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Evaluation of Cloud Computing for Advancement LMS through Different Environments

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Abstract

In this innovative study, we tackle the urgent need for practical Learning Management Systems (LMS) in educational settings, highlighting the often-overlooked aspect of strategic infrastructure planning. Central to our enquiry is Moodle LMS, a versatile, open-source platform highly regarded for its adaptability to any educational institution's needs. Our research adopts a two-pronged approach. Firstly, we rigorously test Moodle in both local and cloud environments, revealing remarkable results: cloud setups boast up to 89.6% faster period times, 85.7% quicker processing, an 88% increase in throughput, and a 74.2% reduction in overall load time. These findings underscore the cloud's superior efficiency. The second aspect of our study focuses on Moodle's performance across various geographical regions involving three different service providers. The results are clear-cut: proximity to the service provider dramatically enhances system efficiency, with response times improving by 35.7%, 28.4%, and 8.9% for each provider's closest regions, respectively. This research sheds light on the efficiency gains of cloud-based LMS infrastructures and equips educational institutions with a comprehensive testing protocol. By following our outlined steps, institutions can make informed decisions, ensuring a bespoke, high-performing LMS solution, thereby significantly mitigating the risks associated with unsuitable system choices. Our study is an essential guide for educational bodies striving to optimize their LMS strategy in today's digital landscape.

Keywords: *Cloud Computing, Infrastructure as Service, E-learning, LMS*

1 Introduction

Internet access and computers are employed as tools to improve teaching and learning. The World Wide Web's multimedia features and hypertext navigational tools give users

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access to various perspectives on a particular issue and some degree of control as they attempt to understand the content. Traditional teaching techniques, such as lecturing for hours before a blackboard, do not “work” with today’s pupils and most definitely won’t with those of tomorrow. The teacher’s job is changing from a traditional profession to an intermediary supporter towards assisting the students in achieving knowledge through Information and Communication Technologies (ICT). The technique of involving students in activities to encourage them to reflect on concepts and how they are being applied is known as active learning. We live in an ICT-dominant era, and over the past ten years, several legislative initiatives have amply illustrated the opportunity students have to study, acquire skills and think critically through ICT. ICT in Education should be viewed as a modernization of the teaching and learning process [1]. The computer now plays a significant role in students’ daily lives. Today, it should go without saying that teaching and learning strategies should incorporate computer-based, e-learning components that involve proper preparation for the 21st century, which calls for a ”new pedagogy”. Over the past ten years, the use of modern technologies in language instruction has grown significantly across the globe. The development of the World Wide Web has made it conceivable and practical for teachers to utilize instructional resources efficiently. The ability of instructors to quickly find the most current and relevant material for their students is one advantage of using Internet resources [2].

E-learning is a topic ripe for research into how technology influences the teaching and learning processes and is a valuable instructional tool. Due to the inherent differences between e-learning, the developer creates the material’s outline structure and training questions in the second stage; material improvement is the electronic form of Education via an intranet or Internet network while utilizing a learning management system [3].

With a significant increase in data volume and online users, the cost and management requirements of the traditional processing infrastructure are rising. Data retrieval everywhere and every time is inefficient when using earlier computing approaches. For this reason, Data archiving via external drive architecture is now crucial. Additionally, traditional computing cannot handle the user data volume as more people use the web, virtual meetings, and comparable technology. Here is when cloud computing is practical, allowing for the management of data availability, volume, and variety to be more flexible and effective. The cloud is an extensive, intricate system with many clients, cloud providers, devices, latency, service intermediaries, organizing methods, and storage space, among other elements. According to the” National Institute of Standards and Technology” (NIST), cloud computing is a technology architecture that provides resource pooling, prevalent, on-demand access that is simple to supply with many types of service provider engagement. It works simply by using a ”pay-as-you-go (PAYG) method; consumers only pay for the services they work on. By supplying infrastructure, the costs can be significantly lowered when using this strategy. The end-user has complete control over all hardware requirements, including types of CPU, RAM, HDD, operating system, networking, and access control. Cloud computing uses virtualization to make infrastructure available for users. The cloud’s practicality, availability, and scalability are essential characteristics. It is also practical, pervasive, multi-user, elastic, and stable [4].

