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CLOUD COMPUTING AND E-LEARNING (COMPUTER NETWORK LABORATORIES FOR CURRICULUM DEVELOPMENT IN CLOUD COMPUTING)

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Abstract: *This work demonstrates that the use of laboratories for the development of curricular work in the area of information technology exclusively supported by cloud computing technology does not decrease the level of learning and assessment objectives on the part of students. This scenario arose due to the need to interrupt face-to-face classes in physical laboratories due to the COVID-19 Pandemic.*

Keywords: Cloud Computing; Azure; Distance learning; WEB App, Virtual Labs.

INTRODUCTION

In common language Cloud Computing (CC) is a set of computational resources made available to a set of users, remotely, taking the form of services. And like any service today, electricity, water, gas, etc., are always available for both individual and business use. This is possible because throughout the second half of the 20th century, the technological industry adopted a set of standard models from different sources and technological platforms. CN works as a universal, paid service, but always available to users/customers who need it, in the same way that they have the electricity service. The main principle that supports this technology and this model is the provision of computing, storage and software as a service. Cloud is a distributed and parallel computing system, consisting of a collection of virtualized and interconnected computers that are presented as a set of dynamic and unified resources, based on the Service Level Agreement (SLA) established between the service provider and the end customer. Due to the crisis caused by the pandemic of COVID-19, almost all universities had to change the model of classroom classes to a model of distance classes. The paradigm is radically different. In certain scientific and technical areas, the transition was easier, however in the case of laboratory classes the process became more complex or even impossible. In the specific case of computer network laboratories in which they were based on computers and servers installed on universities on-premise infrastructures, the process was almost impossible and these laboratory classes had to be postponed, or complex processes had to be created so that students could go to the labs. What we intend with this work is to develop a demonstration of a model that can allow to simulate the teaching of the development and operation of computer networks through a laboratory created by the teacher in a Cloud Computing system, in this case at Azure.

The main objective of this work is to verify whether the use of cloud computing laboratories (in this case in Azure) for curriculum development as a substitution for physical laboratories on university campuses, due to the mandatory interruption of classroom classes in the context of COVID-19, had an impact in learning on school success, as manifested in assessments. This study is contextualised in the area of informatics and involved MA-level students in Computer Science.

1. FUNDAMENTALS OF CLOUD COMPUTING

1.1. Definitions

The term cloud computing (CC) has become somewhat of a sensational term, almost everyone in the industry has its own definition of CN, in this paper we adopted the definition of CC adopted by *National Institute of Technology and Standard*s (NIST) (NIST, 2020): "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics (On-demand self-service, Broad network access, Resource pooling, Rapid elasticity, Measured Service); three service models (Cloud Software as a Service (SaaS), Cloud Platform as a Service (PaaS), Cloud Infrastructure as a Service (IaaS)); and, four deployment models (Private cloud, Community cloud, Public cloud, Hybrid cloud). Key enabling technologies include fast wide-area networks, powerful, inexpensive server computers, and high-performance virtualization for commodity hardware. The Cloud Computing model offers the promise of massive cost savings combined with increased IT agility. It is considered critical that government and industry begin adoption of this technology in response to difficult economic constraints. However, cloud computing technology challenges many traditional approaches to datacenter and enterprise application design and management. Cloud computing is currently being used; however, security, interoperability, and portability are cited as major barriers to broader adoption. The long-term goal is to provide thought leadership and guidance around the cloud computing paradigm to catalyze its use within industry and government. NIST aims to shorten the adoption cycle, which will enable near-term cost savings and increased ability to quickly create and deploy enterprise applications. NIST aims to foster cloud computing systems and practices that support interoperability, portability, and security requirements that are appropriate and achievable for important usage scenarios" (MELL T, 2011).

