

# Exploring didactic possibilities of an electronic devices remote lab with students of Electronic Engineering

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## Abstract:

*This paper presents some results of an exploratory study carried out with the collaboration of students, whose aim was to examine the teaching potential of a self-developed remote lab, called “Electronic Physics Remote Lab”. The remote lab allows us, among other things, to test different kinds of diodes and transistors. Students of Electronic Engineering attending Physics IV have been asked to use the remote lab for the development of the following activities: a) to study the development of different junctions and infer about their constructive features and b) to obtain parameters of the devices under different test conditions, and to explain the behaviors observed from the point of view of the physical processes. Besides, students prepared test reports of the remote lab.*

**Key words:** *Tele-learning, remote lab, exploratory study, possibilities of teaching use.*

## 1 Introduction

The inclusion of remote real experimentation through the use of remote labs in the field of engineers training is not new. A review work [1] which included the analysis of 42 publications between 1997 and 2007 reveals the existence of remote labs in different parts of the world designed for the teaching of contents in different Engineering disciplinary fields; among them, we may highlight Electronics, Robotics, Automatics and Physics as the fields that contain the largest amount of developments. The authors of this work [1] also point out the lack of teaching proposals through remote labs supported by education from a constructivist conception of learning. Whereas, in another work where the use and evaluation of a remote lab from the students' point of view is reported [2], it is pointed out that there are few articles focused on the didactic usefulness of remote labs as a teaching tool.

According to this and with the support of the words mentioned above for the training in the field of engineering, the question is: What does it mean to state that a remote lab – such as any other kind of technology – is a “teaching tool”? It is stated that a remote lab has “didactic usefulness”, but with the aim of building what kind of learning, or for the development of which competences? Which cognitive processes shall be favored by its use in a teaching context? Is it necessary for certain conditions to be present for the remote lab to become a teaching tool or resource? Which conditions?

This paper presents some results of an exploratory study carried out with the collaboration of some students, whose aim was to examine the teaching potential of the remote lab, called “Electronic Physics Remote Lab” for the elementary training of engineers to be at Universidad Nacional de Rosario (UNR) in the field of electronic devices. The experimental conditions under which the study was carried out were: a) instruction based on a constructivist approach which included the use of the remote lab by 12 students within the syllabus of the subject Physics IV, belonging to the career of Electronics Engineering (UNR) for the topics Junctions and BJT Transistors, b) students’ self resolution of the learning activities through the use of the remote lab and c) students’ development of test reports about the remote lab.

The present work has been organized as follows. In part 2, the didactic usefulness of the remote lab is inquired into; the objectives of engineers training are analyzed and the scene in which the study is carried out is described. In part 3 the constructive features of the remote lab used are detailed, pointing out those that a priori, stand out as the most useful ones from a didactic point of view. In part 4 the results of the analysis of test reports elaborated by students who used the remote lab in the experimental conditions are shown and in part 5 the improvements already fulfilled in the remote lab are described and the results of the study are discussed.

## **2 Looking for didactic reasons to the incorporation of the remote lab**

### **2.1 *Engineers training... In which context..?***

New technologies, the exponential growth of knowledge, the changes in the organization of work, the constant social change, the internationalization of professional training, are some of the characteristics of this knowledge society, which poses new training needs to university institutions. As it is known, they are also the support of a continuous claim for quality training stated by public organizations, professional associations and accreditation agencies all over the world.

With reference to the said before are highlighted as needs, the development of some skills for the search and selection of information; of mental processes that allow the graduate for the critical and creative use of it in order to define, face and solve problems in which there is uncertainty in the data or which are simply unknown; the development of competences to see the overall as a whole, as a complex integrated and related system, but which, at the same time, allows to see, analyze and/or infer the specific. It refers to a profile of an engineer who, almost irrespective of his specialty, formulates, develops and uses models; expresses and explains his ideas; has gained cognitive autonomy for the exploration of alternatives and methods; for the operation of different variables; for the taking of responsible and ethical decisions within contexts of uncertainty as much as of work emergencies; but who has also obtained full understanding and acceptance of a way of collaborative work, feeling him/herself as part of a team, for which he/she will need to have developed communicative and expressive skills both in his/her relationship with other people and with the objects (technologies and resources in general) he/she works with. All this is stated with the aim of designing, planning, developing, innovating, arranging, supervising, directing, leading, with a high sense of responsibility and ethics, integrated systems including people, materials, equipments, energy and information in the search for quality, the lowering of costs, the sustainable growth of the company or organization that he/she belongs to or serves from different professional or academic areas.