Large organizations, like Amazon Elastic Compute Cloud (EC2), Microsoft Azure, and Google, invest hundreds of millions of dollars in cloud technology to service users and meet their requirements and expectations. Cloud computing companies use service-driven models. All resources—hardware, platforms, and software—are rented to customers on demand. The most well-known cloud providers are Amazon EC2 and

Microsoft Azure. Each one provides the IaaS platform. The choice of the compute node and its operating system is complicated by the various hardware and software that both providers support. According to a report by Gartner, Inc., in June 2017, the IaaS market is dominated by Microsoft's Azure cloud and Amazon's AWS cloud. IaaS market share is roughly split between the two suppliers, while other providers are niche competitors [5].

The idea uses the Internet's widespread use to provide utility computing and flexible resource consumption, including apps, hardware, networks, and storage. In addition, the computing paradigm incorporates several service levels, such as Platform as a Service, Infrastructure as a Service, and Software as a Service. Service providers propose that cloud computing be applied in private, public, collective, or hybrid domains. The private service deployment models can only be used by organizations managed by outside parties or the organization itself. In this idea, organizations establish resource restrictions.

On the other hand, the public service deployment option is more popular because it extends resources outside the firm. Additionally, approaches for deploying community services entail the creation of a shared cloud by two or more businesses that provide equivalent services. The community deployment approach calls for partner groups to share resources, rules, and benefits. Different cloud deployment models are combined to create hybrid service deployment models. These deployment models can be private, public, or community-based [6].

2 E-Learning and Learning Management System (LMS)

Higher education institutions must employ modern technology and continuously develop it. Although information technology investments are expensive for schools, the goal was to provide the community with high-quality Education at an accessible price. The global COVID-19 epidemic has recently affected every country, bringing about a shift in the way Education is provided globally. Using new technologies is essential to addressing the problems this epidemic has brought about [7].

Four stages can be used to describe the e-Learning Methodology [1]: In the first stage of skill evaluation, the learning manager gathers the relevant material information and analyses the learner's current skills and skills designated as learning goals. The manager then looks for the pertinent information. The developer creates the material's outline structure and training questions in the second stage, material improvement. Pages with explanations are incorporated within the material structure. In the third stage of learning, the learner participates in learning appropriate for the situation, whether individual learning to acquire knowledge or group learning to participate in workshop-style learning. In the fourth evaluation stage, the learner completes activities and exams with questions created with the learning aim in mind. The learning manager evaluates each learner using the outcomes of activities and tests.

Learning management systems (LMS) are platforms that make it easier to distribute educational information online. Suppose you're looking for a more technical explanation. In that case, an LMS is a web-based technology used to streamline the delivery of blended, online, and face-to-face courses in both commercial and academic environments. Regardless of the manner of delivery, an LMS is regarded as the most effective tool for promoting learning because it is created to enhance learner-centred techniques using included educational activities based on learning goals. The training structure (such as the sequencing of the information) and the nature of interactions are both under the discretion of the course designer or teacher in an LMS (such as who, when, and how learners interact). Both developers and educators can produce learner-centered classes using a variety of methods, including public message boards and video chat; LMS is currently the apex of how educational technology is used to create collaborative, engaging, transformative teaching-learning experiences that best capture and hold students' attention across a variety of platforms that best meet their needs [3].

LMS is now necessary for many educational and training situations. Public and private educational institutions utilize LMSs to develop learner-centered training, promote global inclusiveness, and boost profitability. Educational institutions have primarily led to adopting LMS, although consulting firms and enterprises have recognized its potential. Businesses are implementing LMS to facilitate workplace safety training, onboard recruits, and continue employees' education [7, 19]. The following are some advantages of using the LMS:

(i) consolidates all e-learning resources and content in one place;

(ii) offers timely and unlimited access to course content;

(iii) easily tracks students' performance;

(iv) lowers the cost and time required for learning and development processes; (v) expands quickly and conveniently, updates, and modifies e-learning courses; (vi) Some LMS tools have built-in analytics capabilities.

A LMS, which can be either open source or commercial, offers a secure, dependable, and adaptable e-learning environment. Its idea was born out of the interactive e-learning paradigm, which links teachers and students in a way that aids in the process of reinforcing learning [3].

There are three different categories of learning techniques: e-learning, distant learning, and mobile learning. All of these categories supervise and oversee the instructional process using online resources. The educational process should enable timely and synchronous interaction between instructors and students from anywhere, whether using desktop, mobile, or cloud-based applications (Software-as-a-Service). Some LMSs automatically adjust their functions based on user requirements by utilizing machine learning ideas, automatic recognitions, social networking, and user preference prediction. As a result, each LMS has unique components, functions, and modules that can be customized. Course management, user management, communication tools, student evaluation, online testing, feedback administration, machine learning, and security are examples of such models [8, 20-21].

