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Electronics remote lab integration into a MOOC – Achieving practical competences into MOOCs

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Abstract

Massive Open Online Courses (MOOCs) phenomenon introduces a new philosophy in educational models. Regardless of users'/students' motivation when enrolling (lifelong learning, educational support, interest in new educational areas, etc.), MOOCs expand the ways of reaching knowledge. Flexibility is one of the key aspects of this new educational methodology. This flexibility has to be expanded/translated to all the aspects/features of the course. For educational institutions, traditional approaches must be left behind when designing courses and must provide a new approach to educational process.

MOOCs fit very well to several areas of knowledge. However, they involve significant challenges for science MOOCs to be really effective, especially in developing courses. These educational challenges are highlighted in courses which need to offer practice-oriented learning in order to build successful cross-curricular capabilities and abilities. Nowadays, educational institutions trust in experimentation as one of the pillars in which learning is based. In fact, theoretical models used in books and in traditional classrooms just try to bring closer to students the actual behavior of real systems. Unfortunately, it is not possible to provide students with a laboratory in a totally/one hundred percent remote learning environment.

This paper deals with the results of the integration of a remote laboratory in a MOOC; how it has been taken advantage of VISIR pros and how its cons have been solved, as well as the evolution of the global system (LMS+VISIR) in continuous improvement.

Keywords: Index Remote laboratory, MOOC, VISIR, Electronics, Experimentation.

1. Introduction

Broadly speaking, the experience acquired through laboratories provides active learning complements to traditional lecture-based education and an understanding of the subject beyond ideal modelling. In-person laboratories, remote laboratories, virtual laboratories and simulators are the options available for educational institutions in order to complement the learning materials and are necessary for the structure of courses in which experimentation plays an essential role [1]-[5].

Nowadays, there is an extensive variety for providing theoretical contents in distance learning (videos, documents, tutorials, scaffolding activities, peer-to-peer reviews, forums, etc.) to students. These tools, by an efficiently and appropriate selection from professors and use from students, can complement or replace successfully in-person education, even they can reach some aspects that in-person education cannot achieve. Unfortunately, practical issues are not as developed as theoretical ones are. A first approach to this problem is clearly the use of simulators and virtual labs. Although, they are still a bit far from providing to student the real performance and features of equipment under real-life operation conditions. The major challenge is the provision of laboratory working online along with the theoretical contents in a massive context.

A remote laboratory is a tool which comprises a hardware layer (equipment, instruments and experiments) and a software layer (responsible for monitoring equipment and instruments over the experiments). The main advantage of remote laboratories - when compared with traditional electronic laboratories, - lies on its availability that has either temporal nor geographical restrictions. With remote laboratories students are provided on-line with real equipment located in an educational institution. A review of the current literature shows a great number of universities or organizations which have created their own virtual and remote laboratories to support life-long learning and students' autonomous learning activities [6]-[12].

Remote laboratories, if properly designed and managed, provide controlled and safe scenarios at the expense of flexibility. This loss of flexibility when experimenting is due to the protections and constraints established by teachers in the design stage of the experiments and limitations established by remote lab operation. For example, destructive experiments that students may be carried out erroneously in in-person laboratories, cannot be allowed in remote labs. But sometimes, this loss of flexibility in the interest of safety also limits the students' freedom, thus limiting students' options to explore.

The essential difference between remote laboratories and in-person laboratories results from how the interaction between student and workbench is performed. Therefore, remote laboratories have very limited ability to provide manual skills; "Physical presence however is only one element in the perception of reality, a student's subjective mental reality" [3], [13]- [14].

VISIR (Virtual Instruments System In Reality) is a remote lab for electric and electronic circuits experiments, developed at Blekinge Institute of Technology (BTH) in Sweden and in use in several universities all around the world [15]. Although VISIR allows concurrent users, it does not allow an indeterminate number of them. The intrinsic limitations of a real laboratory such as VISIR collide with one of the most relevant features that any MOOC must have: scalability.

