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Co-funded by the Erasmus+ Programme of the European Union

Conference Proceedings

The Online, Open and Flexible Higher Education Conference

Hosted by Università Telematica Internazionale UNINETTUNO, 19-21 October 2016

Enhancing European Higher Education;

“Opportunities and impact of new modes of teaching”

Work in Progress - The MicroElectronics Cloud Alliance: A way to delivere OERs in a Cloud-based European Infrastructure

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Abstract

This article is framed by the project "Knowledge Alliance 562206-EPP-1-2015-1-BG-EPPKA2-KA MicroElectronics Cloud Alliance (MECA)". The MicroElectronics Cloud Alliance (MECA) brings together 18 partners from higher education institutions (HEIs) and enterprises to develop Cloud-based European infrastructure and organisation for education in micro- and nanoelectronics providing a range of open educational resources, remote access and sharing of educational and professional software, remote and practice-based learning facilities.

The project's focus is on jointly development of MSc degree level courses for the new skills needed for the new jobs in the multidisciplinary sector of micro- nanoelectronics to be delivered as open educational resources in a cloud-based e-learning environment. The addressed problems and needs were identified through: literature study of European policies in the field of education and the needs and priorities of partner higher education (HE) institutions and enterprises in the sector, analysis of subject of area (microelectronics design, fabrication and application), labour market needs, study of the state of the art in cloud computing.

UNED, as a partner of the project, is developing two MSc courses in Microelectronics as open educational resources (OERs) with specific requirements to be part of a cloud-based e-learning environment.

Keywords: Cloud-based e-learning environment; European infrastructure; Microelectronics; Nanoelectronics; Open educational resources

1. Introduction

As mentioned above, the MicroElectronics Cloud Alliance brings together 18 partners from higher education institutions (HEIs) and enterprises to develop Cloud-based European infrastructure and organisation for education in micro- and nanoelectronics providing a range of open educational resources, remote access and sharing of educational and professional software, remote and practice-based learning facilities.

Neither university can afford the necessary infrastructure, clean rooms, technology and experts in all fields of this multidisciplinary science. Sharing of laboratory experiences, CAD tools, project ideas, and a common infrastructure represents a sort of “educational cloud” on top of the cloud software/hardware infrastructure. 8 European HEIs and 8 SMEs will develop e-learning materials for 16 courses on: CAD systems, microelectronics technologies, test, characterisation and application of integrated circuits and systems, and we will provide them as open educational resources to strengthen the virtual mobility. Each university will provide remote access to its facilities, laboratory experiments or software systems for the partners in a cloud teaching system, giving them access to new resources. The common ones can be optimized, reducing the singular cost per institute and increasing the available computational and structural power.

The impact of the university-business alliance will be in the education responsive to the labour market needs, graduated students prepared for the job, enterprises satisfied by the knowledge and skills of young specialists.The impact on the students will be in the highest quality of the specialised courses developed by the best departments in the field, the opportunity to train practical skills and competences with remote access to laboratories with advanced equipment and facilities, for the teachers – rich infrastructure and new shared teaching materials, for universities - the European dimensions in HE, particularly with regards to curricular development, virtual mobility of students and academic staff and integrated programmes of study, training and research.

2. Aims and Objectives

In MECA project 18 partners from HEIs and SMEs will provide open educational resources in micro- and nanoelectronics to facilitate the exchange and co-operative creation of knowledge at European level.

The aim of the mClouds project is the definition and development of cloud-based European infrastructure and organisation for education in micro- and nanoelectronics providing a range of open educational resources, remote access and sharing of educational and professional software, remote and practice-based learning facilities. Its specific objectives are:

