Cloud Computing and its Application to Blended Learning in Engineering

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Abstract—**The education process in engineering means theory and practice, individual study, group-based projects or experimental work that involves equipment, simulation/emulation software packages and laboratory applications. In order to develop e-learning platforms for higher and postgraduate education in engineering, new methodologies should be taken into consideration: project- and problem based learning, virtual laboratory (remote access to laboratory infrastructure and task evaluation) or remote assistance for diploma projects and mobility grants. This paper presents new blended learning methodologies and the manner they can be customized for higher and postgraduate education in engineering by using the cloud computing paradigms.**

Keywords - cloud computing; blended learning; virtual laboratory; hybrid classware; project-based learning; problem-based learning

I. INTRODUCTION

In recent years, with the advances of the Internet and e-learning technologies, a blended mode of learning, which effectively combines the traditional face-to-face learning and e-learning, has evolved. Yet, this blended learning mode is not widely adopted in higher and postgraduate education in engineering. One major reason is that teachers are not familiar with the practice of designing courses under the blended learning environment. Another important aspect is that many teachers do not consider the e-learning methodologies as stable and functional enough for engineering, especially for laboratory and project task completion. The third reason is that academic staff considers the act of teaching/learning engineering as more than individual study and online assessment.

Engineering consists of lecture attendance, project development, hands-on laboratory-based activities and computer simulation work. In this way, the educational act can be considered as learner-centered. Manseur [5] presented the synchronous distance learning concept (SDL) and its application to Electric and Computer Engineering and Mathematics. Students follow lectures live via videoconferencing but they attend laboratory sessions taught by on-site faculty. The advanced technology has been used for linking the local and the remote classrooms: the lecturer teaching in one location is videotaped and can be seen live on a TV screen in the other classroom. The hands-on experimentation is difficult to conduct without access to often expensive equipment and components and without competent on-site laboratory tutors. In order to complete the lab, the SDL environment consists of two sets of fully equipped and staffed laboratories, one on each end of the SDL-connected campuses.

Qiu [7] proposed a blended learning environment that implements the face-to-face teaching and e-learning capabilities in Advanced Software Engineering. A set of integrated projects was selected as stimulus to learning. Both inter- and intra-group collaborative learning are encouraged. A survey conducted at the end of the course revealed that students accept the problem-based learning quite well, and their academic achievements were also better than expected. The methodology consists of grouping student in teams, dividing the semester in project phases and developing the project using iterations.

This paper is organized as follows: the related works and proposals are presented in Section II. Section III is dedicated to the blended learning models for higher and postgraduate education. Several important aspects are taken into consideration: how to improve the retention factor in the individual study, how to provide remote access to laboratory infrastructure and applications and how to support fundamental and applied research activities within individual, group-based projects or international partnerships. Section IV starts with the technological aspects and continues with the deployment diagram of the blended learning platform for technical education and continues with the elastic cloud environment presentation. The experimental results, especially the platform deployment for “Economic and Exact Sciences” and “Applied Electronics, Telecommunications and Information Technology” domains, including the blended learning support, practice and assessment processes, are highlighted in Section V of this paper. In conclusion, the authors underline the importance of SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) concepts in higher and postgraduate education by presenting a complex scenario for extending legacy e-learning systems in order to support blended learning capabilities.

II. RELATED WORKS

Mendez [3] illustrates that in traditional web-based learning mode, system construction and maintenance are located inside the educational institutions or enterprises, which led to a lot of problems, such as significant investment needed but without capital gains for them, which

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leads to a lack of development potential. In contrast, cloud-based e-learning model introduces scale efficiency mechanism, i.e. construction of e-learning system is entrusted to cloud computing suppliers, which can make providers and users to achieve a win-win situation. The cloud-based environment supports the creation of new generation of e-learning systems, able to run on a wide range of hardware devices, while storing data inside the cloud.

Laisheng [9] highlighted a new business paradigm in educational area by introducing the cloud computing in order to increase the scalability, flexibility and availability of e-learning systems. The authors have evaluated the traditional e-learning networking model, with its advances and issues, and the possibility to move the e-learning system out of schools or enterprises, inside a cloud computing infrastructure. The separation of entity roles and cost effectiveness can be considered important advantages:

- The schools and enterprises will be responsible for the education process, as well as for content management and delivery, and the vendor takes care of system construction, maintenance, development and management;
- The e-learning system can be scaled, both horizontally and vertically, and the educational organization is charged according to the number of used servers that depend on the number of students.

