Work in Progress: Microelectronics Courses: Needs and learning in the MicroElectronics Cloud Alliance

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Abstract

The MicroElectronics Cloud Alliance brings together eighteen partners from higher education institutions and enterprises to develop Cloud-based European infrastructure and a new educational system for micro and nanoelectronics, providing a range of open educational resources, remote access and sharing of educational and professional software as well as remote and practice-based learning facilities. The aim of the mClouds project is to define and develop this cloud-based European infrastructure. For this purpose, an analysis of the needs in shared IT infrastructure, teaching materials and learning resources of institutions, teachers and students was carried out thus meeting the requirements of companies in micro- nanoelectronics. This analysis was translated into functional specifications of mClouds, obtaining direct information from users of these courses that allows a feedback and an improvement of the courses. UNED - as a partner of the project - is developing two MSc courses in Microelectronics as OERs over mClouds architecture for the rest of partners to access and share them.

Keywords: cloud-based e-learning environment, microelectronics, open educational resources.

1. Introduction

As aforementioned, the MicroElectronics Cloud Alliance provides a range of open educational resources (OERs) and virtual or remote access to practice-based learning facilities. In general, no university is able to afford the necessary infrastructure, clean rooms, technology and experts in all fields of this multidisciplinary science. To share laboratory experiences, CAD tools, project ideas and a common infrastructure, a sort of "educational cloud" over the software/hardware infrastructure can be a solution. All the partners of MECA, Higher Education Institutions (HEIs) and Small and Medium Enterprises (SMEs), will develop e-learning materials for 22 courses in CAD systems, microelectronics technologies, test, characterization and application of integrated circuits and systems. These 22 new courses foster virtual mobility. Each university will allow partners of a cloud teaching system remote access to its facilities, laboratory experiments or software systems, giving them access to new resources.

The two courses that are being developed by UNED are: 1) Microelectronics Literacy and Technologies, and 2) Integrated Circuits and Design, explained in detail in Section 5.

2. Methodology

This is a three-year project, thus planned in order to include the pilot test and the implementation of system for virtual mobility, i.e. the full cycle of design, development, evaluation and implementation. The milestones are:

1. Report on the analysis of needs (5th month)
2. Specification of the three Clouds architectures for open learning resources sharing, IT infrastructure and CAD software common use (end of the 9th month),
3. Job-oriented courses and programs on entrepreneurship, project management (15th month),
4. Updated HE curricula in microelectronics in collaboration with the experts from the industry; mClouds system developed and implemented with a minimum of 16 courses delivered as OERs (20th month),
5. Training to all staff involved in the developed OERs
6. System officers and teachers and trainers from enterprises trained (24th month),
7. Pilot tests (27 month),
8. Exploitation/field trial (36th month).

For defining knowledge, skills and competences needed for the project, we have started with an extensive analysis n microelectronics and electronics packaging companies.

Specific needs and issues of HE in microelectronics that we intend to solve are:

- Little reference is made to the needs of the workplace; changes in it are not met with changes in education,
- Curricula has to be updated and universities have to collaborate for sharing course materials, intellectual property blocks and ideas.

Therefore, we need a new partnership between education and work to attain synergy between education and industry, to foster the development of competences, technological and entrepreneurial skills.

On the other hand, the emergence of cloud computing is transforming the way organizations and companies purchase and manage computing resources. According to Cruz [1] cloud computing is changing how people carry out personal learning, interactive learning and many-to-many learning, in primary, secondary and higher education. An advantage of cloud computing is ensuring longevity of information. Another important feature is that it allows students to interact and cooperate with an expanding circle of peers, regardless their location.

Following all the above, this proposal is based on the past experiences of almost all HEI partners in the development of e-learning courses and on the expertise of UNED in the development of training courses through remote laboratory access. The focus is on the implementation of an e-learning framework with open educational resources, rooted on the tools developed for cloud management, thus allowing cooperation and distribution of lab sessions, CAD tools and teaching experiences.