1. Analysis of institutional, teachers’ and students’ needs in shared IT infrastructure, teaching materials and learning resources, meeting the requirement of the enterprises in micro-nanoelectronics and translation into functional specifications of mClouds. This objective targets the challenges of the multidisciplinarity of the subject area and the needs of powerful CAD systems and servers, of sophisticated equipment and laboratories.
2. Networking of project partners from HE institutions and SMEs, to share ideas, methodologies and experiences in order to improve the HE programmes to face the rapid technological change in the sector and joint development of job-specific training modules. This objective addresses the needs of more responsive HE to the needs of the labour market.
3. Development of the mClouds system and realization of a shared server infrastructure, shared e-learning resources and the remote access to the CAD tools. This objective targets the needs of innovative and multidisciplinary approaches to teaching and learning in the interdisciplinary sector of micro- and nanoelectronics and the needs of closer cooperation between HE and business using the infrastructure, technology of partners’ universities and expertise of practitioners.
4. Pilot test of the virtual services and training teachers and technical staff in their use. This objective addresses the needs of the main users of the project results: the students and teachers in high quality educational resources and services.

5. Implementation of jointly developed cloud-based open educational resources in micro-nanoelectronics in the partners' educational contexts. This objective addresses the necessity of striking a balance between what is offered in the educational system and what is needed by the enterprises in the sector.

All project partners have some experience in the setup of learning environments with some common, but also some specific, solutions. The use of networked server systems, for giving to the students the possibility of developing hands-on laboratories, is a common setup, present in all the institutes. And both these aspects are the keys of the proposed project: the specific capabilities will be shared between the partners of a Cloud teaching system, giving to the others access to new resources, and from the other side the common ones will be optimized, reducing the singular cost per institute and increasing the computational and structural power that is available for each partner.
To summarise, within mClouds project we will strengthen the virtual mobility by providing open educational resources for virtual campuses and integrating access to virtual learning resources and online communities of practice into traditional courses.

3. Methodology

The project is planned for three years 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:

- Need analysis report (5th month)
- Specification of the three Clouds architectures for open learning resources sharing, IT infrastructure and CAD software common use (end of the 9th month),
- Job-specific courses and courses on entrepreneurship, project management (15th month),
- Updated HE curricula in microelectronics in collaboration with the practitioners from the industry and mClouds system developed and implemented with minimum 16 courses delivered as OERs (20th month),
- System officers and teachers and trainers from enterprises trained (24th month),
- Pilot tests (27 month),
- Exploitation/field trial (36th month).

For defining the necessary knowledge, skills and competences we will start with an extensive job analysis, i.e. work process analysis in companies in microelectronics and electronics packaging. The learning outcomes will be defined for each course with the corresponding credits after an assessment adopted by all partners.
The curricula will be reviewed in collaboration with the experts from the companies and joint practice-oriented modules will be developed. Jointly with SMEs business-oriented courses will be developed: on quality assurance in the enterprises, management of projects, entrepreneurship. The e-learning materials will be developed/adapted in such a way that substantial parts can be used in a self-instructive manner.
After training teachers and trainers in the Cloud system, the pilot test will be conducted with small groups of learners – minimum 10 per country. The field trial will be performed during the last 9 months of the project with minimum 240 students. Specific evaluation methods will be used and corresponding tools designed for assessment of knowledge (e.g. knowledge tests for the basic components, assembling procedures, defaults, automated machines etc.); of skills (e.g. tasks for finding solutions for routine problems); of competences (e.g. tasks to take responsibility for completion of tasks in work or study).
The evaluation and valorisation activities are planned for the whole project's lifetime. Project quality assessment will be based on a careful procedure of self-evaluation. Based on evaluations, the management of the project will make the necessary decisions and plan activities for their implementation. The evaluation will be more oriented to the end users, i.e. to obtain feedback to help developers to improve the products

and services, as well as to optimise the project development process through early diagnosis of defects, to reveal of unforeseen circumstances in the training environment, to ensure better communication in the development team, to measure whether training objectives have been achieved and trainees needs have been met and that results could be used for decisions about the implementation on European level and dissemination of the products.