Being these formative needs considered true, it becomes essential to focus the attention on the features that the teaching action shall assume. In relation to this, there is no doubt that the classroom is the privileged area where the teaching action expresses itself, framing a whole series of conditions that affect the teaching process, in either its relational and technological relationship, thus contributing to or inhibiting the development of certain strategies, which are necessary for the achievement of the training objectives wanted. Such as Gimeno says [3] both the students' behavior as much as the teachers' is explained since it is integrated into a context that determines the communicative-didactic processes involved.

On this matter, the "classroom context" is considered as a "learning environment" [4] of dimensions extended by the optimization of the potential for the representation and communication which arise from integrating means and resources (even those which have been traditionally held in non-formal educational or labor training areas). In this extended environment /classroom, the teaching action appears as the generator of situations [5] allowed by the community of real and simulated, direct and intervened practices which are epistemologically, psychologically, sociologically [6] and technologically based for the establishment of a real educational interactivity [7]. It gains sense with the aim of promoting among students, within an idiosyncratic but shared process, highly significant and functional learning, towards the achievement of autonomy in the resolution of tasks, in the application of concepts, in the implementation of reflexive and pro-active attitudes; planning efficiently, choosing strategies, testing processes and products, acquiring self-control of the learning activities themselves.

That is why saying that a remote lab is a useful resource from a didactic point of view, means – in the opinion of the authors of the present work - to be able to see clearly its potentiality for it to become a useful means/tool for the generation of learning situations that promote the development of those complex cognitive processes. So, what can the remote lab offer for the construction of that learning environment?

Different authors have set forth as some of the advantages of remote labs the following: the possibility of free experimentation over real devices without the need of being physically in the lab; the flexible time schedule to carry out the practice; time saving in previous tasks to be developed in a traditional lab; safety and confidence in the experimentation [8]. Other benefits pointed out in the bibliography are: the improvement in the availability of the lab equipment; the increase in the amount of lab tasks or practices; the flexibility and extent of timetables available for the experimentation [9]; the possibility of using human resources and materials from traditional labs; the increase in the amount of hours for the training of the students and the possibility of carrying out experiments in an arranged way or even a more open one, where students develop problem solution, observation, interpretation and result analysis skills in a way that is similar to what researchers do [10]. It is clear that not all of these advantages appear per se and that while some advantages are based on the improvement of cognitive processes, others – without arguing about their validity and importance – refer to aspects that are nearer the educational and technological management of the institutions.

## **2.2 The syllabus as scenery for the research**

The experimental course for the achievement of the study object of communication in the present work has been carried out in the subject Physics IV found in the second semester of the second year in the career of Electronics Engineering, at UNR. The topics from the syllabus of the subject include the study of matter and its structure, and also the study of different kinds of materials and of the physical performance of junctions and devices from the

electronic world. The approach starts with the analysis and re-shaping of the conceptual base towards a model of the matter inside the quantum paradigm. The study of the different materials uses a characterization that starts both from the analysis of its structure and of its electrical, optical and magnetic properties with a technological influence. Thus, to the analysis of the devices operation modes and to the considerations about their use it is permanently added the conceptual support supplied by the study of the Materials Science and Technology, stating their relationships, through the development of ways of thinking that dialectically, in the looking ahead about each topic, combine the building and the analysis of scientific and technological models.

The didactic design corresponds to a conception that, in the cognitive area, gives priority to the building of learning, through strategies that seek to favor the establishment of conceptual relationships arranged in a hierarchical order, the construction of models, the search and analysis of information, the study of processes, the creation of hypothesis, analysis, synthesis and integration. This is in order to facilitate different, significant and convergent means of accessing to knowledge, covering the study of devices with diverse resources from a double perspective: scientific and technological. For this, the subject has developed varied study materials: written modules, simulations (applets), a multimedia system and a traditional lab; it also has an Internet site and an electronic list through which communication is permanently held. The experimental dictation includes face-to-face teaching moments and working strategies which typical of e-learning [11].