3 Moodle LMS as Case study

There are numerous open-source and paid LMS available to the public right now, each with unique advantages and disadvantages for online learning. This makes it crucial that a potential customer is advised correctly to make the best choice. Making the appropriate decision while choosing an LMS is essential because some systems have ambiguous user terminology, obtrusive costs, ambiguous standard features, supported platforms, etc. Because of this, it is necessary to compare the popular ones utilizing crucial evaluation criteria. Performance testing ensures your program achieves the required service levels and offers a satisfying user experience. It will highlight the adjustments you should make to your apps' speed, reliability, and scalability before releasing them into the wild.

Moodle is one technology-based facilitation tool frequently used to transmit teaching and learning. E-learning is a feature of the license-free, open-source Moodle platform. LMS provides an overview of the numerous features that can be used in Moodle, such as blogs, chat, forums, assignment uploading, viewing or downloading, news, and student assessment through online quizzes, among other things. A variety of hardware and software learning tools are available. There are some open learning systems and several closed ones. Universities and other businesses increasingly extensively use virtual learning environments (VLEs) like Moodle. A Moodle is free LMS. A software program called Moodle is used to create websites and online courses. LMS promotes improved collaboration between students, teachers, and other learners [1].

Since Moodle is an”open source” system, developers can modify it to suit their needs. Additionally, it interacts fluidly with various web-based tools (Facebook, YouTube, Wikipedia, J Clik, Hot Potatoes, etc.), giving developers’ flexibility and creativity. Based on socio-constructivist pedagogy, Moodle was created. It aims to offer tools that facilitate an inquiry- and discovery-based online learning method. Additionally, it aims to establish a setting that promotes student collaboration as an alternative to or in addition to traditional classroom learning (CP) [1].

4 Cloud Computing

Cloud computing is classified as a group of service models. Cloud computing apps can be conceived as a collection of tiers on which distributed applications may be developed or hosted. Infrastructure, Platform, and Software are some of these levels. A customer can build on these levels to produce cloud programs, depending on the kind and quality of service provided. The service levels discuss infrastructure as a Service (IaaS), Software as a Service (SaaS), and Platform as a Service (PaaS) [9].

Virtual computer networks or systems can be built using infrastructure as a service. A hosted program that is widely accessible online, typically utilizing the web, is referred to as software as a service. The user uses the hosted application directly when using the software as a service. SaaS, a possible alternative business model to shrink-wrapped software, could replace many of the boxed software products we currently buy. A cloud computing architecture called Platform as a Service provides a programming environment on top of which a program can be built. To produce or improve sophisticated applications like Customer Relationship Management (CRM) or Enterprise Resource Planning (ERP) systems, PaaS offers a model [10].

The cloud deployment model is used to distribute cloud services via the Internet. There are four different ways to deploy cloud services; public, private, community, and hybrid [4, 17], each designed for a particular solution. We must distinguish between them and select the best suits our needs.

In the field of Education, cloud-based learning is the newest thing. What makes it so flexible is the ability to create, share, and collaborate from any location. To provide adaptable learning environments, some universities have already embraced cloud computing [11]. Cloud-Based Education offers numerous services:

1. Saving and Publishing: With the infinite storage capacity offered by the cloud, teachers may save and share their teaching materials with students. Files can be shared and updated on the cloud,

2. Universal Accessibility: Students can use cloud computing to access Internetrnet instead of relying on books and materials. Low-cost terminal access is another benefit of cloud learning, as apps are hosted on cloud servers. Underdeveloped nations will significantly benefit from this;
3. Collaboration: In the cloud, learners can work together to create knowledge through practical interactions. They can monitor their development and learning results. Interaction makes it possible to utilise knowledge fully,
4. Students: The human is the centre of the cloud. It satisfies what the trainees need. Using the cloud, pupils can select relevant materials and monitor their specific results and procedures.

Today's number of cloud service providers offering virtual computing resources through the Internet is Internet. Currently, cloud infrastructure is utilised by 90% of international enterprises [12].

4.1 Infrastructure as a Service (IaaS)

Iaas Providers include:

(A) EC2 from Amazon: Among the most well-liked Amazon Web Services (AWS) products is Amazon Elastic Compute Cloud (EC2). Developers may use this service to request computing resources from Amazon, and subsequent services would be supplied via the AWS control panel.

(B) Azure from Microsoft: Largest cloud service provider and Newsweek has ranked its solutions as the best in (IaaS). Worldwide, there are about 54 servers. Using Azure, clients may create adaptable virtual machines with up to 128 CPUs and 6 TB RAM.