The essential difference between remote laboratories and in-person laboratories results from how the interaction between student and workbench is performed. The main advantage of remote labs when compared with in-person laboratories lies in its availability that has neither temporal nor geographical restrictions. They also have some underlying improvements: low maintenance cost and requirements, no need of human resources during students' experimentation, no associated risks neither for students nor instruments and equipment (if well designed), etc. But, obviously, remote labs have limitations not available in in-person laboratories, for example freedom degrees while designing experiments or destructive

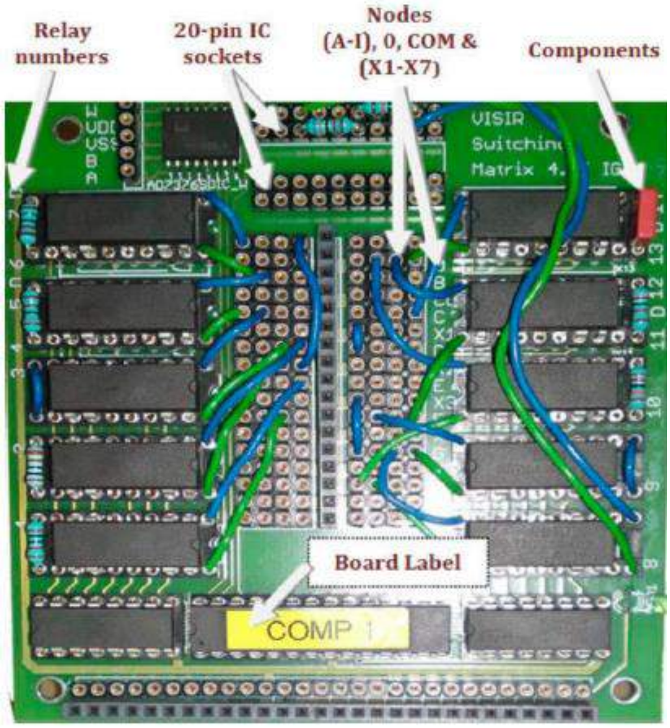

Figure 1. Component board

experiments. Meanwhile remote lab VISIR finds constraints in the number of components available <<hardware limitation stated by the room in the component boards>> (see Figure 2) and constraints in the experiments designing <<hardware limitation due to the components internal disposal and short-circuits implemented in the matrix>>, in-person laboratories have no limitations when using components and designing circuits.

2. Deployment Scenario

2.1. Remote lab

In VISIR, the traditional equipment (DC-power source, function generator, multimeter and oscilloscope) are replaced with an equipment platform, which is suited for remote control such as PXI (PCI eXtensions for Instrumentation), LXI (LAN eXtensions for Instrumentation) and GPIB (General Purpose Interface Bus) [16].
The traditional instruments are replaced by the modules cards NI PXI-Instruments (manufactured by National Instruments). The NI-PXI Instruments and the NI-PXI-Controller (a PC) are plugged into the NI PXI-Chassis.
The relay switching matrix is where the components are allocated and connected to the modules cards NI-PXI. It is manufactured in BTH. The construction of the circuit is possible by means of

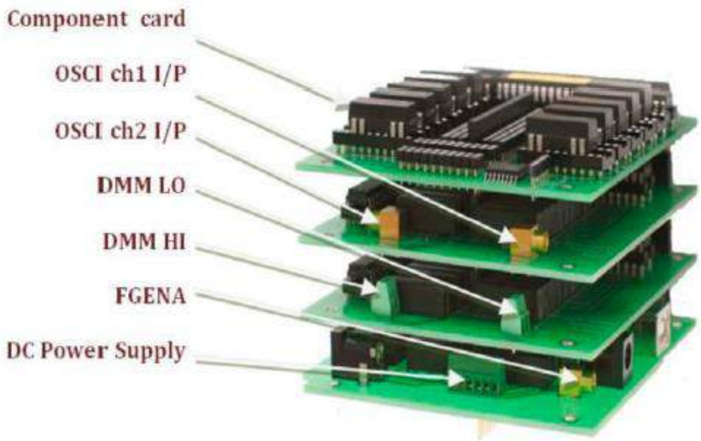

Figure 2. Relay switching matrix.