The basic strategy used to reach the students' progress with contents is the resolution of tasks considered as complex problems for the learning and formative process assessment. This approach is associated to a way of teaching that recovers the use of theory and practice as an integration in permanent reflective dialogue; experimentation as exploration starting from inquiry based on a framework of theory, the building of hypothesis and the solution of problems that, beyond the calculations, ask for the analysis, the construction of models and the production of knowledge in different levels. In this context, experimentation in a traditional lab is conceived as an activity that leads the student, by doing it in small working teams, to gain abilities in different measuring techniques, to acquire an investigative attitude, to get in touch with real devices, to analyze its properties linking them to the concepts already studied, to become familiar with characteristic curves and to discuss applications thus complementing the scientific analysis from the point of view of technological use.

Within the framework of experimental dictation it is stated as a hypothesis that the remote lab integrated into the carrying out of significant open and complex problem solution activities may, in this context, help students of engineering develop abilities in:

- § The observation, interpretation and analysis of results in a way that is similar to what researchers do [10].
- § The stand-alone resolution of tasks, the putting into practice of reflexive and pro-active attitudes, the planning, the self-control of learning activities.
- § Interpretation in order to account for the behaviour of basic electronic devices under different experimental conditions from a scientific perspective.
- § The generation of parameters, the analysis and construction of technological models.
- § Experimental trial through some usual working methodology in working spaces

The incorporation of the remote lab in the experimental dictation occurred within the framework of individual resolution learning activities suggested to students as open written exploratory problems thus covering the topics: junctions and multi-junction devices. The first topic is basic for the understanding of the behavior of the different semiconductor diodes, and

necessary for a based study of the physical processes that account for the behavior of almost all semiconductor devices. The second topic is absolutely important as long as it requires the understanding of the electronic seen when considering complex structures including interacting junctions, such as transistors. Students have been specifically asked:

- § To study the behaviour of different junctions (silicon and germanium rectifying diode, breakdown diode, base-emitter junction and BJT base-collector junction, led diode) and to infer about the constructive features.
- § To obtain characteristic parameters of devices (such as,  $\eta$  in the case of a diode; the current gain  $\beta$  in common-emitter connection and output dynamic resistance, in the case of a BJT) under different rehearsing conditions (different temperatures) and to explain the observed behaviours from the perspective of the physical processes involved.

The statements were supplied to students after making an initial contact with the remote lab, once the first unit corresponding to junctions had been finished. The students' first approach to the resource consisted of:

- An explanation on the most important existing differences between this "real lab" which is accessed to remotely through an Internet connection and the simulations "virtual lab" that the students were familiar with. On this matter, the distinguishing aspects relating to the basic building characteristics of each laboratory, the nature of the information available in each case and the interpretation the user must make of it have been highlighted. On the other hand, students observed several tests in front of the equipment in order to be able to see, at the operator's requirement, the start of the indicator light linked to an active element.
- A round of screens, resources, possible requirements and operating capacity recognition. To get this, apart from a short general explanation, each student was given a user name and a password of their own.

Students solved the suggested activities on their own, outside the classroom. The submission of the corresponding reports containing the solution to the activities to the teachers' team was arranged in two weeks, in agreement with the time devoted in the syllabus of the subject to the treatment of each topic. Once the experimental dictation was over the students were asked to prepare a test report of the remote lab including, in a free writing format, an analysis of its benefits from an educational point of view, apart from the critics and suggestions for its improvement.

### 3 The Remote Lab

The first development of the remote lab [12] was carried out within the context of a final project of the Electrical Engineering degree course. In that opportunity the objectives to be fulfilled through the development of the prototype were:

- § To obtain the characteristic curves of: (a) diode in direct polarization; (b) Zener diode; (c) Bipolar junction transistor (BJT) with common-emitter configuration; (d) J-Fet and (e) Phototransistor.
- § To test the devices in different polarizations.
- § To obtain some characteristic parameters of the devices from the results.