In common language, Cloud Computing (CC) is a set of computational resources made available to a set of users, remotely, taking the form of services. And like any service today, electricity, water, gas, etc., are always available for both individual and business use. This is possible since throughout the second half of the 20th century, the technological industry adopted a set of standard models from different sources and technological platforms. CC works as a universal, paid service, but always available to users/customers who need it, in the same way that they have access to power supply. However, CC is a term that has many meanings, but an effort has been made in the last ten years to establish common denominators in these meanings, in order to create a more objective definition. This effort has mainly been made through the publications of the Information Technology Infrastructure Library (ITIL), which is a library of good practices to be applied in infrastructures, operations and maintenance of information technology services, having been developed by the Central Computer and Telecommunications Agency (CCTA), today under the Office for Government Commerce (OGC) in England. In the most generic form, and following the ITIL concept, a service is a relationship between a consumer and a provider, in which the provider makes available and delivers to the consumer a value (service) and the consumer avoids the risks and investments in providing it this value (service) itself, currently the CC is also inserted in this context. For example, the simple storage and database management services of a commercial store on the Web, if they are using the CC, are always available to the store owner, as well as to his customers, without the said owner having to worry about maintaining those services, and don't have to bear the investment risks of purchasing a complex platform. If the business does not go well, it simply cancels the services, having had no losses associated with the investment of technological fixed assets (CSIAC, 2020).

The term CC is recent, but the concept and idea go back to the 60s and 70s of the 20th century, when computing was very localised and exceptionally expensive. The concept of CC appears as a result of another concept that was called time-sharing, and which implied a sharing by several entities, at different times, the same computing equipment. However, today, there are substantial differences between the concept of computational time-sharing and CC. At the time of computational time-sharing, the services or machines that held them could only be used by one operator at a time, that is, they were divided into portions of time and not portions of accommodation space; today the question of time sharing does not exist, it pays according to the service that is obtained or the space that the information occupies, but not according to the time that this resource is being used. But the basic idea is very similar, it is to provide a computing service remotely and not locally. Using simple and daily concepts by analogy, we can say that both the computational time-sharing system and the CC system can be seen as a service that is made available in the same way as electricity or water, that is, they are available when we need them , we pay for that availability and for its use, e.g. if we use Office 365 we pay for its use, as when we consume electricity, but we can also pay for the accommodation of the documents produced by it, as we pay if we want to have a storage system for backup power (CSIAC, 2020).

1.2. Main characteristics of cloud computing technology

In on-demand self-service services, a consumer can unilaterally provision computing resources, such as server time and storage network, as needed automatically, without requiring human interaction with each service provider.

Wide network access, resources are available on the network and accessible through standard mechanisms that promote use by thin or thick heterogeneous client platforms (e.g. cell phones, tablets, laptops, and workstations).

Pooled resources, the provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to the consumer's requirements. There is a sense of location independence, as the customer generally has no control or knowledge about the exact location of the resources provided, but may be able to specify the location at a higher level of abstraction (for example, country, state or data centre). Examples of resources include storage, processing, memory and network bandwidth (SOUNDARJAN, 2015).

Fast elasticity, resources can be provisioned elastically and made available, in some cases automatically, to quickly scale out and in, according to needs. To the consumer, the resources available for provisioning generally appear to be unlimited and can be appropriated in any quantity and at any time.

Services with metrics, cloud systems automatically control and optimize the use of resources, leveraging a metering resource at levels of abstraction appropriate to the types of services (for example, storage, processing, bandwidth and active user accounts). The use of resources can be monitored, controlled and reported, providing transparency to the provider and the consumer of the services used (BRANDAO, 2019).

1.3. Service Model

Currently, cloud computing technology has three service models (cf. Figure 1):

Infrastructure as a Service (IaaS), the user can implement and execute software arbitrarily, which can include operating systems and applications. The user does not administer or control the underlying cloud infrastructure, but has control over operating systems, storage, deployed applications and limited control over some network components, for example, host firewalls. The services offered by this delivery model include: hosting servers, Web servers, storage, computing hardware, operating systems, virtual instances, load balancing, Internet access and bandwidth provisioning.