relays which act as a switch between nodes and components (Figure 2). Each NI PXI-Instrument is also connected to the relay switching matrix (Figure 1).
The VISIR software is released under a GNU GPL license [17]. The "Web Interface" is the webpage of VISIR. When a client logs in, it generates a session cookie to be recalled by the "Measurement Server" for authentication purpose. Through the Web Interface, the "Experiment Client" is accessed. The Experiment Client represents the entire laboratory workbench through an HTML page as an embedded object. The roles of the Measurement Server are: The authentication at each request of the session cookie; The validation of the construction of the circuit and instruments values (defined previously by the administrator/teacher); The handling of time-sharing between simultaneous users; The handling of queue of requests. The "Equipment Server" is a stand-alone equipment controller written in LabVIEW, which handles all the instrument hardware together with the relay switching matrix.
The remote lab VISIR used during the different editions of the MOOC is located in Electrical and Computer Engineering Department (DIEEC) of the Spanish University for Distance Education (UNED).

2.2. MOOC platform

UNED-COMA platform (Massive Open Online Course in Spanish: Curso Online Masivo Abierto), aimed at the deployment of MOOCs from different departments of UNED, is an UNED-Abierta (Open-UNED) initiative and part of its platform [23]. UNED-COMA platform is based on OpenupEd MOOC platform provider [23]. Open-UNED was created by the UNED in order to draw together Open Educational Resources (OER) from UNED. The platform explodes the rich experience of UNED educational system in distance education.
MOOC course
The MOOC has been named: "Circuits Fundamentals and Applied Electronics" (BCEP; "Bases de Circuitos y Electrónica Práctica" in spanish) and has been running for 3 editions. The core of the MOOC is the remote laboratory VISIR. The evaluation and activities spin around the remote laboratory and the objectives and evaluation are focused on the handling of the instruments and measurements. The students have not time limitation for completing the different modules and tasks.
The acquisition of the competences for analyzing circuits is not an objective for this MOOC. The knowledge, at least theoretical, on analyzing electrical and electronics circuits and the electrical characteristics of most common components are necessary requirements for participants. However, supplementary materials are provided, in each module of the MOOC, in order to facilitate the understanding of the behavior and circuits for those students that fulfill only part of the requirements but are interested in following the course.
With respect to the objectives associated to the principles established when designing the course, the structure of the MOOC could be divided into 3 blocks:

- Block 1: The purpose of the activities associated to this block is to collect information: basic data such as age, genre, country, labor situation, etc.; training information such as the maximum academic level, previous experience in any kind of laboratories, training, level of knowledge to address the learning outcomes effectively, etc.; and finally the motivation of the enrollment in this course such as the expectations about the remote laboratory, the interest of the students in electronics, etc. The method employed for obtain this information are the non-evaluative exams (two non-evaluative mandatory exams throughout the course) and surveys (three optional surveys during the course). This block is made up of Module 0 and Final Module.
- Block 2: The main idea behind this module is to give the students a work philosophy on how to deal with laboratory practices. Another objective of this block is to disenchant and/or to cause the "MOOCaholics"
- Block 3: This block is where the students interact with the remote laboratory VISIR and where the designed practices take place. This block is made up of Module 3 to Module 8.

2.3. Students

The enrollment philosophy is consistent with the policy of the MOOC courses: Massive —no restrictions on the number of participants— and Open —open access, anyone can enroll the course— [21]; this philosophy is inherited from UNED-COMA platform but it doesn't collide with BCEP principles. However, course's syllabus warns that BCEP MOOC is a nonbasic course and the participant must have previous theoretical knowledge in electronics analysis and components behavior.

3. Actors' Integration

3.1. Scalability

One of the pillars on which MOOCs rest is the scalability: courses are designed to support an indefinite number of participants [21]. In VISIR, there is a physical constraint to the number of concurrent users performing measurements; threshold limit value is 60 even though it is very unlikely that all connected users perform measurements simultaneously due to laboratory time is mostly allocated in the circuit assembling and configuring the equipment much more than for measuring. Unfortunately, the intrinsic limitations of a real laboratory such as VISIR collide with one of the most relevant features that any MOOC should achieve: scalability. This is one of the critical points we wanted to analyze: the adaptability of the remote laboratory VISIR into a massive environment.

