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Model to Implement Virtual Computing Labs via Cloud Computing Services

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Abstract: In recent years, we have seen a significant number of new technological ideas appearing in literature discussing the future of education. For example, E-learning, cloud computing, social networking, virtual laboratories, virtual realities, virtual worlds, massive open online courses (MOOCs), and bring your own device (BYOD) are all new concepts of immersive and global education that have emerged in educational literature. One of the greatest challenges presented to e-learning solutions is the reproduction of the benefits of an educational institution's physical laboratory. For a university without a computing lab, to obtain hands-on IT training with software, operating systems, networks, servers, storage, and cloud computing similar to that which could be received on a university campus computing lab, it is necessary to use a combination of technological tools. Such teaching tools must promote the transmission of knowledge, encourage interaction and collaboration, and ensure students obtain valuable hands-on experience. That, in turn, allows the universities to focus more on teaching and research activities than on the implementation and configuration of complex physical systems. In this article, we present a model for implementing ecosystems which allow universities to teach practical Information Technology (IT) skills. The model utilizes what is called a "social cloud", which utilizes all cloud computing services, such as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Additionally, it integrates the cloud learning aspects of a MOOC and several aspects of social networking and support. Social clouds have striking benefits such as centrality, ease of use, scalability, and ubiquity, providing a superior learning environment when compared to that of a simple physical lab. The proposed model allows students to foster all the educational pillars such as learning to know, learning to be, learning to live together, and, primarily, learning to do, through hands-on IT training from a MOOCs. An aspect of the model has been verified experimentally and statistically through a course of computer operating systems.

Keywords: virtual labs; cloud computing; social cloud; massive open online courses; information technology; virtual desktop infrastructure; bring your own device

1. Introduction

Educational literature invariably reveals new ideas and new technologies when addressing the future of education. Examples of technological advancements most relevant for this study are e-learning, virtual laboratories, virtual realities, virtual worlds, MOOCs, and BYODs. Immersive education integrates many of these ideas together. Many highly reputable institutions, such as the

Immersive Education Initiative [1] and the Immersive Learning Research Network (iLRN) [2], have gathered around the challenging concept of immersive education. E-learning appeared as the first response to challenges resulting from the trend of the increased globalization of education. This inclination meant removing all obstacles that limited access to education, thus making education available to everybody regardless of place, personal disabilities, social status, etc. There have already been significant developments in this direction, as can be seen by the creation of fully Internet-based universities, such as Kaplan University [3] and the University of Hagen [4]. Additionally, there have been some notable successes which are worth mentioning such as the development of MOOCs (Massive Open Online Courses) by MIT [5].

These innovations require the use of new approaches and tools to support collaboration and the creation of new products and technologies online. New platforms that can promote all the educational pillars, such as learning to know, learning to be, learning to live together, and especially learning to do, all performed through hands-on IT training must be included in those new products.

In a recent study [6], Boukil and Ibriz, say: “E-learning uses the Internet and digital content for learning and education activities, that takes full advantage of modern educational technology to provide a new mechanism for communication and a learning environment rich in resources to achieve a new way of learning”, and “One of the most interesting applications of E-learning are virtual labs based on cloud computing”. “A virtual lab is a collection of computing resources, storage and network provided by an educational organization for educational purposes. A virtual lab provides the necessary infrastructure to achieve a classical lab; the resources provided are accessible via the Internet. Therefore, moving from traditional labs to virtual labs is essential”.

Research has shown that hands-on experience in the laboratory plays a central role in education. This is largely due to both its strong impact on student learning outcomes and performance and on its presumed efficacy for professional preparation. However, until recent years, physical, hands-on laboratory experiences were the only experiences available from which these conclusions could be drawn. Lately, data has been found that reveals no significant difference between outcome achievement between a physical, hands-on laboratory experience and a virtual, hands-on laboratory experience. Despite, “there is clearly a need for learning with physical objects at some point, and the key is determining where along the educational process that need lies” [7]. The two methodologies can be considered equally “effective” with regards to outcome achievement [8].

Some universities have difficulties in providing scalable, flexible, and accessible information technology (IT) services to their students in traditional computer labs. There are many limitations such as hours of use, lack of equipment, complicated repair and maintenance, scattered locations of the laboratories, high costs of hardware and software, and contracting personnel for the IT department.

Cloud computing services are influencing face-to-face and online education through their adoption and use [9]. The use of cloud computing services facilitates the implementation of social cloud ecosystems, which allows for sharing and collaboration of all varieties of resources and tools on demand with massive, ubiquitous, and open access [10]. These ecosystems make it easier for universities to recreate e-learning scenarios that are conducive to the teaching of hands-on IT skills, with greater benefits than those provided by physical laboratories, thus allowing universities to concentrate more on teaching and research activities than on the implementation and configuration of complex IT software systems.

The market for e-learning software solutions is extensive. Jane Hart presented a list of 200 of the most popular software tools for learning [11]. E-learning solutions for educational institutions are regularly based on combinations of tools, under the perception that different technologies may be used in order to improve the teaching-learning process.

Most tools have focused approaches, which means that they embrace only specific tasks. For example, tools such as Learning Management System (LMS) and Massive Open Online Courses (MOOCs) support the organization and distribution of resources and activities, while they have yet to embrace social interactions [12]. On the other hand, social networks and cloud computing services have emerged as a result of the generation, collaboration, and sharing of resources and content [13].

In any proposed system, it is essential to promote all the educational pillars, namely, "learn to know", "learn to be", "learn to live together" and especially "learn to do". Using cloud computing services to champion those pillars in a way similar to or better than that which can be received at a university campus laboratory, it is necessary to use a combination of technological tools that promote the pedagogical transmission of knowledge, interaction, collaboration, and hands-on experience.