Platform as a Service (PaaS), allows a cloud user to implement a product created or purchased by the consumer as applications using programming languages and tools supported by the service provider. The user: has control over the implemented applications and, possibly, the settings of the hosting environment of the same. It does not administer or control the underlying cloud infrastructure, including network, servers, operating systems or storage. It is not particularly useful when: the application must be portable; proprietary programming languages are used; hardware and software must be customized to improve application performance (CARLYLE, 2016).

Software as a Service, applications are provided by the service provider. The user does not administer or control the underlying cloud infrastructure or the resources of individual applications. Services offered include business services, such as workflow management, groupware and collaboration, supply chain, communications, digital signature, customer relationship management (CRM), desktop software, financial, geospatial and research management. Web 2.0 applications, such as: metadata management, social networks, blogs, wiki services and portal services. It is not suitable for real-time applications or for those where data cannot be hosted externally. Examples: Office 365, Salesforce.com, Gmail (VOORSLUYS, 2011).

1.4. Implementation Models

There are four models for implementing cloud computing technology:
Private Cloud, the cloud infrastructure is provisioned for exclusive use by a single organisation, composed of several consumers (for example, business units). It can be owned, managed and operated by the organization, third parties or a combination of them, and it can exist on or off the premises (ARMBRUST, 2009).
Community Cloud, the cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that share concerns (for example, mission, security requirements, policy and compliance considerations). It can be owned, managed and operated by one or more community organizations, by third parties or a combination of them, and it can exist on or off the premises (PAGE, 2012).
Public cloud, the cloud infrastructure is provisioned for open use by the general public. It may be owned, administered and operated by a company, academic or governmental organization, or some combination thereof. It exists on the premises of the cloud provider.
Hybrid Cloud, the cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community or public) that remain unique entities, but are united by standardized or proprietary technology that allows the portability of data and applications (for example, cloud augmentation for load balancing between clouds).

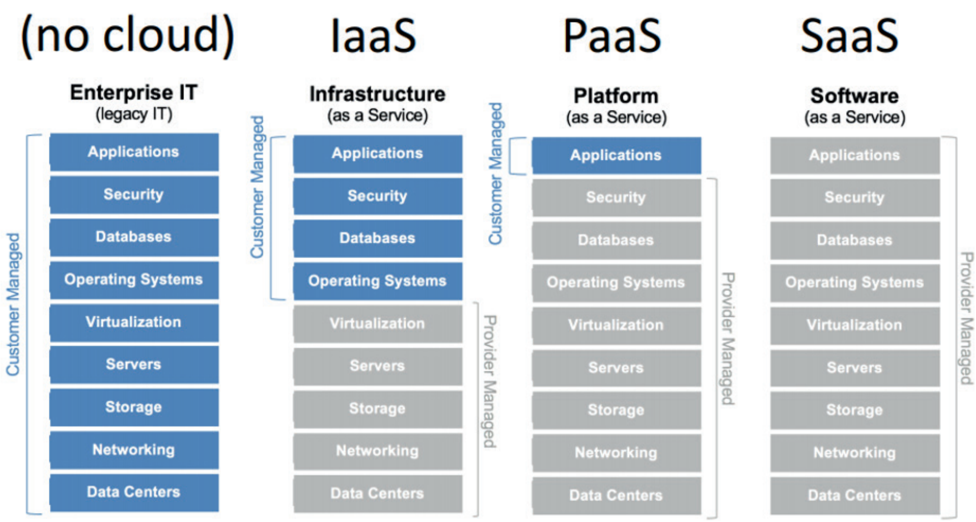

Figure 1. Models of Cloud Computing Services

Source: Own work.

2. LABORATORY TO TEACH HOW TO CREATE A WEB APP

The plan for creating a WEB App follows the exact indications advised by Microsoft in its teaching plan for the development of these solutions in azure (https://docs.microsoft.com/en-us/learn/modules/host-a-web-app-with-azure-app-service/3-exercise-create-a-web-app-in-the-azure-portal?pivots=csharp).