3.2. Remote laboratory response

Remote laboratories have very limited ability to provide manual skills; "Physical presence however is only one element in the perception of reality, a student's "subjective mental reality" [18]-[20]. This difficulty can be overcome by immersing users in the laboratory by means of its interface.

Aside from remote lab interface, which cannot be improved or modified easily, an optimal time response of remote lab improves the immersion in real-time systems.

VISIR allows two ways of measuring: single measurement mode or continuous mode. Single measurement mode is used when measuring with VISIR's digital multimeter, but it also can provide a VISIR's oscilloscope snapshot when using oscilloscope probes. For intermittent measures, such as the ones mentioned above, time response is not a critical factor. However, in continuous mode time response gets critical for users' immersion in a real-time system such as VISIR. On the other hand, laboratory time response depends on several factors: circuit, frequency, number of measuring requests, etc.

Figure 3 to Figure 5 show VISIR's time response in different scenarios.

3.3. Booking system

The limitation imposed by VISIR on the number of simultaneous users that it is able to manage in a satisfactory way requires the use of a booking system. VISIR has its own reservation system, however it requires user authentication. To prevent users from managing two user accounts, one for UNED-COMA platform and another one for VISIR remote lab, it was necessary to create the resource (booking system) in UNED-COMA platform. UNED-COMA sends data coded in a json file: authentication token and id-slot; the resource decodes the json file and sends back a request to check that the the data received by means of an Application Programming Interface

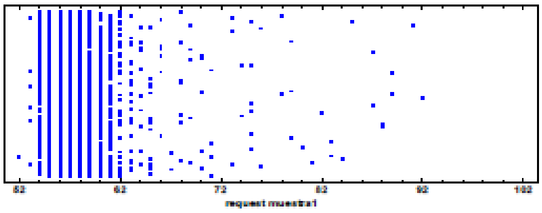

Figure 3. Unique user, time response in milliseconds; 5 minutes in continuous mode.

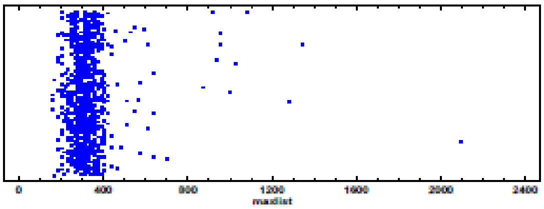

Figure 4. 5 users simultaneously measuring, sample time response in milliseconds; 5 minutes in continuous mode.

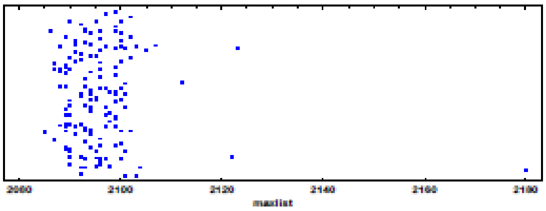

Figure 5. Over 20 users simultaneously measuring, sample time response in milliseconds; 5 minutes in continuous mode.

key (API key). This resource is not designed exclusively for VISIR access, but it is designed for any kind of tool which requires a booking; for example, video-conferencing or web conferencing through AVIP classrooms (Audiovisual tool over IP technology) developed by UNED-INTECCA (Technological Innovation and Development in the Study Centers) [22].

The settings used in the booking system from UNED-COMA for the three BCEP editions has been: 16 concurrent users per turn, 60 minutes per turn, a maximum of 2 simultaneous turns reserved per user and a limitation of 14 reserves throughout the course. With these settings, VISIR allows a maximum of 384 students to experiment with any of the practices designed in MOOC daily. This configuration may have been altered during MOOC depending on the demand, but it was not necessary.

The booking system was developed from the side of the MOOC platform, but it was also required to develop a new authentication service in VISIR for users from UNED-COMA platform. The new (mooc-user access) and existing (traditional access) authentication systems "live" together: both authentication services coexist. Students from other courses, teachers and administrators have accessed VISIR following the traditional process, meanwhile UNED-COMA users have interacted with the new authentication services.