(C) Alibaba: market share has been dominated by Alibaba Group. The Asia Pacific regions, particularly Malaysia, China, Hong Kong, Australia, India, and Japan, have demonstrated a significant presence of this. Local servers are located in Malaysia and Indonesia.

(D) Google Compute Engine: The Google Compute Engine offers IaaS solutions through the Google Cloud Platform. In this cloud, virtual computers operating on the global data centre of Google networks deliver cloud services. This provides a variety of ready-made arrangements, including virtual machines and others.

(E) IBM: Using a variety of data analysis and (AI) capabilities, this company provided both public and private cloud services. This provider produces about 170 goods and services, including virtual servers, for customers worldwide. Using a hybrid infrastructure and deploying IBM servers in their infrastructure is an option that consumers can make.

4.2 Platform as a Service(PaaS)

For developers, (PaaS) makes a significant difference. Developers can concentrate on code and data [12]

(A) (AWS): "Amazon Web Services" is a leading provider of PaaS and offers functions to improve processing and storage capacity. AWS provides clouds for PaaS as part of subscriptions, including AWS Elastic Beanstalk and AWS Lambda service.

(B) (OCP): Oracle Cloud Platform, the Oracle Company, is a significant participant in the information technology domain. The ”Oracle Cloud Platform” is an open-source that is incredibly beneficial for Oracle technology and technology in general. Using a single platform enables the connection and migration of data in a secured form. Oracle’s autonomous data storage services and transaction processing database are helpful to programmers. Access to Oracle services such as MySQL Cloud, Java Cloud, Application Builder Cloud Service, etc., is provided by this.

(C) (GCP): Google Cloud Platform offers computing resources for setting up and running web applications. Google App Engine (GAE) and Google Anthos offer platform services. The GAE uses the same technical foundation as the Google Search Engine (GSE) and supports Python, Java, PHP, Node.js, Ruby, and .Net platforms. GCP provides top-notch saving solutions for businesses, including a cloud deployment manager, SSL/TLS certificates, firewalls, and Google Cloud.

(D) Microsoft Azure: MS Azure uses a PaaS solution to provide and manage infrastructure functions for organisations. All of the typical features, including Platform, server, storage space, network, and security options, are included with PaaS. Numerous programming languages and virtual labs are supported during the COVID-19 epidemic. It supports various programming languages, including Node.js,.NET, Python, PHP, Java, and Ruby.

(E) IBM: The IBM cloud provides solutions for deploying resources like storage, networking, and processing. The consumer can use a variety of techniques to develop deep industry expertise. Additionally, IBM assists home appliance, manufacturing, retail, and medical supply organisations.

4.3 Software as a Service(SaaS)

Many cloud service providers offer clients online access to program software and services. The business’s products are available through the web. Below is a list of the top 5 SaaS businesses ranked by market share and annual growth rates [11, 18].

(A) Microsoft: about 100 products downloaded on over 1 billion devices, it is the largest SaaS provider company. There are 630 billion users on it, and the corporation offers users services including Office 365, SharePoint, and SQL Server.

(B) Saleforce.com: about 2.5 million users and roughly 58 SaaS products. It is a pioneer in CRM and offers assistance with managing customer connections and the ability to integrate with other systems and create new apps. However, it holds a sizable portion of the CRM market and new systems from Oracle and SAP present competition.

(C) Adobe: Offers about 50 products, and its Creative Cloud service has 2.3 million paying customers. It focuses on tools for picture editing, audio and video production, web design, and (PDF) services from any text editor.

(D) SAP: 309 products and 263,000 clients spread over 188 counties. It was designed for more significant and medium-sized businesses, and its SAP suite can operate the entire firm, including the human resources, financials, sales, and supply chain modules.

(E) Oracle: 400,000 people are served by this, which concentrates on selling engineered solutions rather than standard hardware. Oracle has a significant global presence in the public and retail sectors and offers powerful marketing CRM, ERP, and HCM modules.

Performance testing ensures your program achieves the required service levels and offers a satisfying user experience. It will highlight the adjustments you should make to your apps' speed, reliability, and scalability before releasing them into the wild. If you publish applications without testing them, you'll likely encounter issues that could harm your brand's reputation. How well performance testing is done directly impacts application adoption, success, and productivity. There are many testing types; an important one is called a load test, which determines whether a network system can handle a certain amount of traffic and how it will respond to a certain number of simultaneous requests. Load testing should be done to determine the maximum number of users your system can handle. A load test can be set up to replicate different user scenarios focusing on specific system components. Regular load tests should be run to ensure that your system is always accurate.

