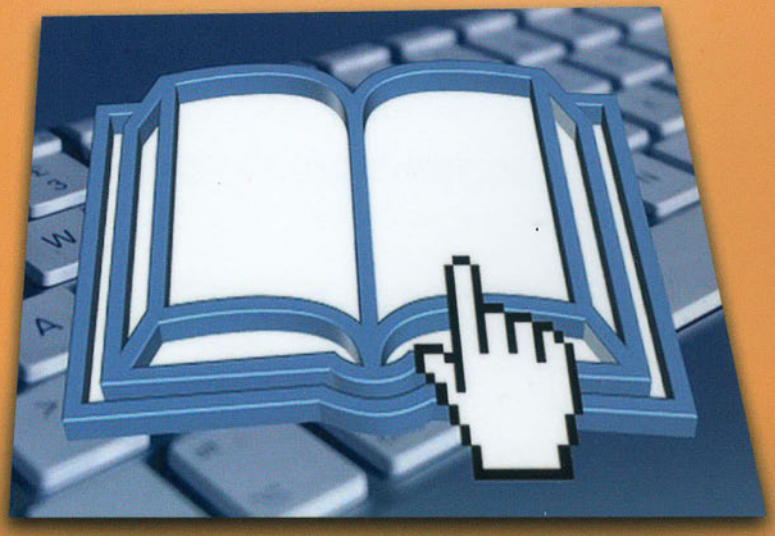
The 3rd e-Learning Excellence Awards



An Anthology of Case Histories 2017

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Note to readers: Some papers have been written by authors who use the American form of spelling and some use the British. These two different approaches have been left unchanged.

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L3-EOLES - Electronics and Optics for Embedded Systems course

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1. Introduction

The L3-EOLES (Electronics and Optics e-Learning for Embedded Systems) course is an entirely online English-taught 3rd year Bachelor's degree in Electronics and Optics for Embedded Systems (L3-EOLES, 2017). Designed as a specialization year, this course is oriented towards a currently expanding field in the electrical and computer engineering area, the field of electronics and optics for embedded systems. This area of knowledge requires students to be able to perform experimental work to acquire the expected technical experimental skills. The execution of laboratory assignments over the Internet required the development of remotely accessible experimental laboratories enabling students to interact in real-time with real experimental setups.

The L3-EOLES is the result of a three-year Tempus project financed by the European Commission - the EOLES project (Eoles.eu, 2017). The project started in October 2012 and lasted until February 2016. The educational goals of the project were established taking into account the national priorities defined by the governments of the Maghreb countries participating in the project – Algeria, Morocco, and Tunisia - for the development of higher education in cutting-edge engineering subjects.

The course is accredited by the educational authorities of France, Morocco, and Tunisia. This accreditation means that all students who successfully complete the course receive a Bachelor degree diploma that is

recognized inside the European Higher Education Area, while students from Morocco and Tunisia also receive a diploma issued by one of the accredited universities of their home countries.

The official recognition of the L3-EOLES course ensures its financial sustainability since it became part of the educational system for which institutional funds are available. The course is also now being offered as a lifelong learning course by some of the EOLES partners' institutions, further ensuring its long-term sustainability. An agreement signed by all the EOLES partners established the rules regarding the issuing of the diplomas, the access to the learning resources, the use of the virtual and remote laboratories and the maintenance of the equipment beyond the end of the EOLES project.

2. The course infrastructure

The program, defined in cooperation with the Maghrebian Universities participating in the EOLES project, is focused on the current tendency of integrating hardware/software into single reconfigurable platforms and on high-speed optical transmission required by the exponential growth in the amount of data produced and transferred over the communications network. The target population of the course is students already holding 120 European Credit Transfer Units (ECTU) obtained in areas like Physics, Electrical, Electronics, Automation, Optics, Telecommunications, or similar and willing to pursue a career in the fields of electronics and optics.

The program is divided into fifteen technical units (TUs) that cover a broader list of topics, plus three optional units. These optional units are preparatory TUs provided at the beginning of the 1st semester to level students' knowledge in critical topics for the course – electronics and optics, since students from diverse knowledge backgrounds may apply to be enrolled in this program.

The list of mandatory technical and optional units and associated ECTUs that form the L3-EOLES course curriculum is presented in Table I.

Each ECTU assumes around 30 hours of work per week, distributed among theoretical study and tutorials, including synchronous classes, and practical/laboratory work.

The course runs for 31 weeks, plus 4 weeks reserved for examinations: one at each semester's end; and two for make-up exams by year's end.

The aim of the first mandatory TU - Virtual Learning Environment – is to introduce the student to the learning platform and to the interactive tools that support the course dynamics. The remaining 14 TUs are divided into three groups: fundamental sciences – including mathematics and physics; applied sciences – digital and analog electronics, electromagnetic waves, digital signal processing, instrumentation, and optics; and complementary soft skill units, like communication techniques in English and business management, or alternatively, an enterprise internship.