3.4. UNED-COMA

UNED-COMA platform does not provide any type of tool for teachers to track the progress of students in the MOOC, only provides general information (number of enrollments, number of badges obtained, etc.). In order to obtain more specific information, i.e. for an individual monitoring or to obtain the grades of the students, the databases (PostgreSQL, MongoDB) of the MOOC platform have been analyzed. Unfortunately, UNED-COMA no longer provides access to the databases; only first and second editions have could be analyzed.

Besides, the possibilities offered by UNED-COMA platform, when establishing activities and assessment tasks in the designing phase of the course, are very limited: the viewing of videos, video-questions or P2P activities are the assessment tools for evaluating student progress. Assessment tools provided by the platform are not ductile for any type of subject, but even less when the target is to evaluate the practical skills acquired.

3.5. BCEP course

In first modules, the MOOC aims to provide students with a work philosophy to follow in the subsequent modules. This work philosophy proposes the students these sequential steps:
Theoretical analysis of the circuit.
Performing an analysis of the circuit using a simulation tool with the purpose of monitoring the time-dependent signals.
Experimenting in a real environment (laboratory).
Analyzing the behavior and comparing the limitations, advantages, differences, etc. between the different methods.
The course contains 97 evaluative activities, 55 standard multiple choice questions (including single-answer questions and multiple-answer questions) and 42 videos. The weight of the videos is 30% of the final grade and they need 80 over 100 to obtain the certifying badge. Besides this structure, two extra modules (one before the beginning of the course and another one once the students have completed the course) are responsible of compiling the students' profile and their knowledge level by means of optional surveys and questions about basic circuit analysis and electronics components. UNED-COMA platform doesn´t have any tool to carry out surveys, so an external tool has been used to accomplish it, therefore there is no way to identify the behavior of students according to their profile. The basic electronic practices included in this MOOC are focused on:

- Basis of laboratory equipment and instruments.
- Measurements of resistances, voltages and currents.
- Rectifiers.
- Filters.
- Zener diode as regulator.
- Rectifier diode and Zener diode as clipper.
- Inverter and non-inverter operational amplifier.
- Operational amplifier as a driver.

The course structure comprises 8 modules: Module 1 is dedicated to electronics simulation: MicroCap software is proposed and several demonstratives videos and a manual are supplied to students together with documentation about the theoretical contents of the course; In Module 2 the remote laboratory VISIR is introduced to students, but they do not have granted access yet, demonstrative videos with the special features of every instrument and a manual are provided to students in order to familiarize with the laboratory workbench; From Module 3 to Module 8 students interact with lab, building real circuits with VISIR and taking measurements related with them. Every module is focused in one or more functionalities and handling of the laboratory instruments (breadboard, multimeter, function generator, power supply and oscilloscope). Module 3 and Module 4 aim specially in teaching the handling of the lab equipment, components and instruments, whereas Module 5 to Module 8 are centered on showing the behavior of real components and specific features of the instruments (coupling, trigger, cursors, measurements menu, etc.).

3.6. Students

The age of students is distributed evenly. Slightly stands out the group of students over 40 years old. By contrast, the group of students under 20 years old was the minority one. This results are

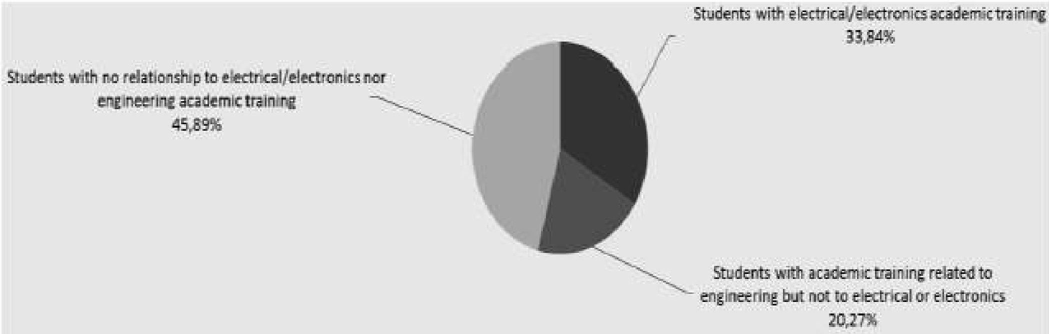

Figure 6. Students'previous training

shown in **¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.**. Regarding to students' availability of time, **¡Error! No se encuentra el origen de la referencia.** shows the labor status of students.
Only 33.84% of those enrolled have some training related to electrical/electronics engineering previously to the MOOC (see Figure 6); from the remainder, 20.27% had some type of training related to engineering but not with the electrical/electronics area. Therefore, only 33.84% of those enrolled had the training required as it is specified in the syllabus of the MOOC.
Figure 6. Students'previous training.