Ouf [10] has presented an innovative e-learning ecosystem based on cloud computing and Web 2.0 technologies. The article analyzes the most important cloud-based services provided by public cloud computing environments such as Google App Engine, Amazon Elastic Compute Cloud (EC2) or Windows Azure, and highlights the advantages of deploying E-Learning 2.0 applications for such an infrastructure. The authors also identified the benefits of cloud-based E-Learning 2.0 applications (scalability, feasibility, or availability) and underlined the enhancements regarding the cost and risk management.

Chandral [11] focused on current e-learning architecture model and on issues in current e-learning applications. The article presents the Hybrid Instructional Model as the blend of the traditional classroom and online education and its customization for e-learning applications running on the cloud computing infrastructure. The authors underline the e-learning issues, especially the openness, scalability, and development/customization costs. The existing e-learning systems are not dynamically scalable and hard to extend – integration with other e-learning systems is very expensive. The article proposed the hybrid cloud delivery model that can help in fixing the mentioned problems.

The e-learning platforms for higher and postgraduate education in engineering should provide remote access to both educational materials and laboratory infrastructure. They also need to implement synchronous/asynchronous collaborative learning features, as well as blended assessment functionality. Such a platform is expensive and its development can take much time. The cheapest solution is to opt for public cloud computing services, even if the component integration and customization will need important investments.

The learning cloud prototype presented here is a fully functional, application-oriented, and in the same time, low-cost solution that provides SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) capabilities. Software as a Service is used to deliver the educational applications to the browser of the user/ customer from the learning cloud. It helps the faculties and departments with limited IT resources to deploy and maintain needed software in a timely manner while, at the same time, reducing energy consumption and expenses. Platform as a Service facilitates the development and deployment of applications, such as laboratory simulation software packages, without the cost and complexity of buying and managing the underlying infrastructure (hardware and associated software). Infrastructure as a Service gets on-demand computer infrastructure (virtual desktop or data center, e.g.).

III. Blended Learning Models

From the teaching point of view, six essentials are identified: teaching subjects, teaching content, teaching environment, teaching models, teaching organizers and teaching administration. In order to improve their knowledge and skills, the students (subjects) actively participate to both real and virtual educational acts. So, the learning service providers should pay attention to both teaching modes: face-to-face and Internet-based. The advances point out the manner of getting them together, in order to expand the real educational environment and make the virtual platforms an important part of the educational system.

A. Blended Learning Model for Higher Education

The traditional e-learning platforms consist of the learning management system, learning content management system, assessment and communication modules (especially forum and messaging). The third generation of e-learning platforms provides with advanced services such as online courses, tutorials and webinars. The education process in engineering means theory and practice, individual study, team projects or experimental work and involves laboratory equipment, simulation/emulation software packages and applications.

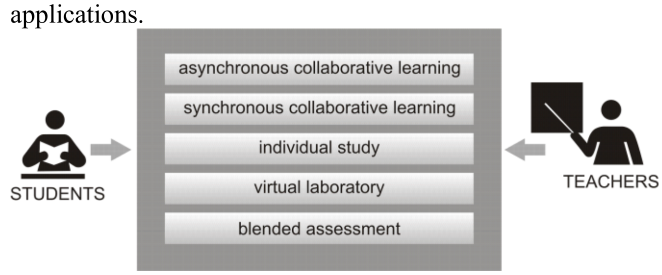

Figure 1. Blended Lerning Model for Higher Education in Engineering.

The e-learning platforms for higher education in engineering implement new methodologies such as: project- and problem based learning, virtual laboratory (remote access to laboratory equipment and applications and task evaluation) or remote assistance for diploma projects and mobility grants. The blended learning model illustrated in Figure 1 proposes the following educational phases: asynchronous/synchronous collaborative learning, individual study support, virtual laboratory and blended assessment. Two main blocks should be taken into consideration in the e-learning system architecture: hybrid classware and asynchronous collaborative learning modules. The hybrid classware is a complex blended learning approach that provides with classroom-based education, synchronous collaborative learning (online course/tutoring/mentoring), virtual laboratory (remote access to laboratory equipment and applications) and blended assessment (practice and theory) capabilities. The problem-/project-based learning and individual study (interactive courses/tutorials) features are implemented in the asynchronous collaborative learning section.