Technological tools rarely work together flawlessly due to each one having unique user interfaces, individual authentication methods, databases, and repositories. Matters are complicated more by the divergent requirements of hardware and software. The time and effort needed to implement and maintain numerous tools in the classroom may deter teachers from incorporating them into teaching and learning, even when teachers are fully trained in the use of educational technologies and they are available in the classroom. Teachers may fail to incorporate technology into everyday life because of the abundant barriers to using technology, which are some of the most difficult barriers to surmount [14].

When resources and materials are offered through various content distribution tools, they sometimes have to be manually transferred between tools to enable collaborative work.

In this article, we propose a model for implementation of an ecosystem called "social cloud", in order to promote all the educational pillars already mentioned, learn to know, learn to be, learn to live together, and learn to do, through hands-on IT training from MOOCs. Several aspects must be considered in order to accomplish this goal. First, it is necessary to use a combination of technological tools that promote the pedagogical transmission of knowledge, interaction, collaboration, and hands-on experience. Second, some obstacles that limit the access to education must be removed, making education available to everybody regardless of place, personal disabilities, social status, etc.

This ecosystem uses pedagogical and technological tools of three services of cloud computing that were already mentioned:

- Software as a Service (SaaS) uses social networks and apps, such as Google Apps, Dropbox, Onedrive, etc.
- Platform as a Service (PaaS) uses Course Builder [15] under the Google App Engine platform for the publication of MOOCs.
- Infrastructure as a Service (IaaS) uses an Open Universal Desktop Services (OpenUDS) [16] as a virtual desktop infrastructure (VDI), which offers virtual machines with preinstalled software necessary to perform hands-on IT training like one would find in a physical laboratory.

This ecosystem mitigates the inherent barriers to the use of technology, simplifying technological complexity. By doing so, it allows the teacher to focus on the creation and delivery of content, making the student the center of online activities, facilitating new forms of creation, collaboration, and assimilation of content, as well as the possibility of delivering hands-on IT training.

To expose the significance of this article, we have structured it as follows: Section 2 discusses the experiences of other authors and Universities in the use of cloud computing services in implementations that help educators teach practical IT skills. In Section 3, we present a model to implement hands-on IT training by means of a "social cloud" ecosystem, whose infrastructure employs the three services of cloud computing as technological tools. Section 4 presents the methodology as it was applied to an operating systems course at the Faculty of Computer Science and Electronics at a University in Ecuador. Section 5 discusses the results of the training experience. Finally, in Section 6, the conclusions are examined and presented.

2. Literature Reviews

Cloud computing is growing rapidly in almost all sectors, including education. Many educational institutions do not have the capacity to sustain the resources and/or infrastructures needed to run an on-site e-learning system and are looking for cloud-based solutions [17].

Cloud computing is an attractive technology for various disciplines of business and IT. Economies of scale, geographic distribution, open source software, and cost-effective automated systems make cloud computing an attractive choice for education.

We live in a world where information is available anytime, anywhere. We not only have a computer at work and another at home, but we also likely have multiple devices like smartphones and tablets that we carry at all times [18].

Significant advancements in cloud services allow individuals to connect through devices wherever, whenever. Cloud services represent one of the driving forces behind modern computing. This fusion of intelligence and connectivity across a wide range of devices complements the scalable growth of internet services to create a new paradigm based on cloud computing. Such a paradigm would allow educational institutions, often lacking resources, to extract the maximum use of information technology, increasing the quality and accessibility of training, especially in remote areas and rural communities that have internet access [8].

Cloud computing provides on-demand resources and services over a network (usually the Internet). These services are divided into three main types: infrastructure (i.e., virtual machines, servers, and storage devices), platforms (i.e., Course Builder, Moodle, and Edmodo), and software or applications (i.e., Google applications and Office 365).

Many aspects of the use of cloud computing in education have been investigated and studied [19]. With the integration of educational resources and the development of pedagogical systems, cloud computing offers opportunities to improve the quality of education, providing flexibility and accessibility through the Internet [20]. It allows teachers and students to have dynamic and interactive learning experiences coupled with collaboration and communication [21]. In addition, cloud-based services can offer educational institutions cost savings and scalability [22].

Students can take advantage of different learning tools available on the cloud, services such as Google Docs, Office365, and Windows Azure [23]. Students can access the educational resources they need from anywhere and at any time with any device that has internet access. Teachers can experience benefits from the flexibility of cloud platforms, principally the ease of preparing presentations, classes, conferences, articles, etc. Researchers can also benefit from the use of the latest technologies and hardware to perform their experiments [24]. Any project or educational opportunity can be scaled-up through the payment for the use of these services [25].

Developers can design, build, and test applications on cloud service provider platforms. System administrators can take advantage of the processing, storage, and management of databases and other resources available in the cloud.

The use of cloud computing for education has been embraced by many leading IT companies such as Microsoft, Google, Amazon, HP, VMware, and IBM, all of whom have launched initiatives to support educational institutions with the necessary learning tools. Some of these initiatives are free. Here are some educational tools in the cloud:

- Microsoft Education Cloud with Microsoft Live@edu contains website creation, file sharing, word processing, desktop sharing, and resource scheduling.
- Google Education Cloud with Google Apps Education (GAE) contains Google Mail, Google Sites, Google Docs, Google Video, Google Calendar, and Google Talk.
- Earth Browser gives real time weather, geological, and other data.
- VMWare with Virtual Desktop provides virtual computing labs.
- IBM Cloud Academy provides virtual computers with a smart analytics system.
- Apache for Virtual Computing Lab (VCL) [26]. It is a free & open-source cloud computing platform with the primary goal of delivering dedicated, custom compute environments to users.
- Amazon

As mentioned earlier, there are several tools based on cloud services that are available to educational professionals. The most frequently used tools fall into the software model as SaaS services.