4. drawbacks and Solutions in the Integration Process

4.1. Booking system

The MOOC's design allows the administrator to use several parameters, as the number of slots per turn, number of simultaneous turns and total number of allowed turns in the course. Each turn has assigned 1 hour. By changing these parameters, we can regulate the remote laboratory availability to the demand of use. However, these parameters were enough to cover the demand of the remote lab: only four turns have had all the slots used. In this regard, the booking system has managed satisfactorily the remote lab turns.
In the other hand, other courses (external to UNED-COMA platform) require access to the lab as well. When these courses need the access to VISIR, it entails to avoid access from UNED-COMA platform. So, the booking system should be unique in order to allow all the courses to share the remote lab resource.

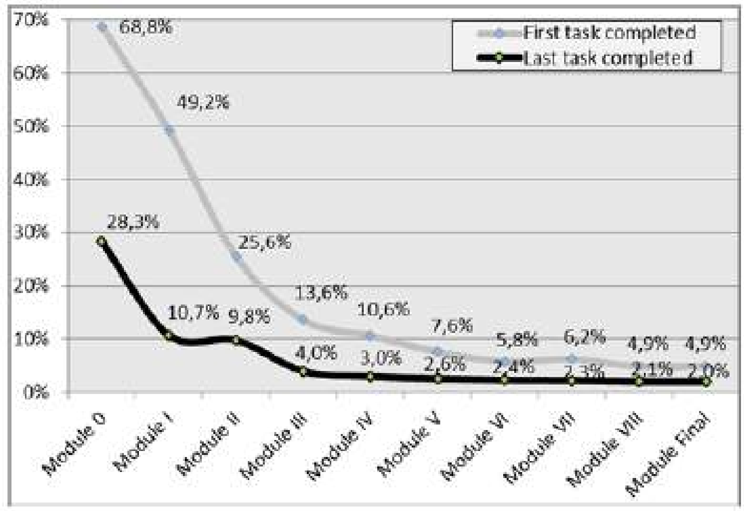

Figure 7. Dropout.
Percentages expressed from enrollments

4.2. Databases

UNED-COMA platform is not intended/designed for the integration of a remote laboratory in MOOCs. Therefore, due to the technical problems resulting from the adaptation, is not possible to cross the data available in the UNED-COMA platform and the one registered in VISIR. Consequently, it is not possible to carry out a reliable learning analytics. Furthermore, the booking system designed in UNED-COMA has not been the most suitable for a post-analysis of students' behavior: the interaction between MOOC BCEP hosted in UNED-COMA platform and remote laboratory VISIR is not carried out as a whole but as two separate entities. The communication between the UNED-COMA platform and remote laboratory has a gap because it is focused on the veracity of the access request and ignores user information, so, in the eyes of VISIR, all the users with a reservation from UNED-COMA are correctly authenticated in VISIR but anonymously.

Students

The dropout rate has been high as is usually in this type of courses (Figure 8); less than 4% have obtained the course credential badge of those who started the course. One of the main reasons for this dropout have been the need of a theoretical background to understand circuits' behavior. This fact is reflected in the high dropout rate in the first modules.

A bad design of the MOOC activities (both laboratory experiments and associated activities derived from the measurements from VISIR remote lab) may cause to students to focus more on completing them than in analyzing the results and understanding the behavior of the circuit and/or components. In this regard, when students have been asked about the duration of the experiments (Figure 9, left) and activities associated (Figure 9, right) with the experiments in general they agree that, both activities, they have had to perform in the remote laboratory (measurements, wirings, variations of the same circuit, etc.) and the activities derived from it (calculations, graphs, tables, etc.), are long. Both distributions are slightly skewed to the right (the mean is slightly greater than the median), exceptional high values impact the mean and pull it to the right, but both distributions are concentrated between "5" and "8" (lower and upper quartiles from Figure 9).