The detailed content of each TU is available on the EOLES project website (Eoles.eu, 2017).

Table 1: Technical Units

TU	Title	ECTU	Mandatory/Optional
TU01	ICT - Introduction to Virtual Learning Environment	3	Mandatory
TU02	Mathematical and Analysis Tools for Physics 1	4	Mandatory
TU03	Communication Techniques in English	3	Mandatory
TU04	Analogue Electronics for Embedded Systems	4	Mandatory
TU05	Digital Electronics for Embedded Systems	4	Mandatory
TU06	Wave and Propagation for Embedded Systems	6	Mandatory
TU07	Power Electronics for Embedded Systems	6	Mandatory
TU08	Business Communication Techniques in English	3	Optional 1
TU09	Mathematical and Analysis Tools for Physics 2	3	Mandatory
TU10	Signal Processing	5	Mandatory
TU11	Instrumentation	4	Mandatory
TU12	Optics for Embedded Systems	6	Mandatory
TU13	Embedded Systems	6	Mandatory
TU14	Introduction to Entrepreneurship & Business Planning	3	Optional 1

TU	Title	ECTU	Mandatory/Optional
TU15	Enterprise Internship	6	Optional 2
UP121	Update in Optics 1	0	Optional
UP122	Update in Optics 2	0	Optional
UP041	Update in Electronics	0	Optional

The Learning Management System (LMS) that supports TUs' organization, learning materials' access and delivering, online assessments, weekly assignments, including any external links to virtual and/or experimental laboratory resources, tracking and reporting, forums and chats, is based on a Moodle 2.7 version platform (Moodle.org, 2017). Apart from being a very versatile LMS, its greatest advantage is to be an Open Source learning platform. This fact enables two distinct features that are very important for the L3-EOLES course:

- The possibility of creating and adding plugins developed to support other resources, namely the access to external virtual and real experimental laboratories designed by the EOLES team;
- Its zero initial and maintenance cost, which contributes to the long-term sustainability of the course.

Each TU is organized on a weekly basis and spans three to six weeks. New study materials are released every Mondays. Pre-recorded asynchronous lectures, where an instructor explains the theoretical basis of a given subject, are supported by different types of visual materials interspersed with self-evaluation questions – multiple-choice, fill-in-the-blanks, matching exercises –, whose aim is to keep students' interest and attention, breaking long expositive videos. Additionally, these self-evaluation questions provide an immediate feedback about their degree of understanding of the subjects being taught. Students may progress at their own pace, viewing this visual material anytime, any number of times, without restrictions. However, the student may only proceed to the next lecture after the successful completion of the self-evaluation questions associated to the previous one. Lecture materials are, whenever possible depending on their nature, available to download in a printable format. A range of other materials is available to support students' study, including

free companion books, web links to other sites containing specialized information and other complementary data.

To force students to respect the course schedule compulsory assignments must be delivered each week. These assignments, composed by sets of problems comprising individual or group assessment works, must be uploaded into the platform by the week's end. The TU's set of works is worth 25% of the TU's final grade.

Tutorial classes are synchronous classes that enable students to clarify any doubts and ask questions related to the content of the TUs. During these classes, tutor and students are required to have their cameras on to have a visual feedback of the whole class making students feel part of a group and facilitating the interaction not only with the tutor but also among each other. These classes are based on BigBlueButton, an open source web conferencing tool for online learning (Bigbluebutton.org, 2017). Sessions are recorded and made available to students.

In order not to conflict with the different cultural and/or religious beliefs of students, Fridays, Saturdays, and Sundays were left for them to finish their individual or group assignments. No synchronous classes or exams take place on those days.

Forums and live chat resources are also available through the LMS platform, with an always open, free access, BigBlueButton classroom where students may meet anytime they want. These resources enable students to feel part of a community, giving them not only a chance to interact with fellow colleagues but also to be pro-active in their own learning progression. Additionally, it helps to counter motivation loss in the face of adversities, either personal or due to demanding subjects, creating a supporting network, and preventing students from dropping out. Furthermore, by encouraging collaboration it is expected an improvement in students' theoretical and practical skills, apart from their soft skills, and in their English language level.

Apart from the final examination held by semester's end, a compulsory one-hour online exam, which is worth 25% of the TU's final grade, takes place before the end of each TU. For control reasons, it is mandatory

students to be connected and visible all along the exam. Otherwise, they get zero in this component.
A two-hour final exam held by the semester's end is worth 50% of the TU's final grade.
A bonus of up to 10% of the final grade may be attributed at teachers' discretion to each student, according to his/her level of participation in the synchronous sessions, forums, and live chats. The intention is to stimulate the interaction among students, something essential but sometimes difficult to achieve in a virtual environment, mainly taking into account that they never met each other face-to-face.
For each TU it was necessary to create:

- The list of practical and laboratory works for the virtual experimentation, modeling and simulation platforms, or/and to be implemented on remotely operated real instrumentation equipment;
- The assessment details (exams, weekly assignments);
- The list of committed teachers selected from the Universities engaged in the course according to their field of expertise.