However, to achieve practical, hands-on IT training through technology, it is essential to turn to other cloud services, such as IaaS and PaaS.

Cloud computing provides students and teachers with the tools to employ on-demand computing resources for the development of classes and laboratories according to their needs. For example, teachers can create virtual computers on demand with pre-installed software to deploy labs quickly [27]. Some educational institutions are already using cloud computing to outsource email services, collaboration tools, data storage, or hosting Virtual Learning Environments (VLE) [28,29].

Educational institutions, such as colleges and universities, recognize the need for the adoption of new technologies as an academic mainstay. Criteria for the selection of new technologies should include factors such as adaptability, performance, flexibility, and efficiency in the platforms [30].

Despite the flexibility, scalability, and lack of resource demand that cloud computing offers, there is a low adoption rate in pedagogical institutions according to Gartner, which reports only a 4% current use. Another study reveals that 12% of participants are not familiar with cloud computing services, while 88% think cloud computing services for education should be exploited [31].

From the review of the literature, several universities have attempted to implement technological infrastructures for the teaching of practical IT skills. Research work [32] is noteworthy because it describes a remote laboratory, or V-lab, in which teachers can configure virtual machines for students to access remotely for networking practices. In [33], the authors present an elastic net model in R, a virtual machine configured with mathematical tools and statistics that can be shared by other educators.

Hochschule Furtwangen University (HFU) implemented a private cloud platform using all three service models, IaaS, PaaS, and SaaS called CloudIA, which provides its students and the general public with e-Learning services and collaboration. In addition, with CloudIA, students can create and reserve virtual machines on demand for their practices, delivering by default three virtual machines with 1Gb of RAM per student, and a maximum of 100 h per semester [34]. With that in mind, [35] shows the case of a private cloud shared by four universities that allowed for the provision of virtual machines with preconfigured images created on demand by the students in a computer sciences course. In a different contribution, we were able to observe StarHPC, developed by the Massachusetts Institute of Technology (MIT), that proposes virtual machines that can be reused among students in a parallel programming course [36].

One of the most interesting applications of E-learning is virtual labs based on cloud computing [6]. This paper presents an opportunity offered by cloud architecture to support Remote Virtual Labs as a Service that can be viewed as a service in the cloud computing arena (RVLaaS). The authors show how to build a model of RVLaaS and its components in cloud computing.

The Go-Lab Project (Global Online Science Labs for Inquiry Learning at School) is a European collaborative project co-funded by the European Commission. The Go-Lab Project aimed to open up online virtual science laboratories for large-scale use in education. Go-Lab created an infrastructure to provide access to a set of online labs from worldwide renowned research institutions, such as ESA (European Space Agency, The Netherlands), CERN (European Organisation for Nuclear Research, Switzerland), etc. These online labs can be used by universities, schools, instructors and students, in order to extend regular learning activities with scientific experiments [37].

Another work [11] presents a model based on the Virtual Machine on Demand (VMD) tool. This model enables the flexible and efficient use of adapted virtual machines in shared computer labs. It allows the student to utilize their tailored VMs on removable media, and to execute them easily in any computer, automatically adapting to the specific requirements of the computer.

Tlaczala, Zaremba, Zagorski, & Gorghiu, present a project VccSSe (Virtual Community Collaborating Space for Science Education) was a three-year project started in October 2006, as a collaboration between several institutions from the UK, Romania, Spain, Greece, Poland, and Finland. The main purpose of the VccSSe was to adapt, develop, test, implement, and disseminate training modules, teaching methodologies, and pedagogical strategies based on the use of Virtual

Instrumentation in different areas of science (physics, chemistry, biology, etc.) in order to benefit students through the availability of virtual instruments in the classroom.

"LiLa" is the acronym for the "Library of Labs", an initiative of eight universities and three organizations, coordinated by the University of Stuttgart (Germany). The goal of the project was to promote the mutual exchange of and access to virtual laboratories (simulation environments), and remote laboratories. LiLa built a portal which provides access to virtual labs and remote experiments. It also includes additional services such as a tutoring system [38].

In order to satisfy the demands of a global and immersive education, education must be based on the pedagogical pillars of collaboration, practice, and accessibility for everyone from any place using any device (BYOD). Table 1 shows a summary of the experiences of some universities that are experimenting with projects using virtual computer labs and cloud computing services. As shown in Table 1, no design satisfies the requirements of all four educational pillars.

Table 1. Universities' projects of virtual computing labs.

Project	Institution	Learning to Know (Pedagogical)	Learning to Live Together (Colaboration)	Learning to Be (BYOD)	Learning to Do (Hand-On)
V-lab	Fulton School of Engineering	no	no	no	yes
CloudIA	Hochschule Furtwangen University	no	no	no	yes
Go-Lab	University of Twente (The Netherlands)	no	yes	no	yes
VccSSe	UK, Romania, Spain, Greece, Poland, and Finland Universities	yes	yes	no	yes
LiLa	University of Stutgart Germany	no	yes	no	yes
StarHPC	Massachusetts Institute of Technology	no	no	no	yes
RVLaaS	University Sidi Mohamed Ben Abdellah	no	no	no	yes
VDM	University of Seville	no	no	no	yes

Institutions must take into account how these new technologies will be integrated with existing programs, pedagogical models, learning styles, and the schedules of the participants.