So, in general, the students' opinion opts to consider that the course's activities are long or very long. Figure 9 take into account all students who have completed several activities into the BECP MOOC, the trends shown in both are more pronounced when taking into account only those students who have completed the course (their opinion have more judgment elements), as reveal Figure 10.

Table 1. Accesses to instruments and components. Shortcuts include all shortcuts allocated into relay switching matrix (24 used). (*) More than one resistor with the same ohmic value used from the relay switching matrix

		R 10	581.437		
		R 75	4.801	C 100 nF	888.139
Solved lists	3.023.794	R 470	193.287	C 10 uF	145.329

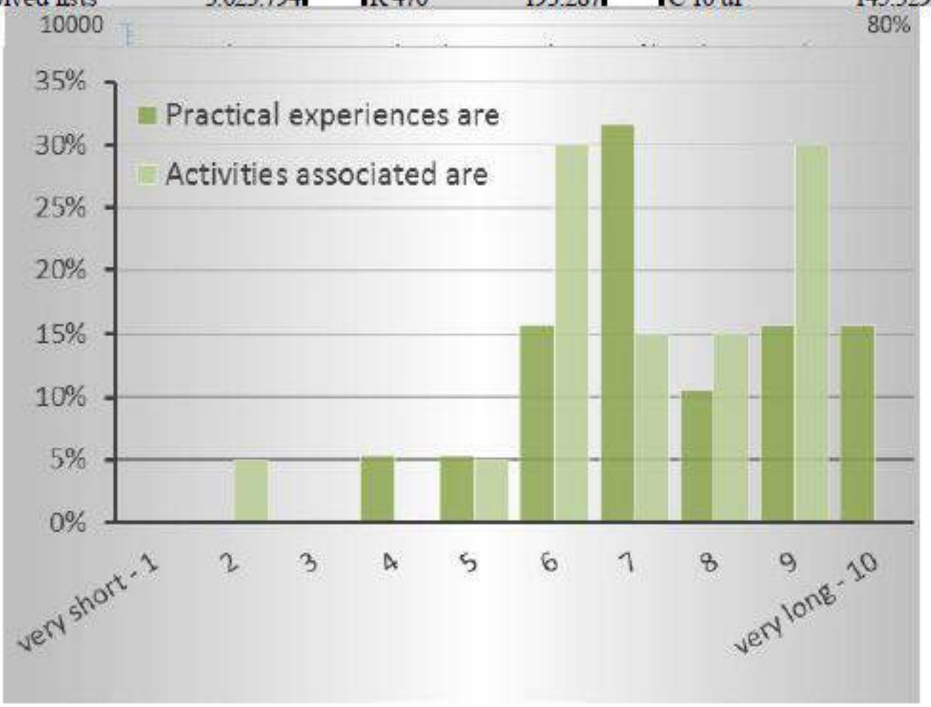

Figure 9. Answers from students who has completed BCEP MOOC.

4.3. UNED-COMA platform

UNED-COMA platform doesn't provide the tools and mechanisms to flexibly the design of courses. However, students have been able to course the MOOC, to complete the different activities and tasks, to interact with the remote lab, to interact in the diverse forums, etc. for students, the platform has accomplished its function without fanfare. But for teaching staffs, the platform doesn´t provide the flexibility and resources that other MOOC platforms as Open edX or Coursera have and that LMSs (Learning Management Systems) have exploited for years. In addition, the data provided to teaching staffs don't allow a learning analytics in order to find potentials dropout causes.

4.4. Remote laboratory VISIR

The reliability of the remote lab has been tested through the massive and continuous access from MOOC. Table 1 shows the number of measurements in every single component. With the constraints imposed there were no need to change any component and the remote lab was active and functional 24/7.