B. *Blended Learning Model for MSc Programmes*

In MSc programmes the students are focused on research and career development activities. The educational schema consists of live lectures, hands-on experimentation, individual and group-based projects, virtual team cooperation and mobility grants. It is defined around the following skills: information synthesis in theory and hands-on experimentation or online simulation, requirement analysis, project design, implementation, or result presentation.

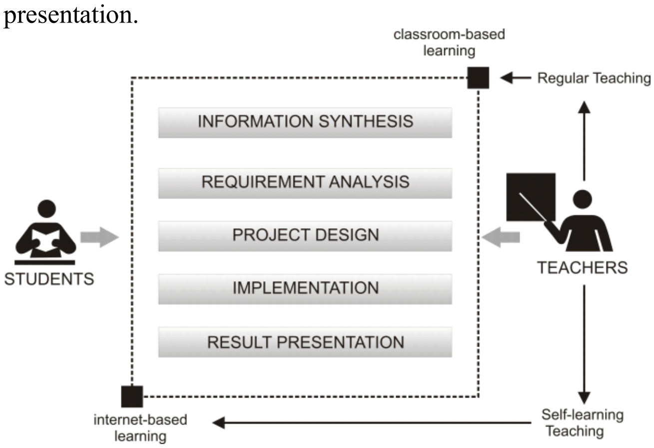

Figure 2. Blended Lerning Model for MSc Programmes in Engineering.

The blended learning model illustrated in Figure 2 proposes the two main phases in the educational act: regular teaching and Internet-based learning. Information technology is important in education, even when regular teaching involves advanced technologies such as multimedia presentations, video projectors, or smartboards. Self-learning means individual study starting from educational materials created and posted onto the e-learning platform by the teachers, then browsing the Internet to find and select correct information about subjects related to the educational materials.

Online tutoring approach consists of interactive tutorials and face-to-face Internet-based learning. Interactive tutorials can be also used as the introduction part of hands-on experimentation activities. The face-to-face Internet-based learning includes the online classroom/webinar sessions and remote assistance during the international research projects or mobility grants.

C. *Blended Learning Model for PhD Programmes*

Blended learning is not new - what is new is the recognition of its potential to help in fundamentally redesigning the learning experience in ways that could enhance the traditional values of higher education and postgraduate scholarship (MSc and PhD programmes). Preparing PhD students according to a blended strategy can be challenging, since it requires gaining different teaching skills and technologies. Redesigning the educational process takes into account new teaching and learning opportunities, managing the educational content both online and in-class, and preparing PhD students to work in a hybrid format.

In Romania, the PhD scholarship based on European Social Funds (ESF) constrains the students to complete their PhD in three years, so, the activities should be well defined and supported by clear results. This aspect completely changed the PhD methodology (illustrated in Figure 3). For the moment, the PhD students must be integrated within research projects and work close to real and efficient research teams. Most of the research projects are developed according to the Scrum methodology [2]. This way, the authors took into consideration the blended learning and Scrum methodology for improving the education and research activities in PhD scholarship based on ESF Funds.

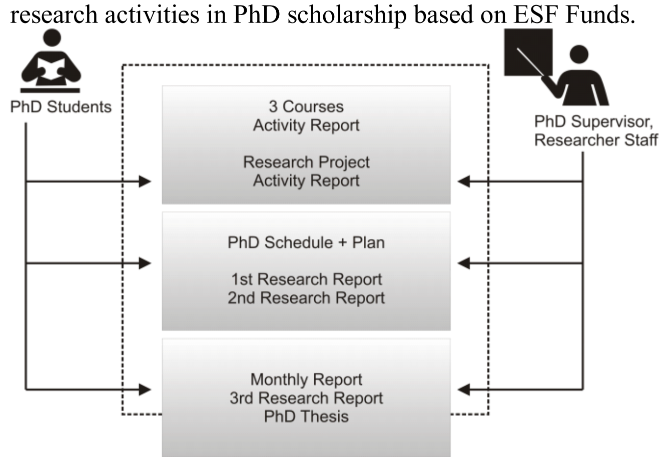

Figure 3. Blended Lerning Model for PhD Programmes in Engineering.

