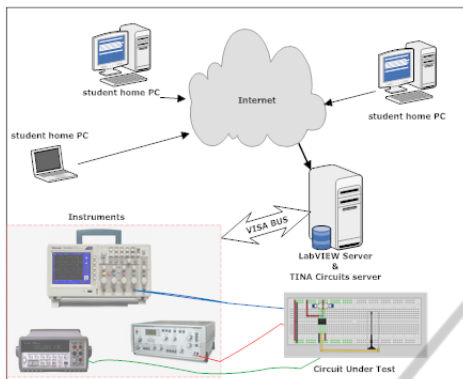

Figure 1: The architecture of the proposed system.

The basic elements of the design are as follows:

1) *The LaBVIEW Server*. The core of the system which runs on VPN servers. Each experiment hosted in a dedicated server which is accessed by web browsers in predefined ports. Configuration is straightforward using NI's knowledge base. Instruments controlled using the VISA interface and acquired data are stored also locally in order to avoid experiment termination in case of Internet failure.

2) *The instruments' remote panels*. For each instrument we design and implement a remote panel (RP) and subsequently transform this RP to a web page. Students access the corresponding web page for each instrument and functioning the RP. The LabVIEW controls and indicators were customized to look slightly different from the real controls of the controlled instruments. This was chosen in order to discourage students to "memorize" the function of each individual control instead of clearly understanding it. Typical examples of a signal generator and an oscilloscope are presented in Fig. 2 and Fig. 3

3) *The TINA 9 remote circuits*. For verification purposes, students require to run a simulation at the time that they perform the remote experiment. Using TI's TINA (which installed in their local hard disks) they have the ability (using TINA's internal web browser) to collect and run the corresponding circuit. Since TINA can run independently from RP web pages each student can run the remote experiment and at the same time checking the validity of acquired values by running the corresponding simulation.

4) *The booking system.* Since LabVIEW cannot provide access to two or more users simultaneously it is crucial to provide single user access through an
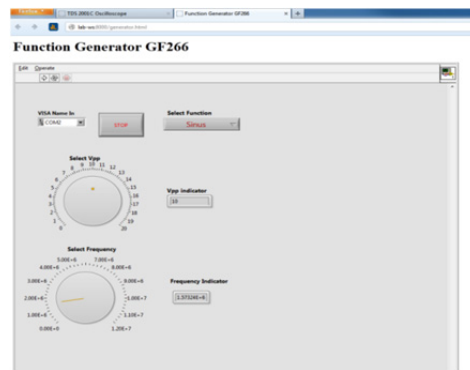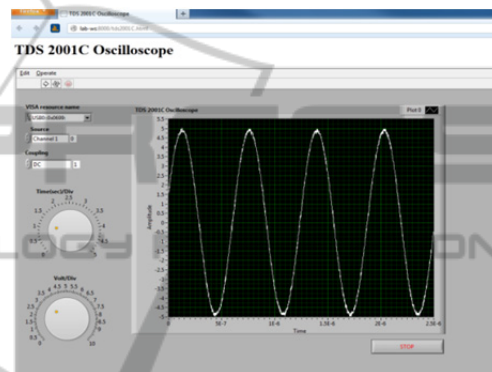

Figure 2: Function Generator RP web page.

Figure 3: Oscilloscope RP web page.

effective booking system. This was achieved using a simple web form which checks the available timetable and informs the user for time-slot availability. Each student is provided by 90min session which is 30 min less than regular lab session. Booking can be made only once and if the student cannot use his session an alternate timetable is provided after the completion (by all students) of the remote experiment.

3 METHODS AND DETAILS

The study was performed using results from multiple choice questions from 15 students. Initially the students follow the experiments' procedures using the traditional approach by completing the preparation steps (which includes simulations and calculations) before enter the lab. Then each student required answering in 10 questions regarding the experimental procedure as well as the interpretation of results. This was defined as Tn_{pre} phase. Then, instead of simulations, students run preliminary remote experiments in order to perform initial

calculations. In correspondence with Tn_{pre} they called to answer the same set of 10 questions. This was defined Tn_{post} phase.

The evaluation of possible improvement by the use of remote experiment is examined by comparing students' results without (Tn_{pre}) and with (Tn_{post}) the use of remote experiments. Initially, results checked for their internal reliability by means of Cronbach's α value for each dataset (Cronbach, 1951; Cronbach & Shavelson, 2004).