The main originality of the L3-EOLES course is the remote laboratory used by students to perform online the practical works.

Successful undergraduate degrees in the areas of engineering covered by the L3-EOLES course demand students to perform experimental work to acquire technical skills in subjects like physics, chemistry, mechanical and electrical machines, or digital and analogue electronics, for example. In a fully online course like the L3-EOLES, this requires the remote access to experimental laboratories and real time interaction with real experimental setups that are complex to implement. Until recently, the only solution has been the use of blended learning solutions as described in (Zhu, 2010), with the entire program being conducted online, except for the laboratory classes. These have to be performed on campus, being usually concentrated by semester's end. Other examples (from the many available) are the Bachelor of Science in Electrical Engineering at The University of North Dakota (Dakota, 2017), or the Bachelor of Science in Engineering Technology: Electrical at The University of North Carolina at Charlotte (Distanceed.uncc.edu, 2017), two traditional universities. But even at The Open University, a distance learning university, the students

have to attend two UK-based residential schools to get a Bachelor of Engineering (Honours) (The Open University, 2017).

Blended learning solutions, however, have obvious disadvantages. First, the student must have the necessary time and funds to travel, in some cases to the other side of the world, and to spend a few weeks a year on the University campus. Second, from a pedagogical point of view, there is no synchronization among theoretical, tutorial and laboratory classes, which creates difficulties to the normal learning process, postponing in a certain sense the correct understanding and assimilation of the different subjects.

The absence of online undergraduate degree programs in Electrical and Computer Engineering is far more incomprehensible since it is possible to find in the specialized literature many examples of different laboratories for different areas of physics and electrical engineering (Albu et al., 2004) (Cardoso and Gil, 2013) (Garcia-Zubia et al., 2010) (Hercog et al., 2007) (Priem et al., 2011) (Restivo et al., 2009) (Said et al., 2012) (Sousa, Alves and Gericota, 2010), each one allowing different degrees of freedom in the configuration of the experiment by the remote user. Some of those laboratories were created in Universities involved in the EOLES project, who had expertise in the development of remote laboratories used to implement various experiments on diverse technological fields, including optics, electronics, and embedded systems (Priem et al., 2011) (Said et al., 2012) (Sousa, Alves and Gericota, 2010). However, in the whole cases, their use was limited, operating mainly as a complement of on-campus laboratory classes and never as a part of fully online undergraduate programs. As far as authors know, the L3-EOLES course is the first where a remote laboratory is used as part of a fully online accredited degree in these areas of engineering to enable students to perform all the required practical work.

To allow a group of students to work and interact in real time with the same Practical Work (PW), a multi-user approach was implemented. This guarantees a high degree of interaction and collaboration among students during the training.

Two kinds of PWs are included in the remote laboratory:

- Virtual experimentation using professional software accessible in an application server or in open access from different companies and universities;
- Real remote laboratory experiments intended for students to perform real-time monitoring and control of technical equipment at distance.

The latter is the most innovative part of the remote laboratory. Each hardware instrument (function generator or oscilloscope, for instance) is connected to the Internet. From each TU's Moodle page, students have access to the related laboratory's web page and to the TU's proposed lab works. Students can change the hardware configuration in real-time via the virtual instrument interfaces that are deployed remotely, which mimic the real instrument's panel. An immediate feedback of their actions is provided through the same or another interface and/or by a high-definition camera, depending on the instrument and nature of the experimental work.

The camera enables students to see what is happening in the real laboratory and how the real instruments react to their remote commands. This feedback is important for students to be sure the interface they are seeing in their own monitors is not the visible face of a virtual world, but the virtual interface of a real instrument.

The remote laboratory is distributed by four different locations to reduce maintenance and installation costs - three in North African universities and one in the University of Limoges.

The EOLES remote laboratory addresses the main technological content described on the TUs syllabus. It has a substantial learning impact since each student or group of students has the possibility of repeating the same experiment several times and trying different configurations in a controlled and protected environment. These possibilities are even not granted in on-campus laboratories due to resources availability, time and access restrictions.

Currently, a total of 42 professors from thirteen European and North African Universities are committed each year to the teaching of the L3-EOLES course. To ensure an efficient collaborative work, the number of

teachers allocated to each TU is limited to three, with at least one teacher from a European institution and one teacher from a North African institution. This teaching division between European and North African teachers strongly helped on the official accreditation of the Bachelor's program, and recognition of the Bachelor's degree in the countries participating in the EOLES project. Apart from teachers, technicians from the different Universities engaged in the course provide the necessary technical and maintenance support to the LMS platform and remote laboratories.