Many educational institutions have adopted online technologies so well that they have eliminated the need for a physical classroom, turning them into online institutions.

3. Model and Technological Framework

3.1. Model to Implement Virtual Computing Labs in a MOOC via Cloud Computing Services

In this section, we propose a model to implement virtual labs to teach practical hands-on IT skills, which, supported by a technological framework, encompasses the trends in education and mitigates the problems detected in other models and implementations.

The model is based on the principles of instructional design [39,40]. It prioritizes task-based education and problem solving in direct relation to the pillars of education [41], "learning to know", "learning to do", "learning to live together", and "learning to be". This is based on technological frameworks, which use the three cloud computing services, software as a service, platform as a service, and infrastructure as a service (Figure 1).

The educational pillar "learning to know" is recognized as providing the contents, concepts, procedures, and skills that the participant must acquire. It is established by demonstration as an instructive principle and uses the cloud computing models Software as a Service and Platform as a Service for the formal publication of resources such as videos, files, slides, and e-books. Google Course Builder is used under the Google App Engine platform. The platform allows the designer to arrange the courses into lessons, activities, and evaluations. Additionally, it offers the option of integrating other cloud services.

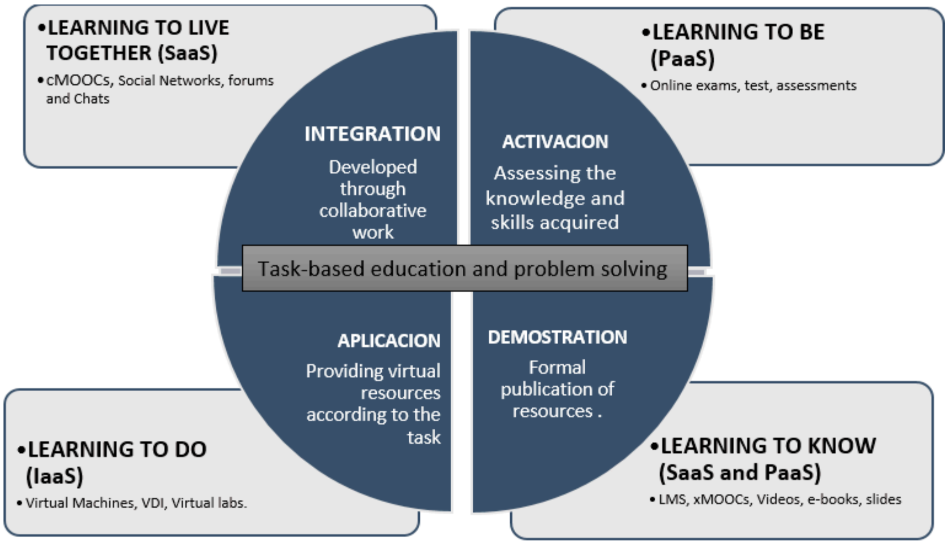

Figure 1. Model to teaching practical Information Technology (IT) skills.

The learning pillar "learning to do" is established by providing virtual resources according to the task that the participant wishes to learn. It is supported by the application or practice of the learned tasks as an instructive principle and uses the cloud computing model Infrastructure as a Service (IaaS). Virtual desktop services (VDI) offered by OpenUDS [16] are used, which act as a traffic manager, allowing or denying access to resources according to what has been defined by the administrator.

The educational pillar "learning to live together" is developed through collaborative work and through social networks, forums, and chats. It is sustained through integration as an instructive principle and uses the cloud computing model Software as a Service (SaaS) and incorporates the use of Facebook, Twitter, Dropbox, apps, and other social networks.

The learning pillar "learning to be" is established by assessing the knowledge and skills acquired by the participants. It is supported through activation as an instructive principle, and uses the cloud computing model called Platform as a Service (PaaS), reinforced by published resources such as online exams, tests, and assessments. Course Builder is also used as a platform.

3.2. Technological Framework to Implement Virtual Labs in MOOCs

The following is a description of an example of a design and architecture of the infrastructure of a cloud service implemented using OpenUDS. OpenUDS has several components, the most important are as follows.

- Connection broker,
- MySQL database,
- LDAP authentication service,
- Tunneling,
- Virtual desktop services with oVirt.

All these services were consumed from the institutional intranet or the internet through MOOCs and implemented using the open source platform for online education called Google Course Builder, which was hosted in the Google App Engine cloud (Figure 2).