4. Needs Analysis in Higher Education and labour market

The project's focus is on jointly development of MSc degree level courses for the new skills needed for the new jobs in the multidisciplinary sector of micro- nanoelectronics to be delivered as open educational resources in a cloud-based e-learning environment. The addressed problems and needs were identified through: literature study of European policies in the field of education and the needs and priorities of partner higher education (HE) institutions and enterprises in the sector, analysis of subject of area (microelectronics design, fabrication and application), labour market needs, study of the state of the art in cloud computing.
Specific needs and problems of HE in microelectronics that we intend to solve:

- Little reference is made to the needs of the work place and changes in the work place are not met with changes in education,
- Curricula need to be updated and universities need to collaborate to share course materials, intellectual property blocks and ideas.

So, we need a new partnership between education and work to address the need of synergy between the education and industry, to foster the development of competencies, technological and entrepreneurial skills. Moreover, no one university or SME can afford the necessary infrastructure, clean rooms, technology and experts in all fields of the multidisciplinary science of microelectronics. Sharing of laboratory experiences, of CAD tools, of project ideas, of common infrastructures represents a sort of "educational cloud" on top of the cloud software/hardware infrastructure. The advantages 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, thanks to the optimization of laboratories and courses.
The main step necessary to obtain these results is the implementation of an e-learning framework rooted on the tools developed for cloud management, allowing the cooperation and distribution of lab sessions, CAD tools and teaching experiences.
On the other side, the needs of such a project correspond to the needs of the sector of microelectronics design and fabrication, which is moving nowadays, back from Asia to Europe. There is a non-exhaustive list of enterprises in assembling/packaging in (micro)electronics. At the same time last 10 years there is a shortage of engineers in microelectronics and systematic decrease of students in electronics at the university can be a threat to the European economy competitiveness.
This project is designed to meet the needs of labour market of trained personnel and the needs of mobility of the workforce in the sector.

4.1. Survey results for students, teachers and business

Regarding to design the different OERs in the project, an online survey was developed, where teaching and learning needs were evaluated on the three points of view: students, teachers and professionals from the business. Following is described the most relevant results. The survey can be described as follows:

- Objective
    - To analyse user 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 HRD departments, universities and colleges;
- Professionals from the business;
- e-learning environment developers and administrators.

- Sample
  - Students at different universities from 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
  - Literature study;
  - 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 on the project Web site.
  - We have collected
    - 152 answers from the students,
    - 59 – from teachers and
    - 23 – from the representatives of the industry.

4.1.1. Summary of results of the students' survey

- 13% of the respondents study Micro-nanoelectronics. The highest percentage is in Electronics with 37%, follows by Informatics/Information Technologies with 27%.
- 62% of the students their educational level is only graduated, 29% have a Master and only 7% have a Ph.D.
- 89% of the students use open educational resources and those who do not use are willing to learn with OERs.
- Few students have experience with virtual laboratories and remote access to CAD systems but most of them would like to (Figure 1).
- It is very important and encouraging with regard to the project objectives that the students fill comfortable with using virtual laboratories and they are ready to 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 the learners prefer passive teaching methods: electronic books and videorecorded lecture to the interactive courses.
- PowerPoint presentations are not liked at all by the 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 the students prefer to use OERs by online course; 32% by blended/hybrid course, and 27% by face-to-face course.