5 Related Work

Galpaya focuses on developing a ”Stress Testing Tool” designed to evaluate the performance of a Moodle Instance. The primary objective of the tool is to assess how well a Moodle Instance can handle stress or heavy loads, simulating a large number of users accessing the system simultaneously. The tool likely achieves this by generating simulated user interactions with the Moodle Instance to measure responsiveness, scalability, and stability under different stress levels. Perform performance metrics, likely measures various performance metrics such as response times, resource utilization (CPU, memory, network), and throughput to assess the system's performance under stress. Scalability testing the tool may help determine the system's ability to scale up and down, evaluating how it performs as the load increases or decreases. The main aim of this research is to provide Moodle administrators and developers with a valuable tool for assessing the robustness and reliability of their Moodle Instances under heavy usage, helping them optimize the system for a better user experience [6].

A Moodle instance was moved to a cloud-based architecture as part of the case study carried out at GoceDelchev University. Using cloud computing advantages for hosting and maintaining the Moodle platform is the primary purpose of this transfer. This study selects three cloud providers (AWS, Azure, Google Cloud) to host the Moodle system. The chosen provider can impact cost, performance, and security. The migration process involves many steps: data transfer, setting up virtual machines or containers, configuring network settings, and ensuring data integrity during the migration. The benefits of migrating the Moodle system to a cloud environment include improved scalability, easier maintenance, reduced infrastructure costs, and enhanced disaster recovery options. The main aim of this study is to examine the causes, difficulties, advantages, and results of this transfer and provides insightful information on how to move a crucial platform for educational technology to the cloud [8].

Ali and Alourani researched the different applications of cloud computing in educational settings [9]. This might include advantages related to scalability, virtual classrooms, cloud-based storage options, and collaborative tools. The study discusses several e-learning systems and how they fit into contemporary higher education. Include online courses, learning management systems (LMS), and digital resources. The study emphasizes the benefits of cloud-based e-learning, such as accessibility, adaptability, cost-effectiveness, and the capacity to support remote learning. These benefits are particularly pertinent to circumstances like distance education and the current trend of remote learning. The blackboard system was used as a case study and was tested by 60 participants to evaluate the effectiveness of the system under use. This study aims to examine how cloud computing technologies might improve e-learning opportunities. It explores the advantages, difficulties, and practical concerns of using cloud-based solutions in educational contexts, guiding teachers, administrators, and policymakers looking to use technology to promote education [9].

Alier et al. aim to solve scalability problems in LMS depending on learning tool interoperability (LTI) standards [13]. The study addresses the scalability difficulties educational institutions encounter when administering online tests, such as managing several students simultaneously. In this study, the authors chose Moodle's open-source system to apply the Atenea Exams and show the advantages and impact on scalability. This study explores how the IMS LTI-based Atenea Exams application efficiently tackles scaling issues in the delivery of online exams, providing a solution that improves the accuracy and efficiency of online assessment systems in educational contexts. By deploying a version of the Moodle Quiz Module and an external program that depends on a cloud service provider (SaaS), the compatibility feature of Moodle was solved [13]. Wiechork and Charao investigate the benefits and effectiveness of using cloud-based hosting settings to run the educational platform Moodle. The study's primary objectives centre on how beneficial database queries run on the Moodle system when it uses cloud infrastructures. This work describes how Moodle instances were hosted using various cloud infrastructures (AWS, Google Cloud). The article explores the performance indicators, such as query response times, scalability, and resource use, that are used to assess the effectiveness of Moodle's database queries. The findings of their tests, which included comparisons between different cloud providers or setups, enabled them to identify any bottlenecks, scalability problems, or other difficulties that may affect the speed of database queries in cloud-hosted Moodle. The study's conclusions and recommendations offer potential fixes or optimizations to improve database query speed in Moodle settings hosted on the cloud [14].

The integration of Amazon Alexa, a voice-activated virtual assistant, with Moodle is explored in this study. With the help of this integration, users will have voice-activated access to Moodle's capabilities, which should improve the learning experience. The authors outline how to integrate Amazon Alexa with Moodle. This includes technical information such as setup procedures, development methodologies, and utilized APIs. The article outlines the possible gains from integrating Moodle and Alexa, including improved accessibility, practicality, and involvement in online learning. As a consequence of the study, provide architectural suggestions for Alexa using safe methods to integrate a skill application with Moodle and providing insightful data for academics, programmers, and researchers curious about how voice technology intersects with online learning environments [15].