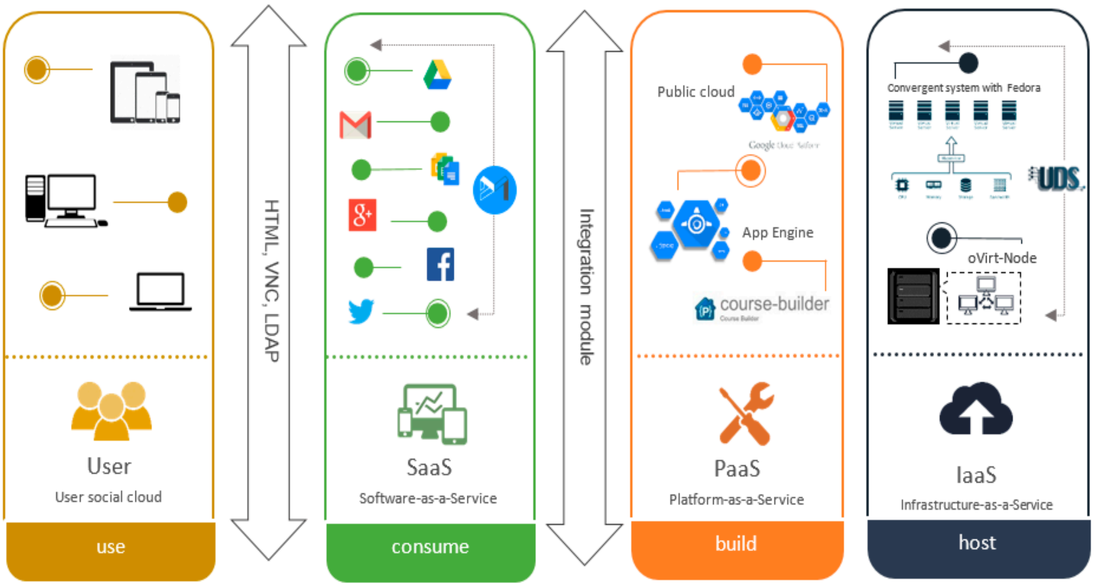

Figure 2. Design and architecture of the infrastructure of a social cloud.

Two physical servers were used for the deployment of OpenUDS. The first was a 64-bit Linux Fedora Server with an operating system that virtualizes all components and services for the operation of OpenUDS, using the complete virtualization offered by KVM/QUEMU. On the second server, version 3.0.4 oVirt-node operating system with 64-bit architecture was installed as a separate physical server to handle the amount of memory, processing, and network required when allocating resources to virtual machines for the stable and scalable operation of virtual desktop infrastructures (VDI). The diagram in Figure 3 shows the architecture used in the OpenUDS deployment and all of its services.

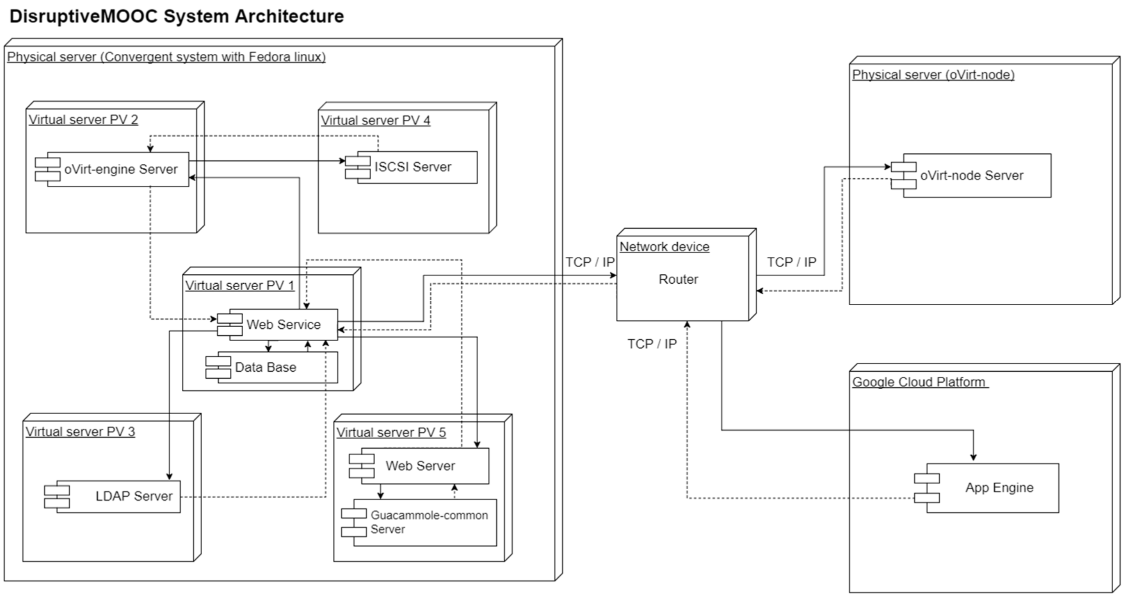

Figure 3. Architecture used in the OpenUDS and all its services.

The first server hosted several virtual machines, which provided the necessary services for the operation of the infrastructure. The servers are as follows:

Virtual Server PV1 uses the Debian operating system version 8, and can be used as a connection broker for the administration and deployment of virtual desktops. The components that make up the connection broker are a web service in Apache that provides a front-end for the use of OpenUDS services, the MySQL service as an internal management database for the connection broker, the UDS Actor that facilitates interaction between the connection broker and a virtual desktop, and the task manager daemon that allows for the graphical administration of OpenUDS resources.

Virtual Server PV2 is a virtualized server with CentOS version 6.8 64-bit operating system and oVirt-engine version 3.4. It is responsible for providing resources through oVirt-node to virtual machines or nodes. It also handles the allocation of free shared network storage (FreeNAS).

Virtual Server PV3 is a virtualized server with operating system Centos 6.8 with LDAP service for the centralized authentication of the social cloud ecosystem.

Virtual Server PV4 is a virtualized server with operating system FreeNAS 9.10, which is responsible for storage management to be used by the virtual machines throughout the network under the ISCSI protocol.

Virtual Server 5 is a virtualized server with the Debian 8 operating system that acts as a tunneler for access to the services provided by OpenUDS through html5 and supported by Guacamole-Common sub-systems available on the Guacamole web server.

All the infrastructure explained here was employed by MOOCs, developed with the platform of Course Builder with version 1.10, from Google, which in turn was able to be integrated with Google tools like Docs, Hangouts, Calendar, Drive, Groups, and others. Course Builder was customized using the Django framework and Python programming language.