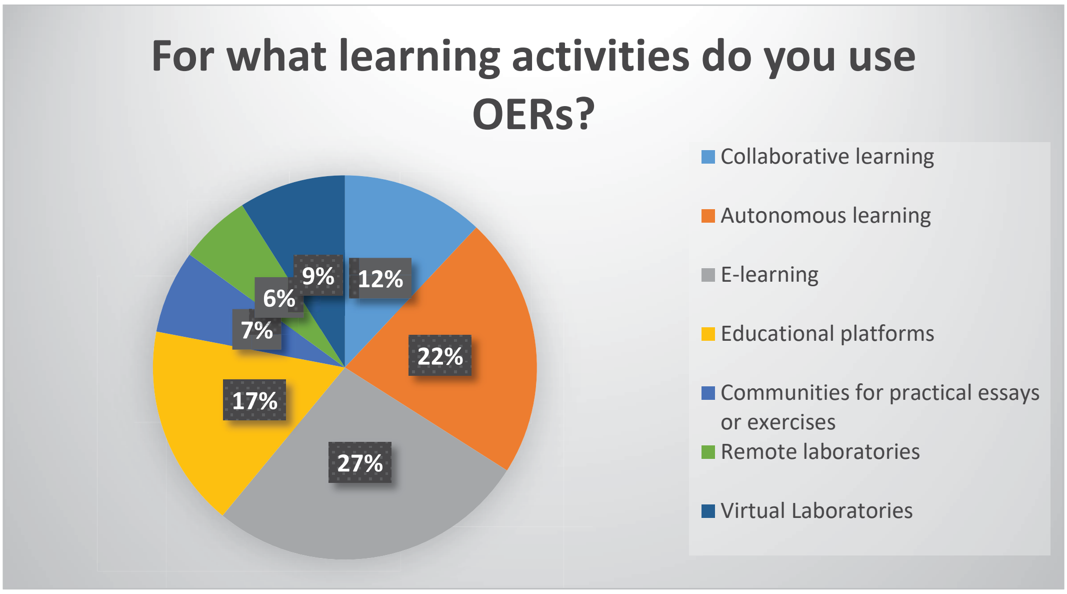

Figure 1: Results for the question: For what learning activities do you use OERs?

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 on 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%

4.1.2. Summary of results of the teachers' survey

- 59 teachers from traditional and distance education universities and vocational education institutions answered the questionnaire, being the profile of university teacher the most common with a 81%. Inside the specialty of the unviersity, the most common is Polytechnics with a 54%. And the highest educational level that teaches our unversities is: PhD with a 36%, Master with a 32% and Bachelor with a 30%.
- If 89% of the students use open educational resources the 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 high level of knowledge for the subject matters in technology. However, the procentage of teaching activities for the use of OERs is shown in the Figure 2.
- With regard to the 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 the adaptation to new situations – not so much.
- The teachers consider that e-learning does not improve students' performance as the student also think about but it makes learning more appealing.
- Most of the educators believe that the use of OERs would improve their practice and reduce their efforts and time used for teaching.

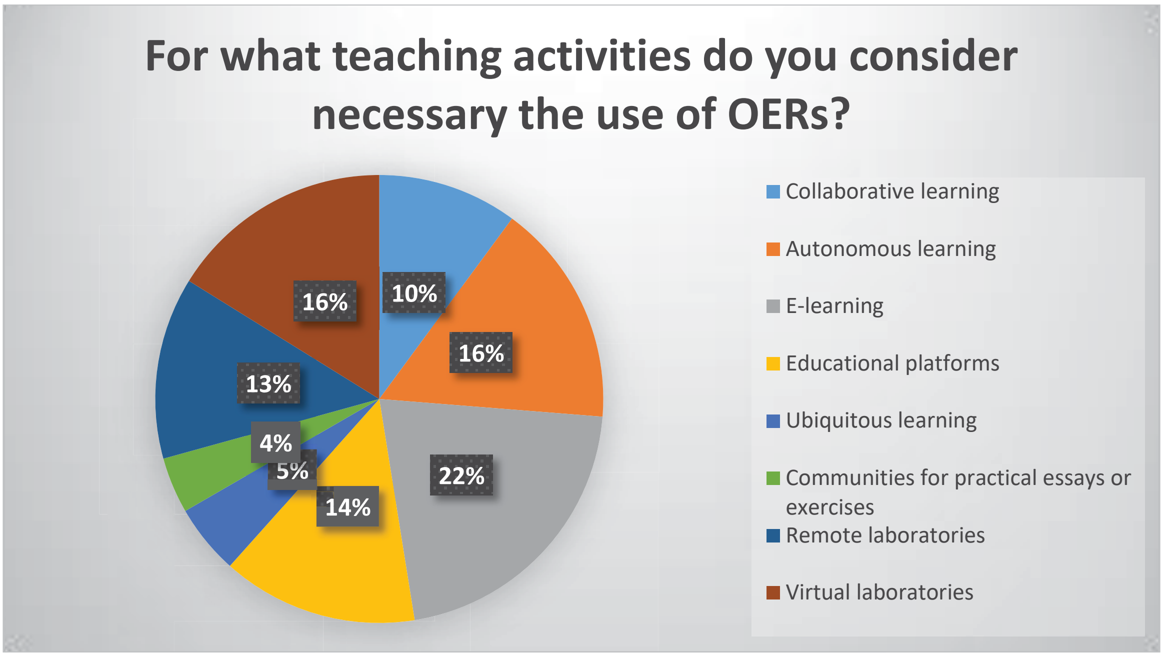

Figure 2: Results for the question: For what teaching activities do you consider necessary the use of OERs?