3. Analysis of Needs

As discussed in the previous section, we need a new partnership between education and the work field to fulfill the needs between education and industry. The advantages of cloud computing in terms of education effectiveness are course organization efficiency, instructors focusing on the area of expertise, common experiences of students of different countries based on similar infrastructures, tools, lab organization, learning improvement, all due to the optimization of laboratories and courses.

Furthermore, the needs of such a project correspond to the needs of the sector of microelectronics design and fabrication. Firstly, there are not many companies experts in assembling/packaging in microelectronics. And secondly, in the last 10 years there has been a shortage of engineers in microelectronics and a systematic decrease of students in electronics at the university that can pose a threat to the European economy competitiveness.

3.1 Results of the survey for students, teachers and business

For the design the different OERs in the project an online survey was developed, where teaching and learning needs were evaluated based on three points of view: students, teachers and professionals from the business. The survey can be summarized as follows:

- Objective
  - To analyse users' needs in shared IT infrastructure, teaching materials, learning resources in micro- nanoelectronics relevant for the labour market.
- Target Groups
  - Students in micro- nanoelectronics engineering education;
  - University teachers and trainers in HR departments, universities and colleges;
  - Professionals from the business;
  - E-learning environment developers and administrators.
- Sample
  - Students at different the universities involved in the project;
  - Professionals and managers from enterprises in micro- nanoelectronics and microsystems, electronics packaging and communication from all participating countries;
  - Teachers in micro- nanoelectronics from all participating countries;
  - System administrators at the universities and enterprises involved.
- Instruments
  - Review of literature;
  - On-line survey:

        - 3 questionnaires for teaching/learning needs analysis for the three profiles (students, teachers and professionals).
    - Interviews.
- Implementation
    - On-line questionnaires with a link to the website of the project.
    - We have collected
        - 152 answers from the students,
        - 59 – from teachers and
        - 23 – from the representatives of the industry.

Summary of results of the students' survey

- 13% of respondents study Micro-nanoelectronics. The highest percentage is in Electronics with 37%; follows Informatics/Information Technologies with 27%.
- The educational level of 62% of students is undergraduate, 29% have a Masters Degree and only 7% hold a Ph.D.
- 89% of students use open educational resources and those who do not use them are willing to learn with OERs.
- Few students are experienced with virtual laboratories and remote access to CAD systems but most of them would like to.
- It is very important and encouraging for the objectives of the project that students feel comfortable when using virtual laboratories and them being ready for these educational practices (Table 1)
- Most of the students do not think that the use of OERs will improve their learning, but 73% consider that the learning is more attractive with OERs.
- It is interesting that learners prefer passive teaching methods to interactive courses: electronic books and video recorded lectures.
- PowerPoint presentations are not liked at all by students and it might be because the content in the presentations is not sufficient for self learning.
- All advantages of OERs are appreciated: flexibility, reusability, virtual mobility of students, cost efficiency, connectivity with teachers.
- 41% of students prefer to use OERs in an online course; 32% by blended/hybrid courses, and 27% by face-to-face courses.

Summary of results of the teachers' survey

- 59 teachers from traditional and distance education universities and vocational education institutions answered the questionnaire, being the most common university teachers, 81%. Within the specialties of the university, the most common is Polytechnics, 54%. And the highest educational levels teached at our universities are: PhD with a 36%, Master with a 32% and Bachelor with a 30%.
- If 89% of students use open educational resources, teachers using OERs are only 69% and most of them use them occasionally.
- It is not surprising because probably most of the teachers are from traditional universities with face-to-face education.
- All advantages of OERs are appreciated: flexibility, reusability, virtual mobility of teachers and students, cost efficiency, connectivity with students.