If you want building a website for a new business, or you're running an existing web app on an aging on-premises server. Setting up a new server can be challenging. You need appropriate hardware, likely a server-level operating system, and a web hosting stack. Hosting your web application using Azure App Service makes deploying and managing a web app much easier when compared to managing a physical server. In this module, we'll implement and deploy a web app to App Service.

Learning objectives: Use the Azure portal to create an Azure App Service web app; use developer tools to create the code for a starter web application; deploy your code to App Service.

Using the Azure portal, you can easily add deployment slots to an App Service web app. For instance, you can create a staging deployment slot where you can push your code to test on Azure. Once you are happy with your code, you can easily swap the staging deployment slot with the production slot. You do all this with a few simple mouse clicks in the Azure portal.

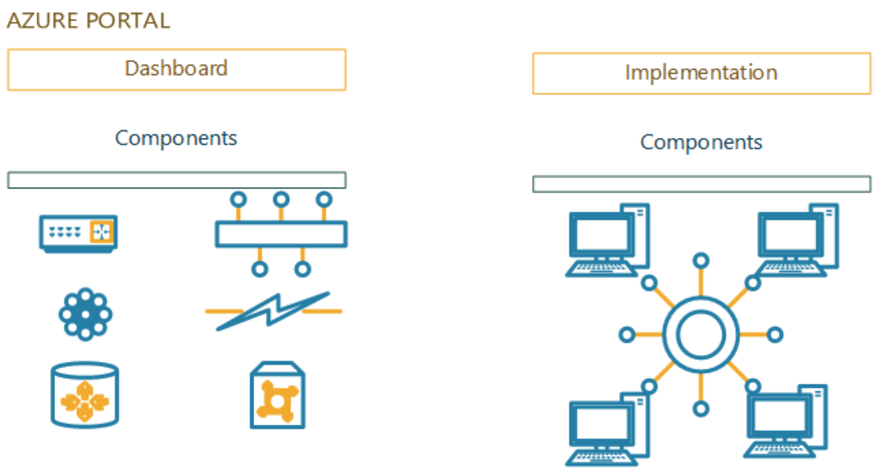

Figure 2. Azure Portal

Source: Own work.

When you're ready to run a web app on Azure, you visit the Azure portal and create a Web App resource. Creating a web app allocates a set of hosting resources in App Service, which you can use to host any web-based application that is supported by Azure, whether it be ASP.NET Core, Node.js, Java, Python, etc.

If you are deploying your app as code, many of the available runtime stacks are limited to one operating system or the other. After choosing a runtime stack, the toggle will indicate whether you have a choice of operating system. If your target runtime stack is available on both operating systems, select the one that you use to develop and test your application. If your application is packaged as a Docker image, choose the operating system on which your image is designed to run. Selecting Windows activates the Monitoring tab, where you have the option to enable Application Insights. Enabling this feature will configure your app to automatically send detailed performance telemetry to the Application Insights monitoring service without requiring any changes to your code. Application Insights can be used from Linux-hosted apps as well, but this turnkey, no-code option is only available on Windows. An App Service plan is a set of virtual server resources that run App Service apps. A plan's size (sometimes referred to as its sku or pricing tier) determines the performance characteristics of the virtual servers that run the apps assigned to the plan and the App Service features that those apps have access to. Every App Service web app you create must be assigned to a single App Service plan that runs it. A single App Service plan can host multiple App Service web apps. In most cases, the number of apps you can run on a single plan will be limited by the performance characteristics of the apps and the resource limitations of the plan. App Service plans are the unit of billing for App Service. The size of each App Service plan in your subscription, in addition to the bandwidth resources used by the apps deployed to those plans, determines the price that you pay. The number of web apps deployed to your App Service plans has no effect on your bill.