4.1.3. Summary of results of the professionals' survey

- 23 representatives of the business (Figure 3) answered the questionnaire about the importance of different learning contents.
- All the proposed courses are considered to fulfill a more than average need in short term.
- In long term the industry will needs even more skills and competences in the proposed topics.
- We can conclude that the university world is close to the industry needs.
- Effective communication with groups, presentation techniques, project management and survival on the labour market are considered as highly important by almost all respondents.
- Additional topics are suggested in power electronics, graphene technologies and system integration.

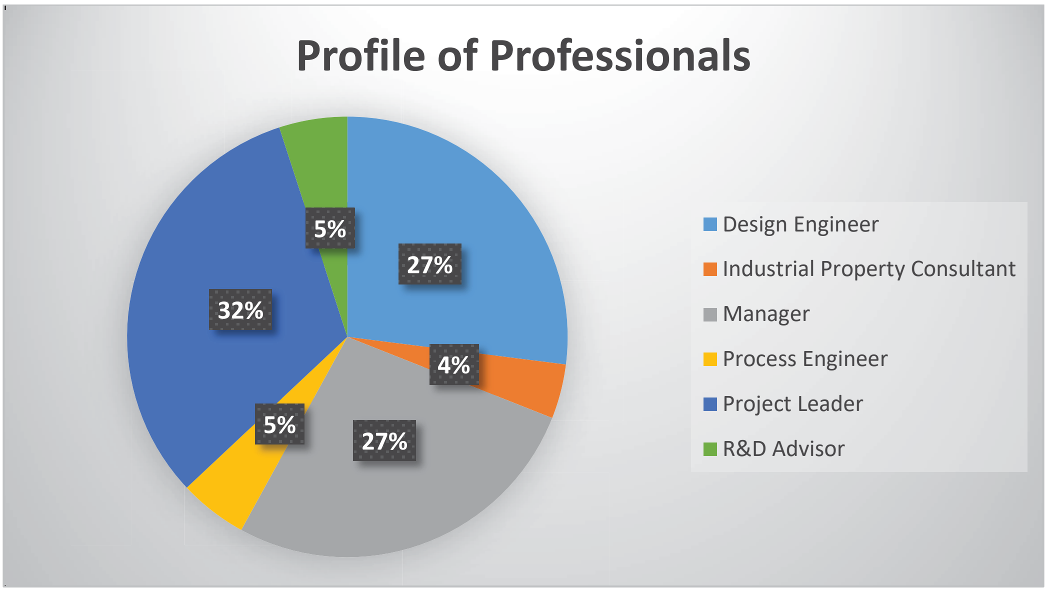

Figure 3: Profile of professionals from business

5. mCloud Architecture

The use of Information Technology (IT) infrastructure in the learning environment is a demanding challenge. The increasing system complexity requires the setup of powerful computer systems, the use of high performance networks, the acquisition of trained IT personnel to manage these hardware and software platforms. Moreover, computing power requirements, joint to learning tool complexity, are pushing academic institutions to build private data centres to host applications and give the service to students and academic staff. Traditional computing architectures are inherently inefficient from the point of view of both energy wasting and utilization efficiency. Statistics shows that the average utilization factor of a server in a traditional data centre is less than 10% and decreases with the reduction of the IT infrastructure complexity. Hardware virtualization can improve efficiency but it does not solve problems related to management costs, as local data centre maintenance is mandatory.

The cloud computing approach, created mainly for Internet application needs, can be adapted amongst other things also to IT architectures for e-learning. In fact, the design of an efficient training infrastructure based on a cloud approach can be also a key solution for traditional classroom training through sharing server resources.