- Logically, the teachers consider that it is less likely that OERs provide a high level of knowledge for the subjects in technology. The percentage of teaching activities for the use of OERs is shown in Figure 1.
- With regard to generic skills, it is considered that the abilities for independent learning and working, managing information, using ICT are favoured, and the capacity of criticism and self-criticism and adaptating to new situations is not as much.
- Teachers consider that e-learning does not improve students' performance but it makes learning more appealing - just as students think of.
- Most of educators believe that the use of OERs would improve their practice and reduce their efforts and time used for teaching.

Table 1: Results for the question: *Do you want to be involved in the activities described below, in the near future?*

Activities	Frequently	Occasionally	Rarely	Never
Studying additional e-learning materials given by the teacher	43.71%	39.07%	13.91%	3.31%
Searching for educational materials in the internet	53.64%	34.44%	9.93%	1.99%
Following Open Courseware(s) provided by other universities	38.41%	32.45%	20.53%	8.61%
Watching recorded lectures or presentations given by experts outside your institution	38.41%	40.40%	17.22%	3.97%
Working virtually with students from other universities internationally	27.15%	37.09%	21.85%	13.91%
Carrying out experiments within remote laboratories	36.42%	31.79%	22.52%	9.27%
Designing electronic/ integrated circuits through remote access to the workstations	35.10%	33.77%	15.89%	15.23%

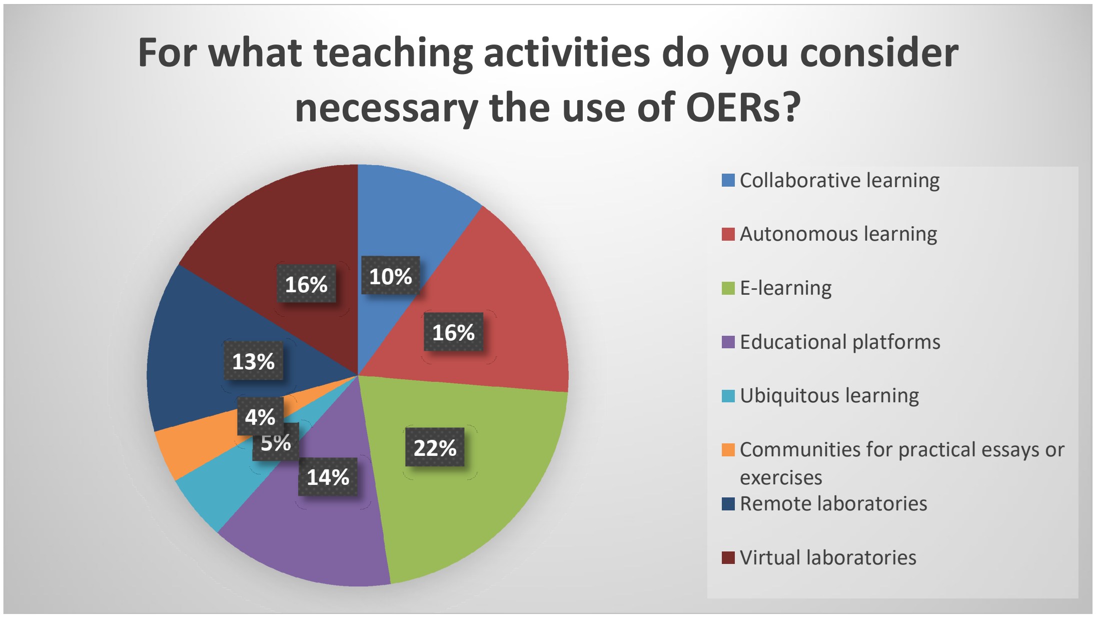


Figure 1: Results for the question: *For what teaching activities do you consider necessary the use of OERs?*

Summary of results of the professionals' survey

- 23 representatives of the business (Figure 2) answered the questionnaire on the importance of different learning contents.
- All the proposed courses are considered to fulfil more than the average needs in the short term.
- In the long term the industry will need even more skills and competences in the proposed topics.
- We can conclude that the university is close to the needs of the industry.
- Effective communication with groups, presentation techniques, project management and survival on the labour market are considered highly important by almost all respondents.
- Additional topics are suggested in power electronics, grapheme technologies and system integration.