The PhD programme means theory, practice and research activities with results published in scientific journals and conference proceedings. This way, the problem- and project-based learning should be considered as necessary. The Technical University of Cluj-Napoca provides with PhD programmes in the following domains of interests: Automation, Computer Science, Electric Engineering, Applied Electronics and Telecommunications, Civil Engineering, Mechanics, etc. With the big number of domains and the increasing number of MSc and PhD students, the blended learning environment that supports MSc and PhD activities should be both horizontally and vertically scalable. In conclusion, an elastic learning cloud infrastructure should be implemented.

IV. E-LEARNING CLOUD INFRASTUCTURE

From the beginning, the role of blended learning was to improve the educational process by increasing the degree of students' satisfaction, retention factor and students' enrollment and developing students' skills. In higher education, especially in engineering, the blended learning is a need because of the diversity of teaching/learning activities. The quality of the learning act can be considered another important aspect, so increasing number of students enrolled should not affect the educational process. The learning cloud means reliability and scalability, as well as cost effectiveness.

Laisheng [9] proposed a generic e-learning cloud and identified several challenges such as: charge, bandwidth, security, user's awareness and acceptance, educational forms and methods and resource development, and proposed solutions for each challenge. By setting up a market-oriented charging mechanism and by combining two types of fees, school fees and individual fees (with school charging for general resources and individual charging for special resources) can be considered a solution. The bandwidth problem is almost fixed in Romania because between RoEduNet and each important Internet service provider there are peering services. In order to keep the integrity and confidentiality of data an encryption mechanism should be implemented for both storage and transmission.

The e-learning cannot completely replace teachers; it is only an updating for technology, concepts and tools, giving new content, concepts and methods for education, so the roles of teachers cannot be replaced. The teachers will still play leading roles and participate in developing and making use of e-learning cloud. The blended learning strategy should improve the educational act. Moreover, the interactive content and virtual collaboration guarantee a high retention factor (up to 80%) [4].

A. E-Learning Cloud Architecture

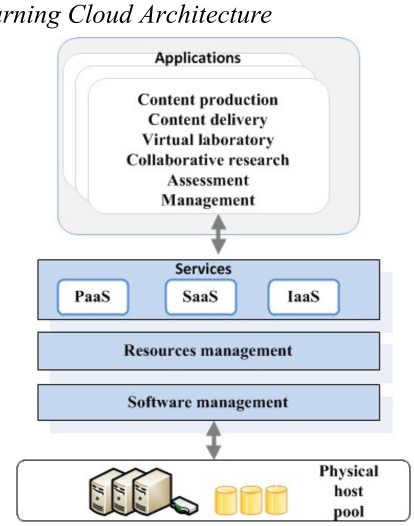

Figure 4. Learning Cloud Architecture.

The proposed learning cloud architecture illustrated in Figure 4 can be divided into the following layers: hardware resource layer as a dynamic and scalable physical host pool, software resource layer that offers a unified interface for e-learning developers, resource management layer that achieves loose coupling of software and hardware resources, service layer, containing three levels of services (software as a service, platform as a service and infrastructure as a service), application layer that provides with content production, content delivery, virtual laboratory, collaborative learning, assessment and management features.

B. E-Learning Cloud Setup

In the classic blended learning model, teachers assign teaching tasks, conduct regular lectures, or train students' skills. The students attend the online autonomous learning act and cooperative learning sessions, or accomplish teachers' assignments. The teachers make assessments over students' learning effect and solve their problems. So, teachers set objectives and tasks of different levels, they put forward requirements and suggestions according to the teaching contents and make assessments to students' learning effects through task-based activities. Teachers also answer students' questions and offer essential teaching to major and difficult points. In addition, teachers can also use multimedia to enhance teaching content. Of course, teachers create flexible and diversified theoretical and practical scenarios and teaching contents, using authentic materials to let students come upon more technical information related to real problems/projects. Students work out their own learning plans, determining learning methods autonomously. They conduct on-line autonomous learning when they study each unit, finish its test via Internet and do some statistics to the test results. Teachers also encourage students to cooperate with each other to finish simple learning tasks or complex group-based projects. Through cooperative learning, students cannot only acquire knowledge, their team spirit and coordination will also be fostered, skills in dealing with people will be improved and abilities to express themselves will be enhanced. In applied electronics, telecommunications and information technology, the learning environment also provides with hands-on experimentation work, simulation software packages and semester/diploma projects.