The emergence of cloud computing is transforming the way organizations and companies purchase and manage computing resources. According to Cruz [2] cloud computing is changing the ways people do personal learning, interactive learning and many-to-many learning, in the primary, secondary and higher education spheres. Not only the distance from a desktop is the advantage or information longevity assured by the cloud resources. An important point is that it allows students to interact and cooperate with expanding circle of peers, regardless geographical location. And in this new way of interaction with other people we can be sure about the fact that the new generations are ready and well trained in this approach, thanks to the deep use that they use to have of social networks, network gaming and similar tools.

Some authors [3] discuss how cloud computing and the shift in the software industry towards software as a service, using agile development has led to tools and techniques that match much better to the classroom than earlier software development methods. At UC Berkeley the authors offer a software course based on cloud computing and agile methods to on-campus students and to 50,000 online students from the IT industry.

This proposal is based on the experiences of almost all HE partners in development of e-learning courses and on the experiences of our university (UNED) in development of training through remote laboratory access.

What is the innovation: Involvement of companies in a collaborative update of existing and development of new courses; sharing of laboratory experiences, of CAD tools, of project ideas, of common infrastructures in a sort of “educational cloud” on top of the cloud software/hardware infrastructure.
The advantages in terms of education effectiveness are course organization efficiency, instructors focusing on area of expertise, common experiences of students of different countries based on similar infrastructures, tools, lab organization, learning improvement, thanks to the optimization of laboratories and courses.
The main step necessary to obtain these results is the implementation of an e-learning framework with open educational resources, rooted on the tools developed for cloud management, allowing the cooperation and distribution of lab sessions, CAD tools and teaching experiences.

5.1. Technical implementation. Public and private cloud

There is the public cloud with big players like Amazon Web Services (AWS) and Microsoft Azure on the one site. And on the other site there are private clouds inside of institutions. Also a mixed flavour exists where private clouds are extended with computing power, additional features like high performance computing and machine learning or just storage from the public cloud. This mix can be used for example when there are peak usage requirements during a short period of time – e. g. a summer camp at a university for which it would not be worth to buy several new computers.
This layers of virtualization and packaging of computer resources leads automatically to thinking not so much in single computers anymore but thinking in applications for the end user. There is an ascending path from:

- Infrastructure as a Service (IaaS) Full access to virtual computers
- Platform as a Service (PaaS) The software development layer is fully administrated by the cloud provider, e. g. a PHP/MySQL web server.
- Software as a Service (SaaS) The complete application is fully administrated by the cloud provider like a WordPress website or a Moodle e-learning installation

5.2. CloudStack for a private cloud

For a private cloud these days there are two popular standards available: Apache “CloudStack” [1] and “OpenStack” [4].
We will concentrate on CloudStack because there were good experiences at one HE partner two years ago with new microelectronics and microsystems courses, which require the use of complex CAD soft-ware. Figure 4 is a screenshot for an example screen of the CloudStack web GUI. And some facts about CloudStack are:

- is an open source cloud management software.
- supports all important hypervisors like KVM, VMware, Hyper-V and XenServer.
- is mainly 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
- controls the virtual machines with agents or APIs of the vendor specific hypervisors
- is end-point agnostic: desktop, notebook, tablet
- a good network infrastructure is mandatory
- configuration data is stored in a MySQL database, so very transparent