3. The challenges

Taking into account the previous and complementary expertise of the EOLES project partners, the technological challenges caused no special issues. On the other hand, bureaucratic challenges were difficult, and sometimes even impossible, to overcome. For sustainability reasons, accreditation of the course was initially defined as the main target of the EOLES project. After the definition of the course program, the accreditation was requested by the North African universities to their respective national educational authorities and by the University of Limoges to the French educational authorities. The University of Limoges demanded the course accreditation to guarantee that any student from anywhere in the world would have access to the L3-EOLES course and would receive, after its successful completion, a Bachelor's degree Diploma recognized in the European Higher Education Area.

The L3-EOLES course was similarly accredited by the national educational authorities of Morocco and Tunisia. All students from these two countries receive a Joint Diploma issued by the university where they are enrolled in their own country and by the University of Limoges. However, the cutting-edge character of the L3-EOLES course raised some obstacles because the current national legislations are not prepared to recognize online courses where students' work and knowledge acquisition are assessed exclusively online as legitimate courses. Therefore, to secure the accreditation of the L3-EOLES course, universities from both countries have to additionally perform final on-campus examinations and, in the Morocco case, to add to the course program an Enterprise Internship TU. These requirements are mandatory if a student wants to receive the Joint Diploma. Otherwise, if the student is not from Morocco or Tunisia, or if s/he is happy with the

Diploma issued solely by the University of Limoges, these requirements are not applicable.
Unfortunately, in Algeria, due to insurmountable legislation barriers, it was not possible to get the course accreditation yet.

4. Students enrollment and success rates

The first edition of the L3-EOLES took place in the school year 2014-2015. The course was mainly promoted by the EOLES project' partners from the Maghrebian countries. The number of applicants, albeit concentrated in one of those countries, largely exceeded the initial expectations, with a total of 660 candidates from Morocco, fifteen from Tunisia, ten from Algeria, one from Senegal, and one from France. After a careful selection, 25 students were chosen to attend the first edition of L3-EOLES. All of them were simultaneously enrolled at the University of Limoges and at one of the accredited Universities of their choice in their countries of origin.

Of these 25 students, four abandoned the course due to personal reasons, and only eleven managed to successfully conclude it and receive the Joint Diploma, a success rate of only 44%.

Apart from those that abandoned the course, the remaining ten that did not succeed experienced mainly language problems, albeit having some previous English knowledge attested by their TOEFL (Test of English as a Foreign Language) certificates.

Taking into account the analysis done by the teachers and the feedback given by the students, some adjustments in the selection of students and on the organization of the course were made. These changes helped to improve the success rate in the following editions.

In the second edition, 24 students, including two lifelong learning students, were selected from a number of applicants that surpassed the seven hundred. Lifelong learning students are part-time students allowed to complete the course in two years. These students were joined by eight repeaters. In this edition, the success rate improved to 70% - 21 graduates, including the eight repeaters, from 30 possible.

In the third edition, the number of applicants was almost eight hundred. 28 new students were selected, including one life learning student. These

students were joined by the seven repeaters and by one of the lifelong learning students enrolled on the second edition. The second one abandoned the course due to professional reasons. At the end of the school year, 24 students got their Diplomas, a success rate of around 66%. At the time of writing (August 2017), the enrolment for the fourth edition was still under way.

5. Future plans

The success of the course drew the attention of Universities in other countries also interested in the development of online engineering courses.

A new European project was proposed aiming at disseminating the acquired knowledge (E-lives.eu, 2017). The objective is to help those Universities to develop innovative e-learning engineering training ("e-engineering") by themselves in a sustainable way.
To achieve it two main actions were identified:

- To help universities to develop (from A to Z) their own remote laboratories. Notice that those remote laboratories can also be used in face-to-face training. Indeed, due to the rapid growth in the number of students in developing countries, numerous universities had to reduce the practical works in the first year of their Bachelor degrees in science, technology, engineering, and mathematics (STEM) fields due to lack of resources;

- To help universities to move through the different mandatory stages needed to build a course (development of the curriculum, getting the national accreditation, training teachers, preparation of online materials, installation of the LMS platform, ...).

The project was approved for funding by the European Commission under the Erasmus+ programme, and it is expected to have an extensive structural impact on the modernisation of the higher education systems of the partner countries.

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Guillaume Andrieu is an assistant professor in Electronics at the University of Limoges since 2009. He is the pedagogical coordinator for the L3-EOLES online course, served as co-coordinator in the EOLES project (2012-2015, Tempus program) and is the coordinator of the e-LIVES project (2017-2020, Capacity Building Erasmus+ program).

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