We proposed a learning cloud environment built around Citrix XenServer. XenServer is an enterprise-ready, cloud-proven virtualization platform that contains all the capabilities required to create and manage a virtual infrastructure and provides an efficient management of Windows and Linux virtual servers and delivers cost-effective server consolidation [1]. The initial setup, illustrated in Figure 5, must support the teaching/learning activities and practice. It should be a dynamic environment, able to create university/programme instances. Each instance consists of six virtual machines: two allocated for web hosting, two for the data warehouse and two for the virtual library. The initial setup also includes the collaborative work environment that hosts the

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asynchronous/synchronous collaborative learning tools: course authoring tool, interactive tutorial, messaging, forum, web conferencing, online focus group, or virtual classroom.

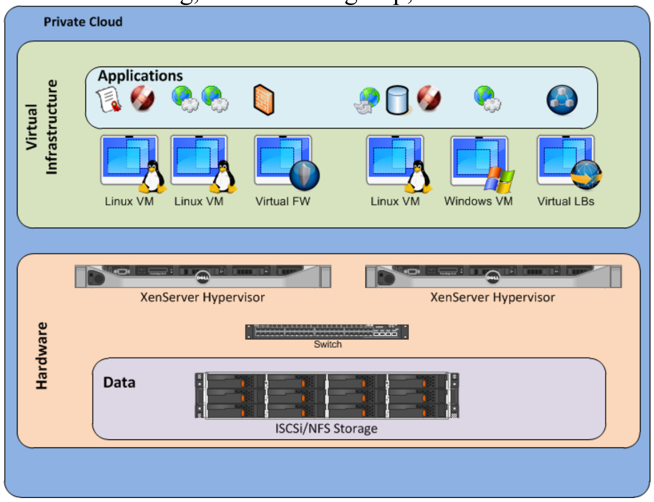

Figure 5. E-learning cloud setup.

The learning management system allows the students to schedule online laboratory activities. The e-learning cloud infrastructure implements an advanced resource pooling mechanism (see Figure 6) that dynamically allocates twenty virtual machines for each university instance when the first student scheduled a virtual laboratory session. When fifteen of the initial virtual machines are allocated, the resource pooling mechanism allocates other twenty. The virtual machine will not be a powerful one. Its role is to provide students with remote access to lab equipment and simulation software packages needed for completing the tasks. The activity starts with an interactive tutorial, where the tutor describes the tasks and gives some suggestive examples related to the current work. The students remotely access the lab equipment and/or applications and complete the tasks.

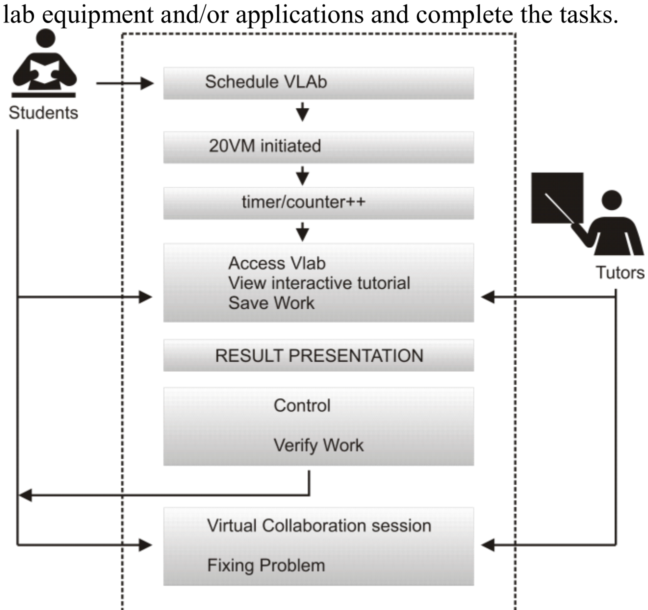

Figure 6. Virtual Lab Approach.