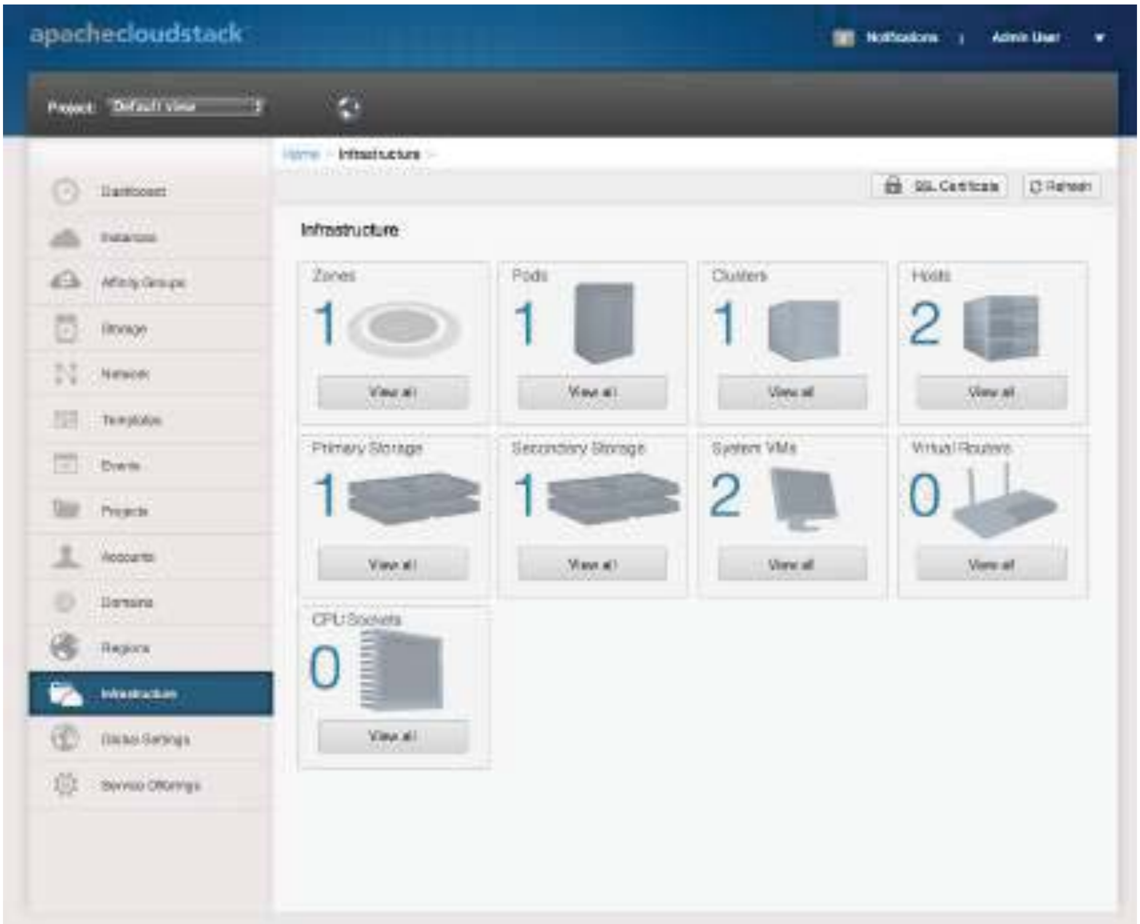

Figure 4: Infrastructure overview screen in CloudStack web GUI

CloudStack can be use for different cases. Some of them are:

User self-service:
Setup resources like virtual computers and applications like CAD software on their own by an easy-to-use and comfortable web application (instead of command line tools or something comparable).

Sharing of processing power, data and virtualized software
It will be possible to share computers and processing power, sharing of data and storage and virtualized software. But not: Sharing of commercial software licenses due to legal restrictions.

Bring in own student computers
Students with their own computers using remote desktops.

- No university PC for each student required
- Students know their own machines
- Can work around the campus or at home (depends on security restrictions, might be solved by a virtual private network VPN with encryption)
- Freezing sessions and continue somewhere else

Remote access to laboratories

- Common experiences of students of different countries based on similar infrastructures, tools, lab organization, learning improvement, thanks to the optimization of laboratories and courses.

- Sharing of 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 which works on desktop, tables and mobile phone)

- 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 unavailability of single machines
- Better preservation of intellectual properties (not a single point of failure)
- Specification of auto-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.

5.3. Infrastructure overview

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

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

5.4. 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 (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

6. Two proposed courses by UNED

Follow the cloud-based e-learning environment, UNED, as a partner of the project, is developing two MSc courses in Microelectronics as open educational resources. The two courses are: 1) Microelectronics literacy and Technologies, and 2) Integrated circuits and design. These two courses joined to the list of 22 courses that are being developed by all the partners of the project. Table 2 shows the learning outcomes that will achieve in these two courses.