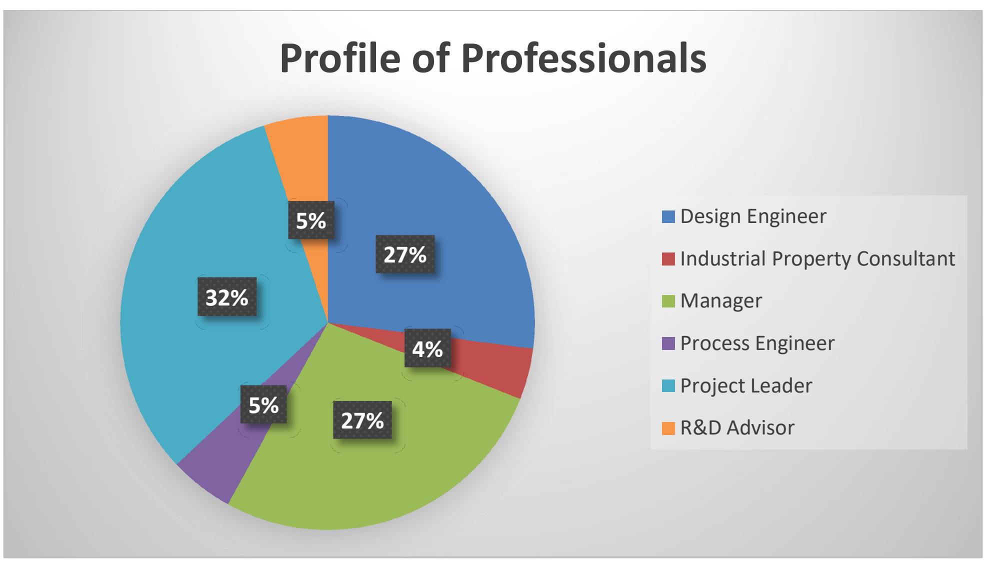


Figure 2: Profile of professionals from business

4. mCloud Architecture

The analysis of needs in students, teachers and employment reveals a good acceptance of the use of OERs and gives rise to the design and development of cloud architecture.

For projects similar to this one there are public clouds such as Amazon Web Services (AWS) and Microsoft Azure on the one hand. On the other hand, there are private clouds within institutions and also hybrid ones. For this project, we will focus on a private cloud, CloudStack, [2] due to the technical expertise of a HE partner involved. The model of software will be Software as a Service (SaaS), where the complete application is fully managed by the cloud suppliers, just as in a WordPress website or a Moodle e-learning site. In our case, Moodle will be the platform used to deliver the new OERs.

Some facts on CloudStack are:

- It is an open source cloud management software.
- It supports all important hypervisors like KVM, VMware, Hyper-V and XenServer.
- It mainly is a Java web application (Tomcat) with an API and a web GUI that allows to overview, organize and manage virtual machines and to create virtual machine templates
- It controls the virtual machines with agents or APIs of the vendor specific hypervisors
- It is end-point agnostic: desktop, notebook, tablet
- A good network infrastructure is mandatory
- Configuration data is stored in a MySQL database, so it is really transparent

CloudStack can be used in different cases. Some of them are:

- **User self-service**: Setup virtual computers and applications CAD software on their own by an easy-to-use and comfortable web application (instead of command line tools or something comparable).
- **Sharing processing power, data and virtualized software**: It will be possible to share computers and processing power, sharing data and storage as well as virtualized software; but not sharing commercial software licenses due to legal restrictions.
- **Bring in own student's computers**: Students with their own computers using remote desktops.
    - No university PC for each student required
    - Students know their own machines
    - They can work around the campus or at home (depends on security restrictions; might be solved by an encrypted virtual private network VPN)
    - Freezing sessions and continuing somewhere else
- **Remote access to laboratories**
    - Common experiences of students from different countries based on similar infrastructures, tools, lab organization, learning improvement, as a result of the optimization of laboratories and courses.
    - Sharing laboratory experiences
- **Delivery of an e-learning environment**: Moodle as an open source software might be an adequate solution (especially in the newest version with responsive design theme working on desktops, tablets and mobile phones)
    - Installed on several servers across Europe to be closer to the learners (could reduce the problem of network latency)

- Maybe distributed installations to have content synchronized between the universities and to be more stable in case of single machines' unavailability
  - Better preservation of intellectual property (not a single point of failure)
  - Specification of self-provisioning logic to scale the web e-learning environment depending on the load, especially for usage peaks and for the mobility of e-learning resources.
- **Some sort of cooperative work software**: It would be useful to share project ideas, courses, files and teaching experiences between teachers and teachers or students and students. This should be supported by the educational cloud.

4.1 Overview of the infrastructure

Each university will install its own technical equipment, but the idea is to share it with each other., and to start with three servers on three partner's sites and see how it will be accepted and what we can learn from this. The methodology that will be followed is:

- A map of the participating HEIs (logos) with their servers,
- Place the CloudStack controller
- Moodle web application installation
- CAD software installation
- Monitoring

4.2 Future outcomes

- Proof of concept for the feasibility with at least 3 participating universities
- Sharing of setup guidelines
- Virtual machine templates (VMs) for end-user self-service (e. g. for teachers or in companies)
- Pre-installed Moodle environment
- CAD software pre-installed (to find a solution for license keys)
- Other learning relevant software pre-installed
- Student learning desktop
- FAQ with the most frequently asked questions for the system administrators
- Training material for system administrators

5. MicroElectronics Courses in UNED

As aforementioned, UNED courses are part of the 22 courses that are being developed by all the partners of the project. Table 2 summarizes the learning outcomes expected from these two courses.

The first course (Microelectronics Literacy and Technologies) focuses on delivering basic knowledge in Microelectronics. The course is divided into two clearly differentiated blocks: 1) Fundamentals of Microelectronics; and 2) Main Technology Processes in Microelectronics.

The second course (Integrated Circuits and Design) deals with more advanced concepts in Microelectronics, and it course is designed for experimenting with remote laboratories. UNED has extensive knowledge in remote and virtual tools, given that a distance learning model is its main feature. This course is also divided into two blocks, these being: 1) Technologies of Integrated Circuits; and 2) Design of Digital Integrated Circuits.

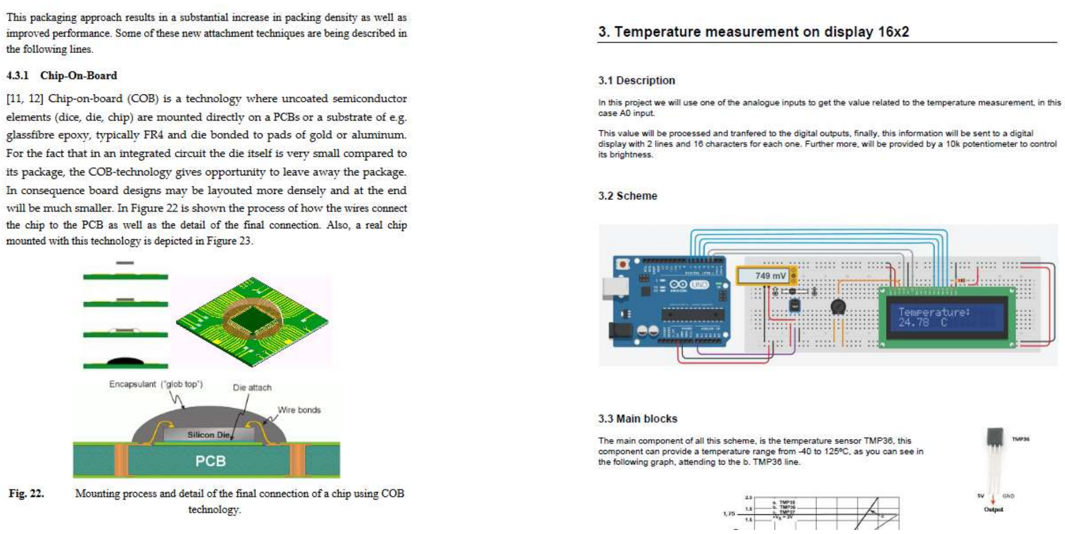
Table 2: Learning Outcomes of the Two Courses developed by UNED.