At the end of the lab session, each student saves its own work, in order for the tutor to verify it. If the tasks are not properly done, the tutor notifies the student to repeat the work or to attend a collaborative session in order to fix the problems together.

The online access to the laboratory infrastructure complies with a well-defined schedule. It is almost impossible to allocate one virtual machine for each student enrolled in the educational program. This way, the students will access the virtual laboratory in groups of ten students. At the same time, we can have groups of ten virtual machines to be allocated for each field/line of study.

V. EXPERIMENTAL RESULTS

Each educational organization should have its own staff that manages both educational act and content. When registering, the account manager should specify the number of students, form of study, education domain, then an intelligent block processes the information and provides with the most appropriate configuration needed for such a programme.

The "Aurel Vlaicu" University of Arad opted for an e-learning cloud-based service, in order to support blended learning in the Faculties of Economic and Exact Sciences. The manager of the Distance Learning Department completed the registration forms and defined a clear structure of BSc programme for 2 faculties, 5 domains, 3 years of study, 72 teachers and more than 3000 students. The educational process in the Faculty of Economic Sciences consists of flexible individual study, individual and group-based projects, online and face-to-face teaching, online and classroom-based assessment, webinars and web meetings between students and/or students and tutors. In the Faculty of Exact Sciences, it also includes virtual laboratory activities, especially remote access to lab applications (software development environment), and semester/diploma project support.

The configuration block automatically creates the virtual machines (VM) and allocates the hardware and software resources: two VM allocated for web hosting, two for the warehouse and two for the virtual library. In the Faculty of Exact Sciences, the virtual laboratory involves one virtual machine allocated for each student, the virtual desktop that allows the student to complete his own work, and a reduced storage space necessary for saving the work at the end of the laboratory session. The virtual machine has minimal hardware and software requirements: it should support the software packages needed for completing the current tasks.

The e-learning cloud prototype is also implemented in the Technical University of Cluj-Napoca, Faculty of Electronics, Telecommunications and Information Technology, for MSc and PhD programmes. One of the pilot courses, "E-Business Technologies", involves 25 students, some of them involved in Erasmus mobility grants. By using the hybrid classware component, the Erasmus students have been able to actively participate to courses and lab activities. The teachers were also assisting the students during semester or diploma projects.

The virtual educational environment will provide with classroom-based lectures, online courses, interactive tutorials, virtual laboratories (especially access to simulation software packages), problem- and project-based learning, and remote assistance for semester and diploma projects. The e-learning cloud automatically deploys an instance for each educational progamme that consists of six virtual machines. The management component processes the learning schedule related to each programme, controls and re-allocates the hardware and/or software resources, invokes the interactive/collaborative tools and provides online access to educational resources and laboratory infrastructure.

The hybrid classware, illustrated in Figure 7, supports both synchronous collaborative leaning and face-to-face teaching. It enables the teachers to present the educational material in the classroom and simultaneously project it in the virtual space. The students can opt for assisting the presentation in the classroom or using the virtual classroom component.

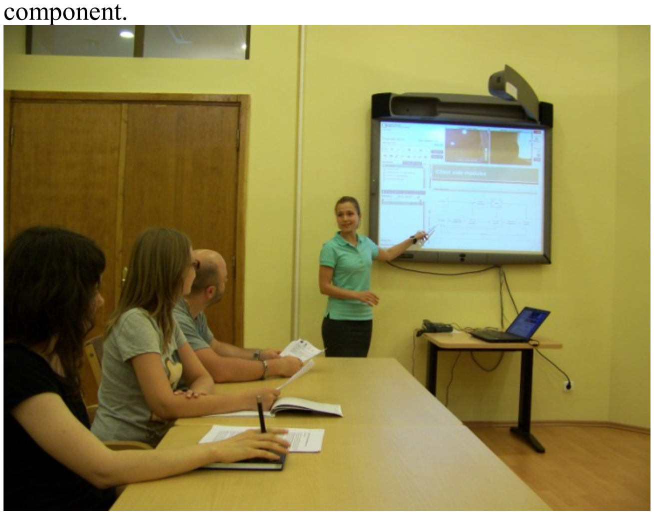

Figure 7. Hybrid classware implementation.