The operation cycle depends on the number of concurrent users, the circuit designed, the settings of the equipments, etc. For example, for a clipping circuit, by means of a Zener diode (practical experience 5) with 182.979 measurements, the mean time needed for a cycle has been 291 ms and the median 203 ms. The minimum time has been 62 ms. Using an operational amplifier as inverter (practical experience 6) with 182.979 measurements, the mean time needed has been 331 ms and the median 219,3 ms. The minimum time has been 78 ms. Taking into account the 3 million of accesses of the whole course for all the practical experiences, the mean time was 118,7 ms and the median 68.

About the time needed by the measurement server in deciding whether or not a circuit designed is allowed, it only takes 6.0496 ms to determine that the design is correct, 6,95884 ms when it is no allowed. This time required by the measurement server is included in the operation cycle.

5. Conclusions

Remote laboratory VISIR has been used (and currently still is) in a massive and tough environment. The results of use it in both engineering subjects as in the MOOC are satisfactory. In addition, the designed practices became stimulating, providing users the clear feeling of working with a real laboratory.

UNED-COMA platform is not intended/designed for the integration of a remote laboratory in MOOCs. Therefore, and due to the technical problems resulting from the adaptation, is not possible to cross the data available in the UNED-COMA platform and the one registered in VISIR. Consequently, it is not possible to carry out a reliable learning analytics. Furthermore, UNED-COMA platform does not provide any type of tool for teachers to track the progress of students in the MOOC, only provides general information (number of enrolled, number of badges obtained, etc.). In order to obtain more specific information, i.e. for an individual monitoring or to obtain the grades of the students, the databases of the MOOC platform have been analyzed. Unfortunately, UNED-COMA no longer provides access to the databases. In this regard, a MOOC platform with the necessary tools for a deeper analysis of the students' learning process and that integrates both environments (MOOC and remote laboratory) seems necessary in order to evaluate the convenience of the supplementary documentation (videos, documents, activities, etc.) and their relationship with learning and dropout.

Given the students' profile enrolled in the course (previously to the course only 33.84% had some type of training in electrical/electronics area), this kind of courses, with a design according to the goals, can be used by educational institutions as a claim for potential enrollments in the field of engineering. In this respect, the interest in electrical/electronics field from potential students under 20 years old (group with minority of enrollments in BCEP MOOC and with the greatest potential interest from universities) should be achieved by means of the design of MOOCs based on experimentation but containing at least a basic theoretical framework with which novice students could be able to understand the behavior of the components and circuits used in the remote experimentation, so they are introduced to a unconnected knowledge area for them until then. Getting access to school-age students through educational institutions and covering their teachers' concerns by means of designing/adapting MOOCs for this group of students could benefit students, teachers, educational institutions and universities providing a more complete education and bringing university to potential students.

Therefore, the integration of remote laboratories in online learning environments, together with good practices in designing practical experiences, can alleviate the disadvantages of remote laboratories compared to in-person laboratories, without leaving behind their inherent advantages.

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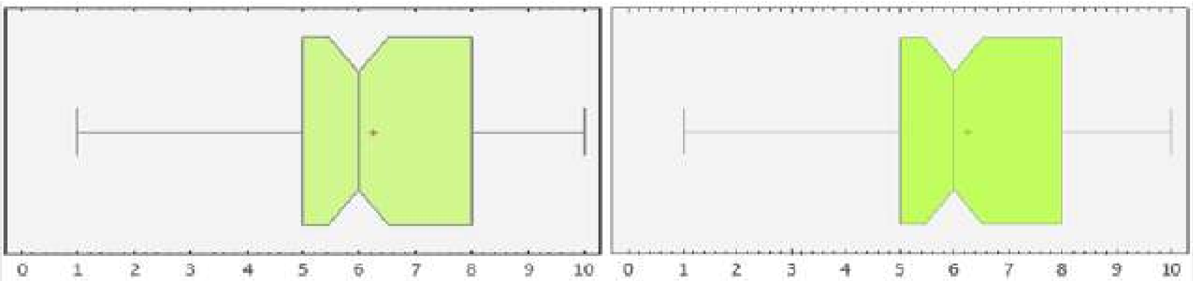

Figure 10. Box plots for: (left) "The realization of the experiments have been:"; (right) "The activities associated to the experiments have been:". Answers from '1' (very shorts) to '10' (very long). Answers from students who has completed at least some activities in BCEP MOOC

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