The performance issues with E-Learning systems, especially Moodle, are covered in this study. The authors suggest the usage of load-balancing clustering and also look into it as a potential means of improving system performance. The authors describe how load-balancing clustering was implemented in Moodle to reduce performance issues. The findings of performance assessments, including measures like response times, server utilization, and system stability, are presented in the report, and any difficulties or restrictions encountered throughout the experiments and execution are described. The study makes a case for the approach's more comprehensive application to other e-learning platforms [7].

Shdaifat and Obeidallah, in their research, discuss the value of mobile devices in education while emphasizing their portability and accessibility [16]. It enables students to use portable devices to collaborate and access educational content anywhere. The paper discusses the rise of online exams in educational settings and highlights their advantages, including lower costs, fewer mistakes, and less stress. This study focuses on two LMSs, Moodle and Blackboard and their mobile apps. It describes the question types supported for mobile quizzes, how question banks are used, and the possibilities for question formatting in these two LMSs. The summary of the similarities and differences between the mobile quiz tools for Moodle and Blackboard serves as the paper's conclusion. The article offers insights into the capabilities and restrictions of the quiz tools inside these two LMS mobile applications, particularly the mobile quiz authoring and offline quiz capability [16].

6 Research Methodology

The research methodology implemented in this study is structured into two primary steps to evaluate the effectiveness of Moodle LMS in various environments. This comprehensive approach ensures a thorough understanding of the system's performance under different conditions, as shown in Figure 1.

6.1 Infrastructure Evaluation

- **Local and Cloud Server Tests:** We initiated our analysis by conducting a comparative study between local (on-premises) and cloud-based servers. This involved setting up Moodle LMS on both types of servers and examining their performance under identical conditions.
- **Testing Procedures:**
  1. **Load Testing:** This involved simulating a realistic user load on the system to assess how well the server copes with high demand. We gradually increased the number of simulated users to observe at what point the system performance has degraded.

     Stress Testing: Unlike load testing, stress testing pushes the system beyond average operational capacity, often to its breaking point. This helps identify the system's maximum capacity and understand how it behaves under extreme stress.

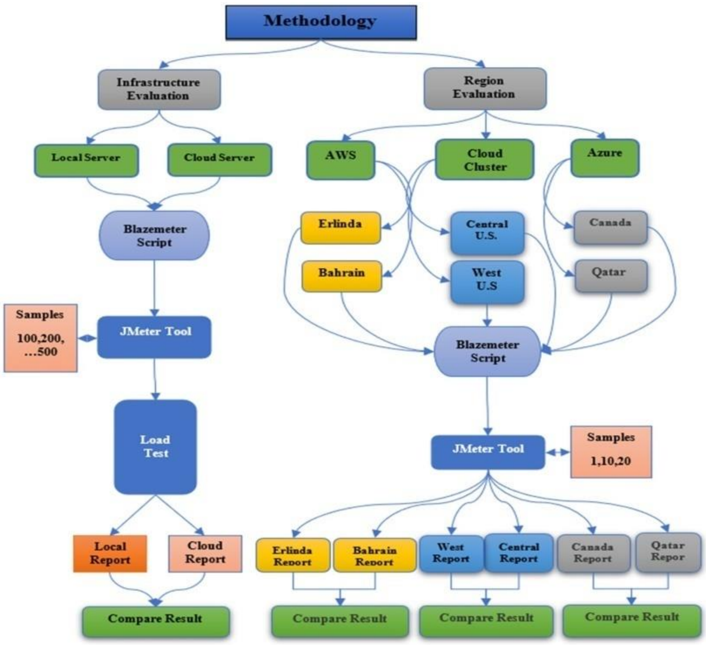


Figure 1: Research Procedure

- **Comparative Analysis:** The results from both local and cloud servers were meticulously recorded and compared. Key performance indicators (KPIs) such as response time, processing time, throughput, and total load time were benchmarks for this comparison.

6.2 Server Configurations for Local and Cloud

In this section, we prepare a local server with certain specifications, install the Moodle system on the server, and prepare all the settings to carry out the tests through which the status and performance of the system will be evaluated on the local server. In the second stage, the Moodle system will be hosted on one of the cloud service providers on a server with the same specifications as the local server to make the comparison process accurate. Preparing the local server, we chose a computer with the following specifications (CPU: 2 core, and RAM: 2 GB), We installed the "WampServer Version 3.2.6" tool to convert the regular computer into a local server, after which Moodle system was installed and running on the device. In the cloud server, we host Moodle on "Cloud Clusters". It is one of the companies equipped for cloud service. This company provides several options for the size and location of the server and the ease of setting up the Moodle system on the specified server. Specified server specifications (CPU: 2 Core, and RAM: 2 GB), the Moodle system was set up and running on the cloud server.