A complementary tool that allows the lecturer to dynamically handle the educational content is integrated into the learning cloud. Two types of educational content are stored into the virtual library: public and private content. If the lecturer considers one of his/her materials as really important for the public interest, that material will be uploaded on the server, converted to an internal format (SCORM compliant) and stored into the virtual library as a public material. If the material is private, or if the lecturer has no rights to make it public, it will be converted to the slideshow format and then stored into the library as private. The tutor is able to browse the media library, load it on the shared space and share it among the virtual classroom session. Asynchronous collaborative learning is also allowed. The lecturer is able to create interactive learning content by using the course authoring tool and store it into the virtual library. The student accesses the virtual library, browses the content and manages his own schedule.

When setting up the hardware and software resources for the MSc Programme “Multimedia Technologies”, the staff should evaluate the laboratory equipment and applications to be integrated. For example, the lab activities for “Distributed Databases” and “Multimedia Databases” courses involve SQL Server and Oracle support, the ones for “Speech Synthesis and Recognition”, “Multimedia Data Compression and Encoding” and “Speech Compression” courses need Matlab. The lab activities for “Advanced Software Methods in Telecommunications” course need Rational, Visual Studio and JBuilder.

Each laboratory activity should be performed according to the tutor’s specifications. The specifications consist of theory, objectives, interactive tutorials, demonstrations and external resources. If the laboratory objectives are related to software development, customization or analysis, the virtual machine allocated to each student just creates an instance of the development environment or software package used for completing the tasks.

There are courses, such as “Mobile communications – 3G and 4G”, that also involve simulation packages and hardware equipment. The simulation packages such as QualNet network simulator, can be exposed in the same manner as the software packages or the development environments, even if they are connected to real hardware devices or not.

LabView can be also used for handling hardware devices. If exposing the hardware equipment via LabView, within the virtual machine, only one student or team can control it, at a moment. In order to avoid conflicts and protect the equipment and student work, the remote access to hardware devices must be optimized.

In the Technical University of Cluj-Napoca there are 3019 MSc students and 1432 PhD students registered in 9 faculties and following different educational programmes. Not just the diversity of themes and interdisciplinary character of MSc and PhD recommend the implementation of a learning cloud environment. Another important aspect refers to research management during the PhD mobility grants, where important priorities are knowledge transfer and approaching of new technologies.

Figure 8. Scrum implementation in research projects.

Most of the diploma, dissertation and research projects comply with the Scrum methodology. So, the authors propose the blended learning approach and Agile Scrum methodology to be implemented in the project-based learning module. The semester and diploma projects will be developed according to Agile Scrum methodology. It allows iterative development and full control of the project phases. The students are grouped in virtual teams (2-3 members). Forum, messaging and online focus group, document management and sharing capabilities (see Figure 8) are added to the project module in order to allow team members to collaborate during the project.

In traditional engineering education, knowledge assessment consists of complex procedures such as periodical evaluation, project evaluation and the final knowledge assessment and it involves the teachers and students. The assessment model in the third generation of e-learning is learner-centered and it consists of questions with one or more correct answers, as well as open answers. So, the students should complete the online assessment tests and the teacher will receive notifications about students' tests and centralizes the results before closing the educational act. The presented prototype proposes a blending assessment method that preserves the traditional assessment methods and the flexibility the online assessment tools grant.

The learning environment allows the management staff to setup the own educational platform or invoke needed interactive/collaborative tools. The cloud computing paradigms (SaaS, PaaS and IaaS) enable transparent access to services, software packages or hardware infrastructure. This way, the head of a department/programme manager that already implemented an educational platform and prefers to use it instead of re-implementing a new approach can opt for transferring the platform onto the new e-learning cloud setup (based on the Infrastructure as a Service paradigm) or extend the existing functionality in order to support more features. It assumes the integration of the legacy system by using the Software as a Service paradigm.

The cloud computing environment, it is open for organizations and enterprises. The registration procedure is very simple: the responsible of an educational/training programme (MSc, PhD, even BSc) must complete the registration forms by specifying the requirements, then the intelligent configuration block automatically allocates the needed resources and creates the hardware and software components that support such a programme.