You can use any of the available Azure management tools to create an App Service plan. When you create a web app via the Azure portal, the wizard will help you to create a new plan at the same time if you don't already have one. The Azure Portal provides a wizard to create the solution with the following options: subscription, resource group, App name, publish, runtime stack, operating system, region and App service plan. To create the WEB App, the following steps must be followed (Figured 2):

On the Azure portal menu or from the Home page, select Create a resource. Everything you create on Azure is a resource. The portal navigates you to the Marketplace page. From here, you can search for the resource you want to create or select one of the popular resources that people create in the Azure portal. Select Web > Web App to display the web app creation wizard. Fill out the wizard with the following values: Subscription (Concierge), Resource Group (Sandbox resource group), Name (enter a unique name), Publish (Code), Runtime stack (.NET Core 3.1 – LTS), Operating System (Linux), Region(chose the close to you), Sku and Size (F1). Then select Review and Create.

3. THE RESEARCH METHODS

The main techniques and tools used for gathering research data include quantitative techniques:

3.1. Observation

That involved counting the number of times that a specific event occurred or encoding observational data to translate them into numbers. In this case, the difficulties in completing the laboratories requested for the evaluation.

3.2. Screening of assessment documents

Obtaining numerical data from the evaluation forms and counting of unrealized events that were considered mandatory objectives for evaluation.

3.3. Comparative experimentation

Testing hypotheses in laboratories, testing cause and effect relationships, through experience in the development of network laboratories, comparing the results in terms of performance between laboratories developed in person before the COVID-19 crisis and the performance in the development of network labs in a 100% cloud computing environment .

4. THE ANALYSIS

The investigation focused on the analysis of the results of school progress, including the final assessment of 21 students in a master's degree course in Informatics.

These are students of the first year of the Master's. The contextual situations were compared in relation to two Curricular Units in which both needed laboratory development in the same scientific technical area.

One of the Curricular Units, Digital Systems Architecture, from the first semester, that is, from a pre-COVID-19 period. In this period the laboratory work was in person, that is, in the laboratories of the University. The other Curricular Unit was Private Cloud Computing, already developed in the period of COVID-19, without face-to-face classes. It is important to consider that our University closed all face-to-face classes at the beginning of March, unlike many other countries, Portugal was one of the first countries to close schools and Universities, the law of university autonomy in Portugal allows University Directors to establish autonomous contingency plans, this is what happened at our institution.

In the confinement phase, students only took online classes, asynchronous classes were taught by Google Classroom, synchronous classes by Google Meet, with the exception of master's that in terms of synchronous classes used CISCO WEBEX, which was also the case for this class. In the case of this master's degree in computer science, the part of technological laboratories migrated entirely to Microsoft Azure. The laboratories developed by this class were all inserted in the area of computational infrastructure.

Analysing the evolution of the Curricular Unit of the first semester, Digital Systems Architecture, it was found that the average of the evaluations obtained was 16 values (on a scale from 0 to 20), it was also found that the standard deviation was 2.718 (cf. Figure 3).

Laboratory work in the first semester was only completed in the last week of that semester. Not all students were able to finish the laboratories on time, mainly because they were student workers and did not have the necessary time to dedicate to the face-to-face laboratories, as well as the fact that they had to miss classes for different reasons. The teacher had to extend classes for over a week for everyone to finish their work.