Course	Knowledge	Skills	Competences
Microelectronics Literacy and Technologies	Overview of fundamentals of microelectronics. Basic knowledge in the main technology processes in microelectronics.	Skills in classification materials, definition of semiconductor substrates and crystals. Ability of understanding the crystal growth processes, all the main manufacturing processes and thin film processes and choosing which is the best process to use for a specific design	Ability to use different types of large scale integrated circuits Being able to design the oxidation and deposition layers and the diffusion and ion implantation in microelectronics
Integrated Circuits and Design	Advanced knowledge in Technologies of integrated circuits and methods for designing digital integrated circuits	Advanced skills in choosing which is the best technology to use for specific requirements in the production of an integrated circuit and advanced ability of choosing more suitable method for designing a specific integrated circuit	Being able to use Lithography technology in the design of integrated circuits. Ability to use CMOS technology sequence and BiCMOS integrated circuits. Being able to manage and design custom circuits and logical matrices.

Both courses consist of 5 ECTS credits (European Credit Transfer and Accumulation System) and are designed to be carried out on several phases. VISIR (Virtual Instruments System in Reality) is the tool deployed in these courses. It is a remote lab for electric and electronic circuits' experiments, developed at the Blekinge Institute of Technology (BTH), Sweden, and used in several universities worldwide [3]. The main difference between remote laboratories and in-person laboratories is how the interaction between student and workbench is carried out. The main advantage of remote labs when compared with in-person laboratories lies in its availability, with no temporal or geographical restrictions. They also have a series of side improvements: low maintenance cost and requirements, no need of assistance during students' experimentation, no associated risks for students and instruments, as well as equipment (if well designed), etc. However, remote labs have obvious limitations not given in in-person laboratories; for example, the degree of freedom in the design of experiments.

Figure 3 shows the website of these courses. Both of them are developed in Moodle and allow free access to all members of the MECA project. In addition to the VISIR, each of these courses integrates several learning materials, such as: documentation (see Figure 4), demonstration videos (see Figure 5), practical exercises, self-assessment exercises and access to virtual tools (see Figure 6).

Figure 3: Website of the Microelectronics courses.



This packaging approach results in a substantial increase in packing density as well as improved performance. Some of these new attachment techniques are being described in the following lines.

4.3.1 Chip-On-Board

[11, 12] Chip-on-board (COB) is a technology where uncoated semiconductor elements (dice, die, chip) are mounted directly on a PCBs or a substrate of e.g. glassfibre epoxy, typically FR4 and die bonded to pads of gold or aluminum. For the fact that in an integrated circuit the die itself is very small compared to its package, the COB-technology gives opportunity to leave away the package. In consequence board designs may be layouted more densely and at the end will be much smaller. In Figure 22 is shown the process of how the wires connect the chip to the PCB as well as the detail of the final connection. Also, a real chip mounted with this technology is depicted in Figure 23.

Encapsulant ("glob top") Die attach Wire bonds Silicon Die PCB

Fig. 22. Mounting process and detail of the final connection of a chip using COB technology.