The possible improvement is measured by means of Hake's gain g (Hake, 1998) which defined as follows:

$$g = \frac{Tn_{post} - Tn_{pre}}{\max\{Tn\} - Tn_{pre}}$$

where $n:$ number of test
    $max\{Tn\}:$ test's maximum score

Hake's gain has been accepted as an important measuring parameter for teaching efficiency because as weighing the students' improvement, the effects from their different level of previous knowledge is corrected (Lenaerts et. al, 2003).

An additional questionnaire was supplied to students in order to investigate the usability and the global satisfaction from remote lab's use.

4 RESULTS AND DISCUSSION

Our preliminary results derived from two curriculum subjects: low and high pass filters. For each subject we perform a multiple choice test thus we present results for tests T1 and T2.

Results for the calculation of Cronbach α are presented in Table 1. Internal consistency of results can be characterized as accepted since all $\alpha > 0.7$ (Cortina, 1993). In all cases the results follow normal distribution according to Kolmogorov-Smirnov test (Stuart et. al, 1999).

Table 1: Cronbach's α results for both tests.

Test phase	Cronbach α
$T1_{pre}$	0.862
$T1_{post}$	0.809
$T2_{pre}$	0.779
$T2_{post}$	0.721

In Table 2 we present the results from all the students per question as well as the improvement according to Hake's g. The average number of students that gave correct answers per question increased from 21% to 50% for Test1 and from 31%

to 53% for Test2. These correspond to Hake's improvement 0.37 and 0.33 correspondingly.

Table 2: Successful results per question (Q) for two experiments (T1 & T2).

Q	$T1_{pre}$	$T1_{post}$	g	$T2_{pre}$	$T2_{post}$	g
1st	4	9	0.45	6	10	0.44
2nd	3	10	0.58	4	8	0.36
3rd	1	7	0.43	5	8	0.30
4th	4	10	0.55	2	6	0.31
5th	0	6	0.40	1	6	0.36
6th	5	6	0.10	7	10	0.38
7th	2	4	0.15	5	9	0.40
8th	3	6	0.25	5	7	0.20
9th	4	8	0.36	5	8	0.30
10th	5	9	0.40	6	8	0.22
Average per Q	*3.1*	*7.5*	*0.37*	*4.6*	*8*	*0.33*

Results indicate that by using remote lab experiments, students were able to improve their performance. The improvement is quite similar between the two tests.

Students' perception toward the remote lab indicated a positive evaluation from students. Usability and overall achievement level earned higher scores in contrast with global satisfaction which earns controversial scores (very high and very low). Results are presented in Fig.4
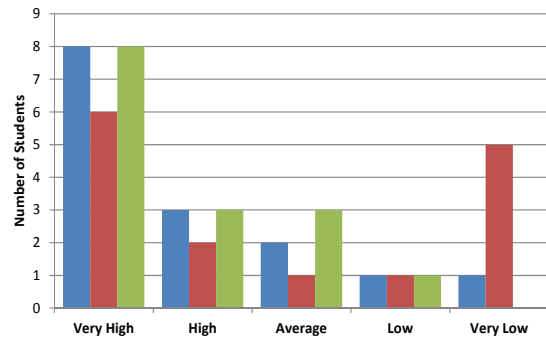

Figure 4: Student survey results: System's Usability (blue bar), Students' opinion on contribution of the Remote Lab to overall achievement level (red bar) and global satisfaction from the complete system (green bar).

Subsequent conversations clarified the latter aspect as a result from the students that graduated from General High schools (as opposite to Vocational High School graduates who had lab experience). Students that didn't have previous experience with physical instruments present a lack of understanding the potential benefits of the remote lab than actually using the real instrumentation.

5 CONCLUSIONS

The current paper presents preliminary results of case study from the use of a remote lab in an introductory course in Department of Electronics at TEI of Athens. Using the National Instruments' LabVIEW and Texas Instruments' TINA we implement a web-based system for remote lab capable of providing experiments using real instruments. Students use their web browsers to control and collect data from real instruments while they have the ability to run simulations on the measured circuit using TINA's web offered circuits.

Preliminary results using multiple choice questions are presented in order to investigate if and how the use of remote experiments benefits students' perception. Using Hake's g measure we estimated that initially there is an improvement in performance which of course is a subject for future work.

Finally a non-measurable parameter that is observed to benefit from the application of remote lab is the time that each instructor consumes in order to introduce and explain each experiment. There was a drastic decrease in time spent by the instructors for the students that used the remote lab. This fact can lead to disperse instructors' time to more personalized sessions with students that show lack of performance.

Future research will focus on the applicability of the proposed system to advanced courses as well as to the elimination of operational drawbacks (e.g. automatic selection of optimum timeslots, booking changes, elimination of overbooking e.t.c)

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