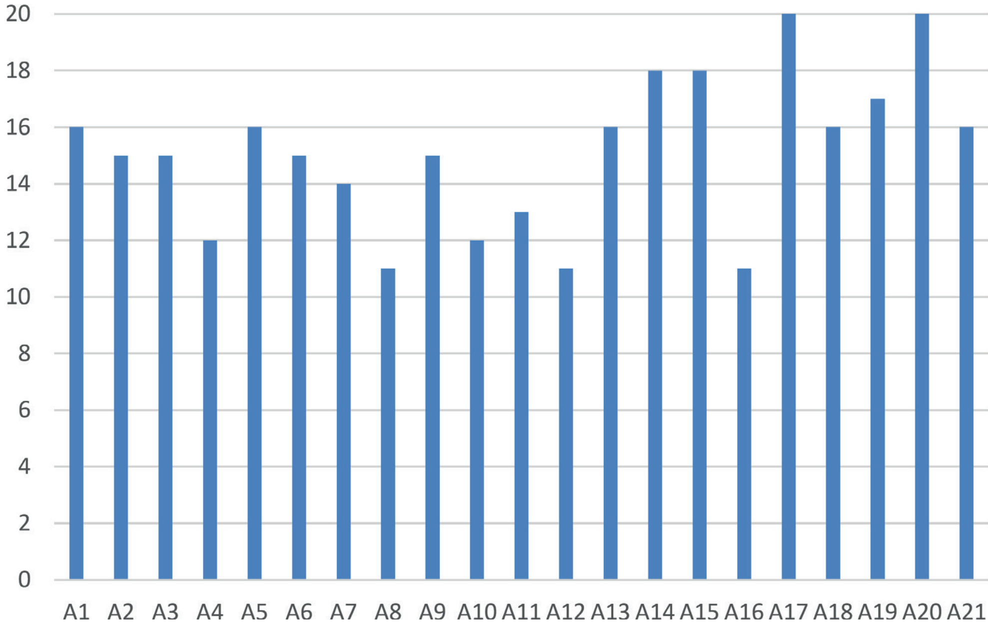

Figure 3. Result of the final evaluation of Private Cloud Computing – Pre-COVID-19 – (the vertical axis represents the assessments and the horizontal axis represents the students)

Source: Own work.

On the other hand, the Private Cloud Computing Course Unit, was taught in the confinement period of COVID-19, all took place in Distance Learning, that is, online, the curriculum development works in the laboratory were all installed in Microsoft Azure infrastructure.

The results obtained from the analysis to the evaluation and performance of the students were truly superior in relation to what had happened in the first semester, and very specific in relation to the other similar Curricular Unit.

The average of the final evaluation was 18 values, and the standard deviation was 1.590 (cf. Figure 4). This is a significantly higher average (the fact that the general population and students were experiencing a period of enormous emotional stress, which did not occur in the first semester) should be considered here, but even so they obtained higher ratings. Another aspect to note is the differences in standard deviation between the two scenarios. The standard deviation of the second semester assessment is lower, which indicates that the general consolidation of objectives and learning, in addition to being more elevated, are more consistent and there were more students who improved their performance.

It was also found that all students finished laboratory work before the deadlines with less doubts about the contents to be developed.

This is not a quantitative aspect, but I consider it relevant and relevant, it is the opinion expressed by all students that the fact that the laboratories are in cloud comput-

ing allowed them to work at any time and repeat the tests and learning in a simpler way. Being able to easily review all the work.
In technical terms, these labs also allowed students to reset any development errors as they are using virtual machines that, due to their characteristics, allow easy to create reverse images.

5. ADVANTAGES OF CLOUD-BASED E-LEARNING

We believe that there are many advantages in laboratory teaching based on Cloud Computing for certain technical-scientific areas of Computer Sciences (RIAHI, 2015), we also recognize that this model does not adapt so well to other areas.
However, some advantages of Cloud based E-Learning should be summarized:
Low cost, E-learning computer users need not configure up for E-Learning applications. They can cloud applications via PC, mobile phone, tablet with Internet connection to run with minimal configuration (MASKARADE, 2014).