Regarding its uses, it was aimed to:

- § The test of several devices in the same lab.
- § The independence of the access platform (compatible with different explorers such as Mozilla, Internet Explorer, Opera, etc.)

- § Operating without using any kind of additional resources in his computer.
- § Simple, intuitive and easy-to-use interface
- § Access only to registered users in order to make it easier for each user to recover their previous trials. On this matter, during the fulfilment of the experiment, the events are kept in the database Server of the lab so the student has the possibility to recover the information and see the results of the experiment.
- § Admission to more than one user through the use of a buffer. Specifically, if more than one student want to develop a test through the remote lab at the same time, the system enables one of them while the others keep waiting. Once the first test is over, the system enables the second one and so on.
- § Data export to Excel spreadsheet for a subsequent analysis and treatment

All in all, our top priority was to develop low cost hardware and software in order to allow a user connected to internet from any PC, irrespective of the model of the PCs and without a high-level technological updating, the remote experimentation and measurement of parameters and the analysis of real semiconductor devices through curves. In this way, even a student connected from a station such as an internet café or a cellular phone, could make the experiments without the need for any complementary devices.

After a first evaluation carried out by the teachers and a small group of students, in both cases as experts, it was seen the need to make adjustments to that first development as well as some changes in the interface in order to make it possible to:

- § Display certain areas of the curves in the tests of bipolar junction and J-Fet transistors which make some physical concepts associated to the observed performance interesting to be discussed together with the students.
- § Carry out the tests made with temperature separately from the rest of the tests.

The architecture of the remote lab has been described in previous works [12] y [13]. One of the trials allows us to see the effects of temperature over the BJT characteristic curves. Fig. 1 shows a screen corresponding to this trial.



Fig. 1: Visualization of a BJT test.

The graphic of only points, values table and way to export to Excel can be seen.

## 4 The Results

Twelve (12) students took part of the experimental dictation. The reports in the data base of the remote lab reveal that all the students entered and carried out tests with all the devices enabled. Not all students made individual test reports, thus only 5 reports were available. In most cases, the report showed a brief list of assessing considerations and specific suggestions about the design of the interface and the functionality of the remote lab; one report included, apart for the assessments and suggestions, the description and explanation of each test and also the results obtained, accompanied by the corresponding charts and graphics. The chart and curves analysis reveals the students' interest in trying the remote lab with section tests, including among them the extreme zones of the curves. The observations carried out by students were analyzed, grouped and categorized, whose results are shown in Table 1:

Category	Dimension	Rating	Suggestions	
The remote lab	Functionality	It answers immediately to what it is asked to do, intuitive and easy-to-use.		
	Relevance	Test are useful to solve the activities	Add more tests: LDR, thermistor, photodiode, tunnel diode	
	Graphic interface			Have a chance of zoom or automatic adjustment on both axes in order to see some curves more clearly.
				Add the circuit picture in the results screen.
				Enable free graphic movement
		Charts show too many values		Leave only the option of exporting data.
		The values in the charts are too accurate. Even the unit mil is appreciated.		It would be good to find a way so that the values measured in different tests were different.
		Group tests from one only device.		
Rectifying diode forward bias test and zener diode reverse bias test	Graphic interface	Very good curves displaying	Add diode complete curve displaying.	
	Test design		Add test at different temperatures. Add some current value in forward bias non-conducting zone.	
Active mode BJT test	Graphic interface	Very good displaying of the characteristics in all the working areas. This makes the experience highly satisfactory.		
	Test design		Add test in common-base connection; it is only possible in common emitter.	
			Add test with temperature and overlap the curves in one only graphic.	
Reverse mode BJT test	Graphic interface	There are skips for lb values next to nil.		
		At seeing in detail the non-conducting zone, small breaks in the curves are observed. It gives the idea of a real test.		