4. Participants and Methodology

To validate the use of social clouds for teaching practical IT skills, a methodology was followed that considers the following phases: (i) The research question and hypothesis was proposed; (ii) The social cloud ecosystem was implemented through cloud computing services, SaaS, PaaS, and IaaS; (iii) The ecosystem is used through a collegiate course in Operating Systems corresponding to the fifth semester of the systems engineering degree studies at the Polytechnic School of Chimborazo (October 2016–March 2017); (iv) Results are obtained; (v) The conclusions are presented.

With the purpose of evaluating our proposed model, the following research question and hypothesis was proposed:

> "Is it possible to provide a superior educational environment via e-learning to that of a basic physical lab by using all of the computing capabilities of cloud services while satisfying all the pillars of education?"

Hypothesis 1. *(H1) Educational pillars differ when IT is taught via a social cloud ecosystem to that of a basic physical lab.*

Hypothesis 2. *(H2) Educational pillars are similar when IT is taught via a social cloud ecosystem to that of a basic physical lab.*

The training program was based on the four cyclical phases of IT projects, (1) Planning; (2) Implementation; (3) Administration; and (4) Maintenance. For each of these stages, general tasks were assigned, as shown in Figure 4.

The following tasks are located at the vanguard:

- Explanation and identification of technologies.
- Planning and designing solutions.
- Installation, configuration, and upgrade of technologies.
- Administration and operation of technologies.
- Problem resolution.
- Repair and replacement of solutions.

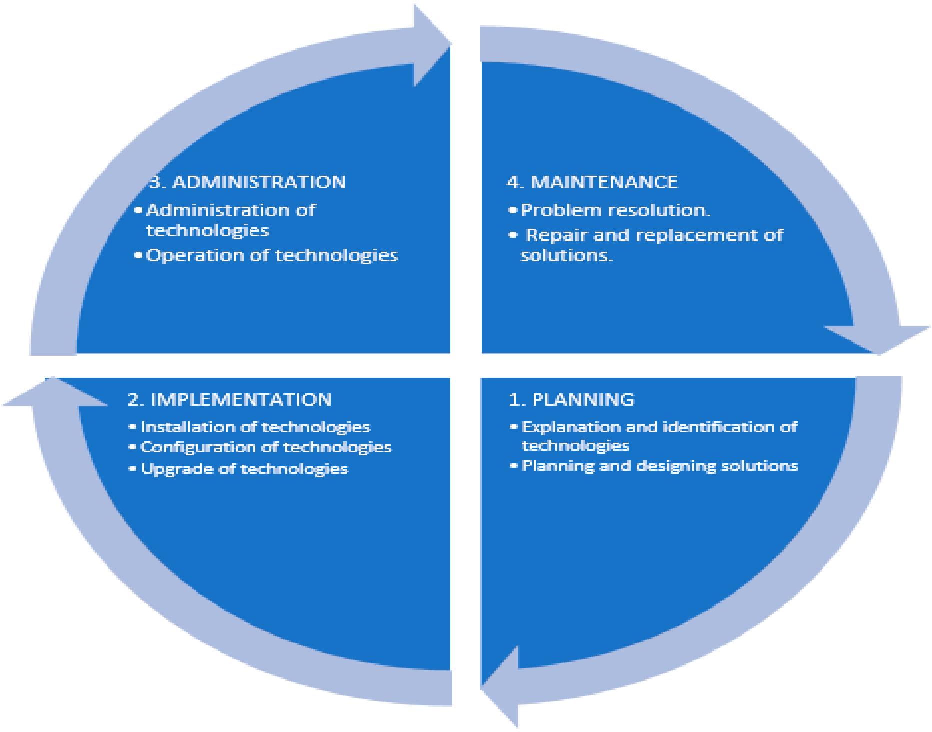

Figure 4. Four cyclical phases of IT projects.

For each of these tasks, 17 Activities which the participant had to resolve through the diverse operating systems were introduced. Each consecutive activity had a virtual machine attached that is deployed as the course progressed.

If a participant wanted to study a different module out of order, he had to take an activation test to be permitted to complete the non-sequential module. Once passing the test, the student had access to activities and, by extension, to virtual resources as shown in Figure 5. Figure 6 shows the MOOC interface.

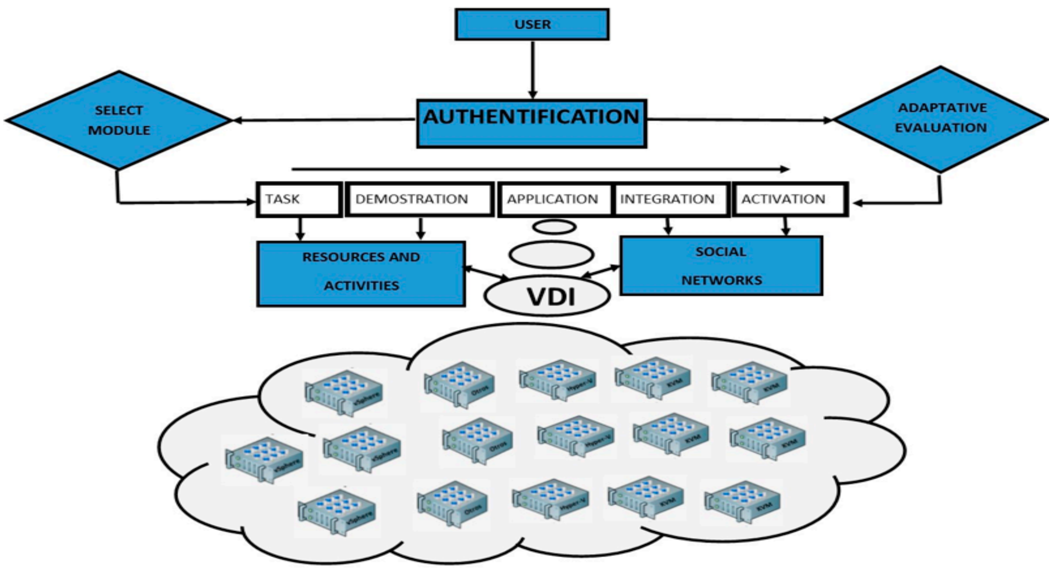

Figure 5. The course progressed.