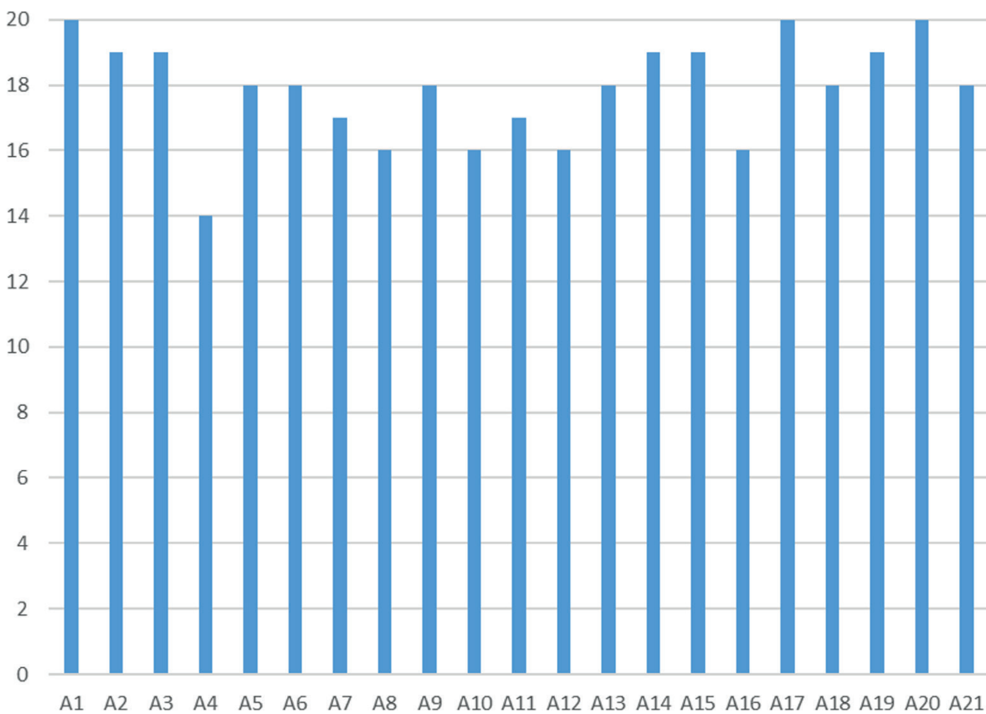

Figure 4. Result of the final evaluation of Digital Systems Architecture – confinement – COVID-19 – (the vertical axis represents the assessments and the horizontal axis represents the students)

Source: Own work.

Improve performance, since cloud-based applications for E-Learning runs with super strength, super-source software is automatically updated. So, always, students received updates (VISWANATH, 2012).

Direct Benefits for students, they can take online courses, take the exam online, received feedback about the coaches, and post projects and assignments online through their teachers (PATEL, 2014).
Cybersecurity, the cloud computing providers provides some major security benefits for individuals and companies that are using E-learning solutions (MOHAMMED, 2014). All the information is more secure.

CONCLUSION

In a new paradigm in which online education or mixed teaching, both face-to-face and online, must be considered, having technologies that allow a correct teaching / learning process that achieves the objectives of obtaining skills through laboratories is a fundamental requirement.
The use of cloud computing technology, with the technological development that it had, allows, today, to give laboratory classes in the area of computer science entirely via online. As demonstrated, we can create an online laboratory on Azure and demonstrate/teach students how to develop a WEB application. On the other hand, students can use the same online infrastructure to develop their own project and put the acquired knowledge into practice. Easily set up and provide on-demand access to preconfigured virtual machines (VMs) to support your scenarios. Teach a class, train professionals, run a hackathon or a hands-on lab, and more. Simply define your needs and the service will roll the lab out to your audience. Users access all their lab VMs from a single place. For this reason, cloud computing laboratories solve problems of not accessing laboratories where students must be in person.
The study carried out using an essentially quantitative method, compared the academic results of two Curricular Units.
Both Curricular Units required the use of computer laboratories, one had access to physical laboratories and the other only had access to laboratories in Cloud Computing. It was found that the results of evaluation, performance and ease in reaching the objectives, were more positive in the Curricular Units that used laboratories in Cloud Computing.
All this teaching activity was developed under enormous social and psychological pressure, due to the context of COVID-19. Therefore, it is a study to be deepened soon.

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