Table 1: Remote lab students' test results

BJT base-emitter junction tests at different temperatures	Graphic interface	Excellent display of the characteristic. Each area can be appreciated.	
		The system naturally shows error when asked to trace the load line.	Add more options for Vbb and eliminate the displaying option from the load line.
	Test design		It would be interesting to measure the working temperatures.
BJT base-collector junction tests	Graphic interface	Excellent display of the characteristic. Each area can be appreciated	
			Obtain temperature variation curves and overlap them in one only graphic.
	Test design		It would be interesting to measure the working temperatures.
Common emitter connection BJT complete test	Graphic interface	It is very useful and didactic to see the complete functioning in only one graphic.	
			It would be interesting to obtain the transference characteristic and observe it in the same graphic.
Study of the BJT gain at $I_b = cte.$ at different temperatures.	Graphic interface	It is clearly seen the gain variation with temperature	
		Results consistent with the ones obtained through other tests.	
		Small breaks in curves are observed. It gives the idea of a real test.	
Complete Jfet test with temperature variation	Graphic interface	Very good display of the output features.	
		The different areas are clearly seen.	
			Add the option of showing the geometrical place of the pinch off
	Test design		Enlarge the Vds rank in order to see the breakdown
	Test design	There is no significant variation in the curves corresponding to different temperatures.	
Phototransistor test with temperature variation.	Graphic interface	Very good display of the output features.	
	Test design	There is no significant variation in the curves corresponding to different temperatures.	
Infrared led test	Graphic interface	The values in the charts are too accurate and are repeated from one test to the next; it implies less realism.	
	Test design		Add some current value in non-conducting zone.

Table 1(cont): Remote lab students' test results

## 5 Conclusions

### 5.1 Improvements carried out in the remote lab

Since the present study some adjustments and changes have started to take place. So far, taking into account the students' suggestions, there have been some changes in the hardware and software as well as in the interface which allow to:

- § Obtain and display in one test the diode complete curve.
- § Obtain and display the bijunction transistor temperature variation curve in one graphic in order to be able to compare them.
- § Change the scale of the axis of the curves shown in order to be able to observe better certain features of each device.

On the other hand, in agreement with some suggestions given by students, the development moves forward according to the results of the previous evaluation carried out by the team of teachers in:

- § Addition of new test devices: unijunction transistor, four-layer diode (Shockley), multicoloured led, germanium bijunction transistor and other variations of bijunction transistors.
- § Improvement of the interface of tests selection

### 5.2 The didactic potentiality of the remote lab according to the analysis of the study results

The remote lab allowed students to test and to obtain different kinds of voltage-current diode, bijunction and J-Fet transistors curves as well as to make significant analysis of the physical processes wanted through the resolution of the activities suggested. Although students used the remote lab with the aim of solving those learning activities at first, the degree of appropriation of this tool by students seems to have gone beyond the objectives of the study. On this matter, all students showed themselves favorably predisposed along the study. Regarding the task of evaluating the remote lab, this has meant an important plus towards learning therefore the student has progressed, from this, in the development of tests that were not required, which has led to a rich and creative use of the remote lab.

Most suggestions were considered appropriate. Students have used the remote lab as a complementary resource to the traditional lab; they have dared to suggest tests with new objectives and to ask for the addition of other devices which are a matter of study in this chair. On the other hand, it is important to highlight that not all the valuations and/or suggestions of improvement developed by students seem to be the most appropriate ones from the perspective of the didactic analysis. It is logical that students as users prefer that the experiment options that give error responses by the system or the device tests under conditions where replies given back by the remote lab do not turn out to be useful are removed. However, this bad or unnecessary reply sent by the system, may represent an important contribution to the students' training, therefore, if it is conveniently used, produces new processes of analysis, the bringing up and test of new hypothesis that will have an effect as a better cognitive structure.

In short, from the point of view of the analysis of the educational results, it can be said that experimental dictation, with the inclusion of the remote lab within the framework of active learning strategies, has resulted in a highly satisfactory experience. Students have got

involved making decisions about their own learning process and they have done interesting valuations and improvement suggestions that, it is thought, will have a positive effect on the design of the remote lab and on the learning of future students. The results encourage new experiences and also make it possible to state that the remote lab may become a valuable teaching resource for the training of engineers. Finally, thinking of the advantages reported in present research as well as of the technological progress, it is possible to consider the integration of the remote lab to a Web 2.0 environment as a possibility for future development.

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