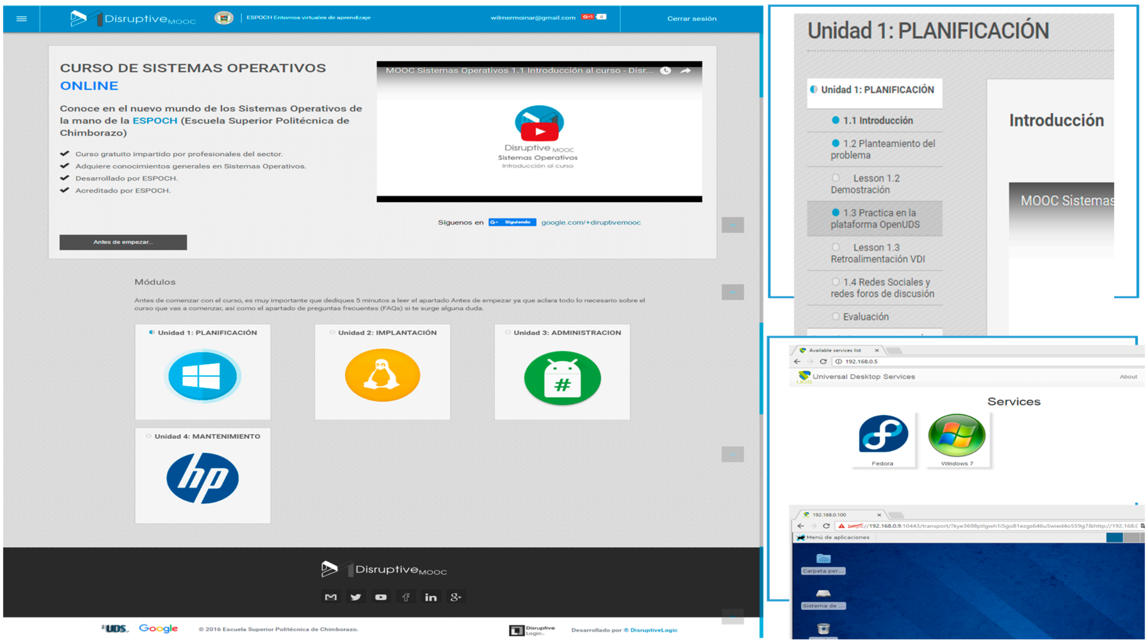

Figure 6. Massive open online courses interface.

5. Results

Hypothesis 1 (H1), *Educational pillars differ when IT is taught via a social cloud ecosystem to that of a basic physical lab*, was verified with the following examination. Of the 78 students who were trained on the social cloud ecosystem, 27 students were selected that had the same study conditions as another sample of 27 students who were trained in a traditional way through the use of a physical laboratory of the institution. The results of the two groups could then be compared. The training was performed in the subject of operating systems during the period of September 2016–March 2017.

After verifying the normality of the data by applying the student's t-statistic with an error level of 5%, the four educational pillars were evaluated.

"Learning to know." The academic results of the two samples were compared and the results indicated an absolute value of the student's *t*-test statistic of 4.38, significantly higher than the critical value 2.05 from the two groups. Therefore, it can be asserted that there is indeed a difference in this educational pillar when teaching via the social cloud ecosystem proposed as compared to a physical computer laboratory. Therefore, H0 is rejected and the alternative hypothesis H1, is accepted.

Similar analysis were performed with the educational pillar "learning to be", where we compared the number of completed activities out of a total of 17. The statistical values are shown in Table 2, with similar conclusions.

Table 2. Statistical analysis.

Educational Pillar		Statistical Test	Critical Value with $\alpha = 0.05$	Calculated Value	Relation
Learning to Know	Learning outcomes	*t*-test	2.05 two tailed	$\lvert -4.38 \rvert$	4.38 > 2.05
Learning to Be	Behavior	*t*-test	2.05 two tailed	$\lvert -2.43 \rvert$	2.43 > 2.05
Learning to Do	Survey	Chi squared	40.10	119.84	119.84 > 40.10
Learning to live Together	Learning style	*t*-test	2.05 two tailed	Active $\lvert -3.70 \rvert$	3.70 > 2.05
				Reflexive $\lvert -2.21 \rvert$	2.20 > 2.05
				Theoretical $\lvert -2.62 \rvert$	2.62 > 2.05
				Pragmatic $\lvert -2.60 \rvert$	2.60 > 2.05

In order to ensure the participants were able to "learn to live together", the learning styles were evaluated using the Honey-Alonso CHAEA questionnaire [42,43]. The questionnaire consisted of 80 statements evaluated on a dichotomous scale of agreement and disagreement, which provided information on the dominance of a defined learning style, such as reflective, theoretical, active, or pragmatic, through the number of positive responses. The CHAEA test, according to its authors, is a satisfactory instrument for the diagnosis of learning preferences of each student. We compared the learning styles in the two samples. The result confirmed a student's *t*-test absolute value as higher than the critical value 2.055 of the two groups across all learning styles. Consequently, it can be attested that there is clear difference related to the educational pillar "learning to live together" when teaching through the social cloud ecosystems as opposed to teaching in a physical computer laboratory, as shown in Figure 7. Therefore, H2 is rejected and the alternative hypothesis, H1, is accepted. The statistical values are also shown in Table 2.