6.3 Region Evaluation

- Service Providers and Site Selection: The second phase of our methodology involved testing Moodle LMS across three cloud service providers. We selected two sites within each provider – one closer and one farther from the study area.

- Performance Monitoring: We closely monitored how the system responded to and executed user functions at each site. This included measuring the system's response time and overall efficiency in processing requests. • Comparative Analysis: We compared the performance results for each pair of sites within a single provider. This comparison primarily focused on response times, highlighting how geographical proximity to the server impacts the system's efficiency.

Infrastructure and Region evaluation methodologies are designed to be replicable and scalable, allowing educational institutions to apply these methods to evaluate other LMS systems. By following these test steps, institutions can make informed decisions about their infrastructure and service provider choices, ensuring optimal performance and cost-effectiveness for their needs.

7 Result and Decision

The testing result in this paper is divided into two phases: infrastructure evaluation, which includes the local server environment and cloud environment, and the second phase, region evaluation. Three cloud service providers are used in addition to two different hosting geographical locations to measure the system performance. Blazemeter and JMeter tools are used in the testing process in both phases. Infrastructure evaluation uses five samples. The first sample started with 100 users and was increased by 100 in each iteration for the two environments (Local and cloud). In each sample iteration, we perform a load test to check the maximum number of users that the system can handle.

Table 1: Summary Report for the Load Test Result on local server

User Num.	Period Time	Average Process	Std. Dev.	Error %	Throughput	Max Response Time	TimeProcessing
100	3.65	438	295	0	0.99	1000	3.8
200	3.95	611	607	0	0.97	3100	3.95
300	4.3	548	492	0	0.90	3900	4.3
400	4.5	478	341	0	0.87	1800	4.525
500	4.84	501	346	0	0.81	2600	4.86
AVG.	4.248	515	416	0	0.908	2480	4.287

7.1 Infrastructure Evaluation

7.1.1 Local Environment

To perform the load test in the local server, we apply a set of tests for each iteration to obtain the best period time for each level from (100-500) users. All results are shown in Table 1. After collecting the data from the system "Load Test" process for the five levels, the following data is obtained according to Table 1. The result of the sample test conduct shows the following: Period Time: We note that the time required before each entry increases with the increase in the number of users, and the system cannot maintain a fixed period when the number of users increases. Average, Std. Dev. and Max Response Time: those two factors show the growing number of users and fluctuating. Throughput: The system's ability to process data decreases as users increase. Through all the previous notes, it is clear that the system's ability to manage the number of users gradually decreases as the number of system users increases, and this is evidence of a decrease in server efficiency with the increase in the number of users and the inability to maintain stable performance. By comparing the number of users and the time required for processing with the results of the five levels, it turns out that the system's best performance is the first level with (100) users and (3.65) period time. Another critical factor, according to the comparison, is the processing time, which represents the time that the system needs to complete all user tasks, which is close to the period. This result indicates that the system cannot accommodate more than one user at a time. The first user logs in and completes all tasks, and then the system will allow the second user to log in. In this case, only the system can control and complete all users' tasks without errors. This is evidence of inefficient system processing and the main reason for the server's weakness. Figure 2 shows the relationship between period and processing time with the processing efficiency (Throughput).

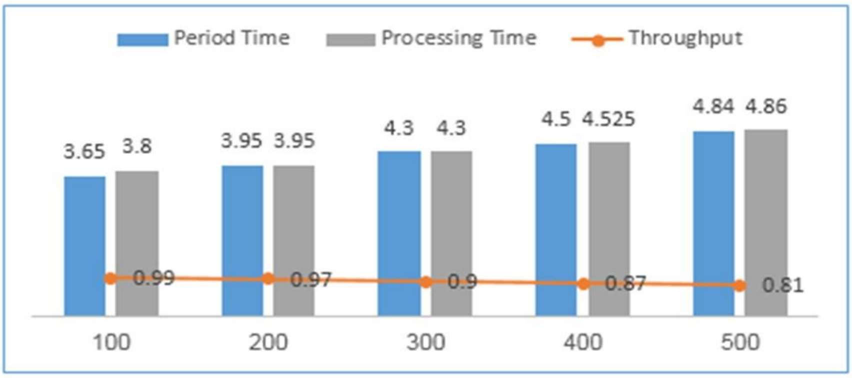


Figure 2: Variables relationships for load test in local environment

7.1.2 Cloud Environment

To perform a load test in a cloud server, we apply a set of tests for each iteration to obtain the best period time for each level from (100-500) users. All results are shown in Table 2. By collecting the result of the load test for five-level, we can note:

• Period Time: the time for entering the user into the system increases gradually when the number of users increases, the best period time obtained in level (1) for 100 users, and the average period time for all levels (0.446 msec).