3. Temperature measurement on display 16x2

3.1 Description

In this project we will use one of the analogue inputs to get the value related to the temperature measurement, in this case A0 input.

This value will be processed and tranfered to the digital outputs, finally, this information will be sent to a digital display with 2 lines and 16 characters for each one. Further more, will be provided by a 10k potentiometer to control its brightness.

3.2 Scheme

749 mV
Temperature:
24.78 C

3.3 Main blocks

The main component of all this scheme, is the temperature sensor TMP36, this component can provide a temperature range from -40 to 125ºC, as you can see in the following graph, attending to the b. TMP36 line.

TMP36
5V GND
Output

Figure 4: Example of the documentation available in the courses.

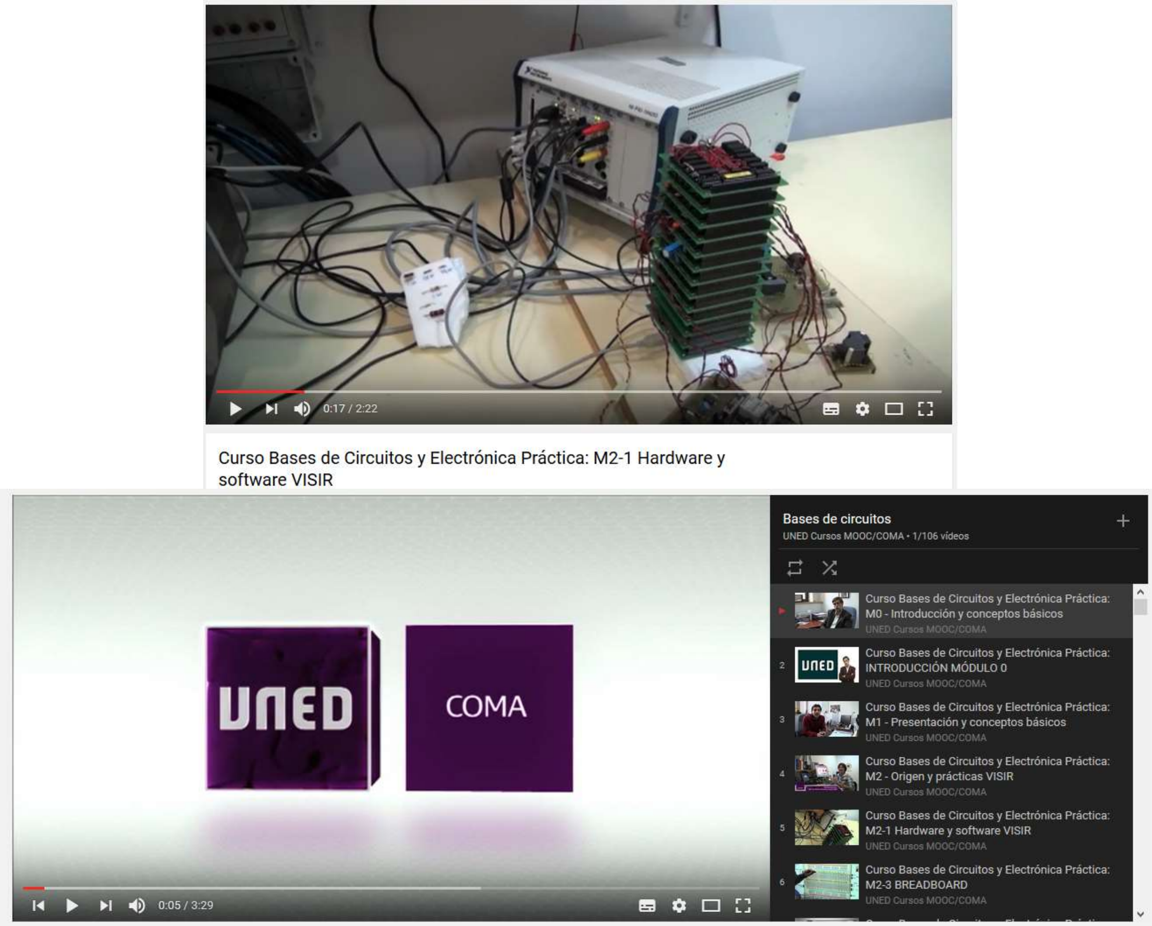


Figure 5: Example of demonstration videos available in the courses.