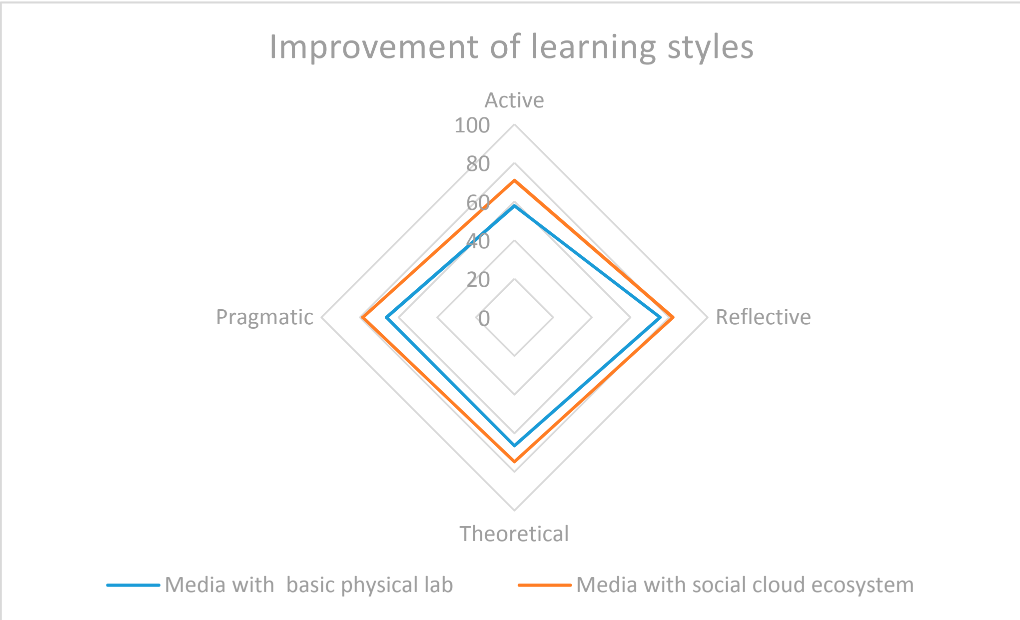

Figure 7. Improvement of learning styles.

As can be seen in Table 3 from the three educational pillars, the mean is higher when the proposed ecosystem is used. Therefore, we can affirm that social clouds provide a superior learning environment to that of a basic physical lab.

Table 3. Student's *t*-test analysis.

Educational Pillar		**Media with Basic Physical Lab**	**Media with Social Cloud Ecosystem**	**Calculated Value**	**Relation**
Learning to Know	Learning outcomes	5.66	6.89	$\lvert -4.38 \rvert$	4.38 > 2.05
Learning to Be	Behavior	16.03	16.88	$\lvert -2.43 \rvert$	2.43 > 2.05
Learning to live Together	Active	57.77	70.92	3.70	3.70 > 2.05
	Reflective	75.37	82.03	2.21	2.21 > 2.05
	Theoretical	66.48	74.81	2.62	2.62 > 2.05
	Pragmatic	66.29	78.51	2.60	2.60 > 2.05

For the indicator that corresponds to the educational pillar "learning to do", another survey was used. The suvey was assessed using a Likert scale and the Chi-square statistical method was applied, resulting in a critical value with an error level of 5% of 40.10. The calculated value was 119.84.

Therefore, H2 is rejected and the alternative hypothesis, H1, is accepted. From the perspective of the students, the results indicate that the proposed model, in reality, improves the practical abilities of the students.

6. Discussion and Conclusions

The principal value of this paper is that it analyzes several computing aptitudes within SaaS, PaaS, and IaaS cloud services, aspects of cloud learning (MOOC), and aspects of social networking and support that indicate a superior learning environment to that of a basic physical lab.

The student is able to interact in a centralized, simple, and ubiquitous way, and directly through a MOOC platform developed with Course Builder. From there, he can access other software services such as social networks and virtual desktop infrastructures (VDI) implemented through OpenUDS, which offers virtual machines to perform IT training similar to the hands-on practice in a physical computing lab.

The execution of this project was divided between two physical servers. The first provided virtual desktop services with OpenUDS and the second generated instances of virtual machines on oVirt. The massification and scaling required were able to be achieved by increasing the number of physical servers as more services or more virtual machines were needed. In addition, thanks to the MOOCs being deployed under the Google App Engine platform, they also were able to scale massively, generating a hybrid cloud model between private and public services.

OpenUDS was not only able to deliver virtual desktops but was also able to deliver the virtualization of applications and the consolidation of the virtual desktop services necessary for the delivery of other services useful for teaching IT.

Once the ecosystem was implemented for training practical IT skills, all the technological complexity of the infrastructure was transparent to the students, who were able to interact directly with the MOOC from their own computers or intelligent devices.

The ecosystem was implemented by integrating open source software such as Linux and FreeNAS operating systems, web services such as Apache Guacamole, OpenUDS, Course Builder, and MySQL, all through a unique LDAP authentication.

Based on the statistical analysis, it has been demonstrated that by using the model mentioned in this research work and a technological framework, the students are able to foster all of the educational pillars such as learning to know, learning to be, learning to live together, and, primarily, learning to do, through hands-on IT training from a MOOCs.

Although cloud computing services have many advantages, it is clear that migration to the cloud is not an easy task. Educational institutions face several challenges that hinder its adoption. Through this contribution, we have shown ways to mitigate some technologically related impediments.

A future research project could focus on an adoption study and user experience analysis in the massive use of these ecosystems.

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