The learning management features include the statistics and reporting capabilities. The reporting and statistics components provide with the information related to education and research activities the actors performed within the platform:

- The number of educational resources and interactive materials created and uploaded into the platform;
- The number of assessment sessions the tutors created and scheduled per month/week/day;
- The number of synchronous collaborative learning sessions scheduled per month/week/day;
- How many students accessed the interactive materials per month/week/day and completed the periodical assessment sessions;
- How many students collaborated within the research/team projects and the contribution of each team member;
- How many topics have been created within the course forum and how many students participated to a topic;
- How many students used the multimedia messaging in order to communicate to the colleagues;
- The number of collaborative sessions the students scheduled within the research/team projects;
- The number of interactive tutorials the students met tutors in order to clarify important aspects regarding the educational content and activities;
- The number of students that completed the laboratory tasks according to the pre-defined schedule;
- The number of students that needed help during the laboratory tasks and how fast and clear was the tutor's support;
- How many team/research projects have been completed according to the pre-defined scheduled;
- How many students studying abroad have been assisted remotely;
- The number of MSc and PhD students are involved in virtual research teams;
- The number of interactive training sessions has been scheduled and delivered via hybrid classware;
- The number of virtual machines has been allocated for laboratory activities;
- The bandwidth usage per month/week/day (Figure 9);
- The CPU usage per virtual machine;
- The memory usage per virtual machine;
- The overloading per virtual setup.

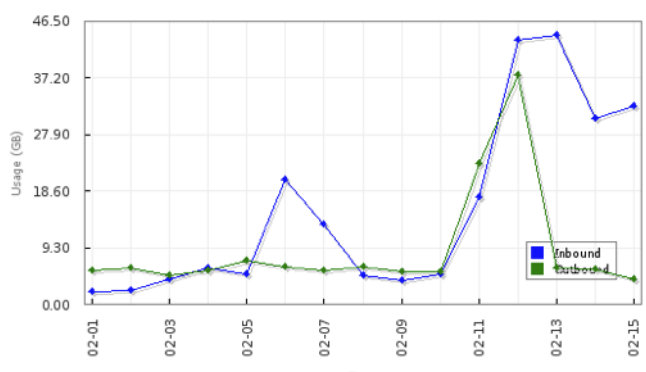

Figure 9. "Aurel Vlaicu" Univeristy. Bandwidth usage (February, 2011).

VI. CONCLUSIONS

The article presents the blended learning concept based on cloud computing paradigms and the manner it can be customized for higher and postgraduate education in

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engineering. It starts from a functional analysis between traditional e-learning platforms and blended learning environments dedicated to higher and postgraduate education then it continues with the technological aspects and the deployment diagram of an e-learning cloud environment for engineering education.

If analyzing the e-learning cloud setup with the platforms presented in the introduction and related works, the advantages are conclusive: individual study support, Internet-based collaborative learning features, online access to lab infrastructure, collaborative research capabilities, project-based learning and problem-based learning functionality delivered using a complex but low cost infrastructure. Due to cloud computing (SaaS, IaaS and PaaS paradigms) implementation, the e-learning service providers can easily setup new learning environments or extend their existing systems in order to support blended learning capabilities.

The most important advantage of the cloud computing is the cost effectiveness. Instead of investing funds in the own e-learning infrastructure and educational software packages, the educational institutions should pay more attention to the content, staff, marketing and student enrollment, which can grant the service improvement. If opting for cloud-based services there are no IT costs, neither IT specialists to employ. The educational institutions register in the e-learning cloud and pay just what they consumed. The online access to collaborative learning tools and flexible individual study are implementing using SaaS paradigm. The development and deployment of laboratory applications use the PaaS concept. In order to implement laboratory equipment/infrastructure sharing or virtual desktop functionality, the faculties and departments can opt for IaaS services.

Such systems allow students to enroll in educational programmes even if the job is very restrictive because most of the learning activities can be remotely done. Several enhancements in the educational act have been identified. The implementation of the interactive learning approach in individual study grants a high retention factor (up to 80%) and the collaborative learning develops the soft skills and teamwork capabilities. The hybrid classware approach implements the synchronous collaborative learning methodologies and allow the students to actively participate to the educational act. Its main role is to keep the responsibility of learning on the teacher's end but also make students more responsible, communicate to each other and work and study as a team. Fundamental and applied research support, task management features and remote access to lab equipment and applications are also supported. The e-learning cloud setup should be considered as the most reliable solution for virtual laboratory and student assistance during the semester, diploma, dissertation or research projects.

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