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	Able to use different types of large scale integrated circuits 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	Able to use Lithography technology in the design of integrated circuits. Able to use CMOS technology sequence and BiCMOS integrated circuits. Able to manage and design custom circuits and logical matrices

The methodology proposed to develop these two courses is as follows:

- Develop contents and material for both courses in a document format (docx or pdf).
- Implementation content and material for both courses in our own e-learning platform, which is in aLF. For the course "Integrated circuits and design", which is an advanced course in Microelectronics, it will design practical activities using the Remote Lab – VISIR.
- Migrate these two course to CloudStack in order to use in a cloud architecture by all the partners.
- Test these two courses with real students from the Master in Information and Communication Electronic Systems conducted by UNED and with students from the rest of partners.

7. Conclusions

The project addresses the needs of enterprises and HE of training new skills for new jobs and the needs of sharing open educational resources, IT infrastructure and expertise in the highly interdisciplinary area of micro- nanoelectronics where no one university can afford sufficient infrastructure and equipment. For the knowledge and cognitive skills training, the learning materials will be ICT-based with remote access to laboratories in the other countries, and the content will be based on the last research results and practices in the most rapidly developing science. The e-learning will allow virtual mobility of students and an easy update of the contents, which should be innovated every year.

Involving employers and labour market institutions in the design and delivery of programmes, supporting staff exchanges and including practical experience in courses can help attune curricula to current and emerging labour market needs and foster employability and entrepreneurship.

The Cloud computing approach, created mainly for Internet application needs, will be adapted to IT architectures for e-learning, but not only. In fact, the design of an efficient training infrastructure based on

a Cloud approach can be also a key solution for traditional classroom training through sharing server resources. The students will be able to interact with the remote experiments including in the real work place, change parameters and in some cases modify and design experiments. The mClouds architecture will enable the Europe-wide distribution of resources, in terms of lab-experiments, by utilizing multiple Web servers in a single network topology. Thus, instructors from different European countries can take the advantages of employing a running lab-experiment and present it in their native language and personal educational point of view.
Some benefits or advantages that we will obtain using this architecture are:

- Up-to-date curricula in the most rapidly developing science with rich offer of specialised elective courses that no one HEI can afford;
- Enlarged and more powerful infrastructure with the virtual use of the resources of the partners in the knowledge alliance;
- Opportunity to collaborate with enterprises in the research projects beneficial for both sides: access of HE researchers to the equipment of enterprises for investigation purposes and contribution of the academic researchers and PhD students to the innovations in the manufacturing processes of SMEs.
- Involvement of company staff in teaching and course development will improve the preparation of future graduates for the business environment, i.e. the companies will have better prepared new employees for their specific needs;
- Opportunity to use for training their staff a large variety of free courses developed by academicians and researchers all over Europe;

The knowledge alliance purpose is to build a long lasting partnership of SMEs with HEIs, which could evolve in joint research activities. Mostly the SMEs, which cannot afford research, may rely on the scientific potential of HEIs and the collaboration in supervising doctoral theses is a logical continuation of the knowledge alliance activities. In France, there is a good practice in such collaboration and it will transferred in the other European countries including the co-tutoring practices by HEI and SME and by supervisors from different countries. And double line feedback, knowledge and synergy gain due to the specific enterprise/HEI partnership, increasing the research and innovation on the enterprise gained from the HEI academic competitive view and improve the HE thanks' to the enterprise's industrial application experience and knowledge.

Acknowledgment

Special thanks to the Electrical and Computer Engineering Department of UNED for their support inside the project "Knowledge Alliance 562206-EPP-1-2015-1-BG-EPPKA2-KA MicroElectronics Cloud Alliance (MECA)", as well as to the eMadrid excellence network, "Investigación y desarrollo de tecnologías educativas en la Comunidad de Madrid – S2013/ICE-2715".

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