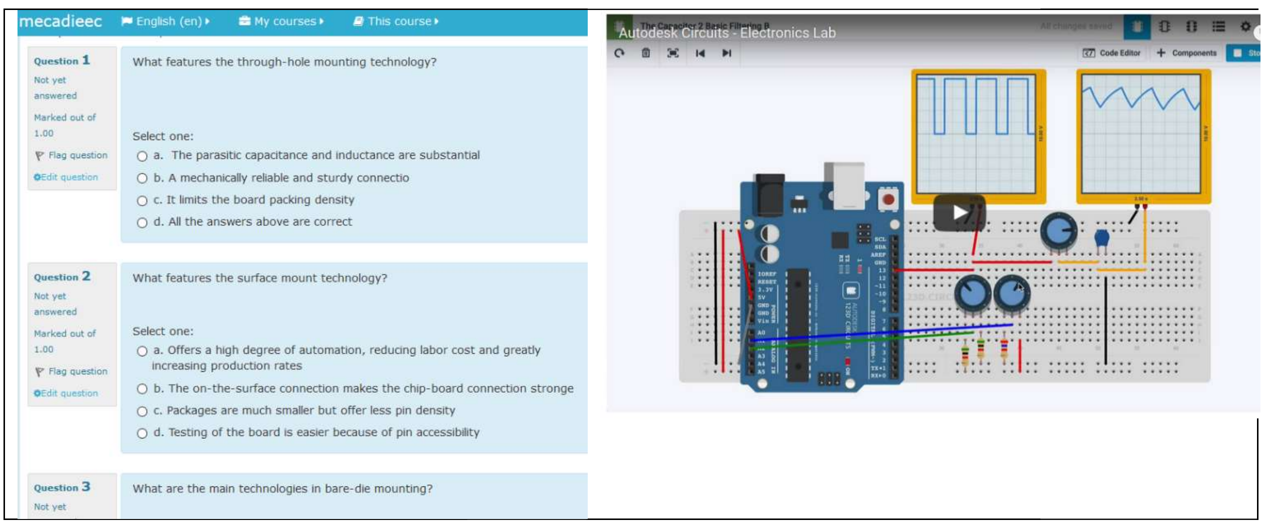


Figure 6: On the left side there is an example of self-assessment exercises and on the right side there is an example of virtual tools.

6. Conclusions

First steps in the development of this model have already been taken. All HEIs have installed their own CloudStack software, virtual machines (VMs) for end-user self-service. The starting point is connecting the different institutions and placing a CloudStack controller in one of our partners. The next step is deploying a

Moodle web platform in each partner. Along with Moodle, all CAD software and remote laboratories will be implemented, being a challenge to find a solution to the issue of sharing software or hardware licenses between institutions.

The implementation of an educational cloud will allow virtual mobility of students and an easy update of contents. Moreover, involving employers and labor market institutions will help attune curricula to current and emerging labor market needs as well as fostering employability and entrepreneurship.

The mCloūds architecture will enable the distribution of resources throughout Europe. Thus, instructors from different European countries can take advantage of using a running lab-experiment and delivering it in their native language.

The purpose of this Erasmus+ Knowledge Alliance project is to build a long-lasting partnership of SMEs with HEIs, which could evolve in joint research activities. Double-line feedback, knowledge and synergy will be gained because of the enterprise/HEI partnership, improving research and innovation on companies due to HEI academic competitive view, thus ameliorating HE as a result of applying companies' industrial application experience and expertise.

7. Acknowledgment

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