Table 2: Summary Report for the Load Test Result in Cloud Server

User Num.	Period Time	Average Process	Std. Dev.	Error %	Through put	Max Respon se Time	Time process
100	0.25	3347	2448	0	9.305	7200	0.6
200	0.4	3192	2381	0	8.169	7200	0.6
300	0.45	3512	2604	0.17	7.852	8100	0.56
400	0.55	3921	2888	0.06	6.651	9700	0.65
500	0.58	3255	2414	0.15	6.462	7500	0.66
AVG.	0.446	3445	2547	0.076	7.688	7940	0.614

• Average: the average time for the total process from sending a request to receiving the result is relatively stable, but the best one in level (2) when entering 200 users into the system is the time (3192 msec), the average for all levels (3445 msec).

• Standard deviation: relatively stable the average for all levels (2547 msec).Error: in levels 1 and 2, there are no errors, and the system processes all tasks for all users in a specific period, but in levels (3-4-5), we cannot obtain results without mistakes because the system is unable to handle all tasks and the other factor effect the Internet serves, and the latency time, after many testing we have obtained the best period time with least error possible, the average error for all level (0.076%).

- Throughput: the average size of KB processing for five levels (5.528 KB/sec).

- Processing Time: the average (7940 msec). Processing time: The time required to process tasks for each user is relatively stable, and there is a slight increase when the number of users increases, which is the average process time (0.614 msec). Figure 3 represents the relationship between (period time, error, process time, and Throughput).

If we want to choose the best level from five levels, level 1 for 100 users is the best. The users enter the system in (25 sec) and the processing time for all users is (60 sec) without errors. An important note is that in the cloud environment, the input time is less than the processing time; this indicates that the system can receive a large number of users in a short time and then process the tasks gradually.

7.1.3 Local VS Cloud

After completing load tests for five levels in both on-premises and cloud environments, It is clear to us that the Moodle system works with high efficiency in the cloud environment; by comparing the previous results, table 3 shows the general average for each user during the five levels of Load testing for both environments.

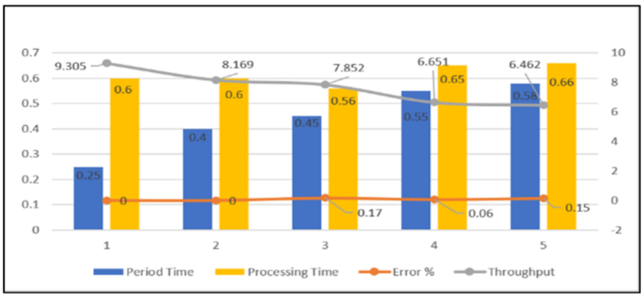


Figure 3: The distinction between the four variables for five levels in the cloud server

Table 3: The final result of the Load Test for Local VS Cloud and Differences

Environment	Period Time	Average Process	Std. Dev.	Error %	Throughput	MaxResponse Time	TimeProcessing
On-premises	4.248	515	416	0	0.908	2480	4.287
Cloud	0.446	3445	2547	0.076	7.668	7940	0.614
Differences	3.802	2930	2131	0.076	6.78	5460	3.673
Differences %	89.6 %	85%	83.6 %	100 %	88%	88%	85.7%

The most critical factors that impact the processing and efficiency of Moodle are (period time, Throughput, and processing time). The results in Table 3 show that the Moodle system works more effectively in the cloud environment in all respects. However, readings show that the local climate has an advantage in average processing (515) and the max response time (2480) and Std. Dev. (416). However, we must take into account that the tests on the Moodle system in the local environment were conducted directly on the same computer, meaning that there was no delay in the time of sending and receiving requests, so the results showed that the local environment is better in terms of average and the max response time for processing. Therefore, when the system is put to work and becomes available to users via the Internet, the Internet factor will also affect the average and the maximum response time. It is also worth noting that one of the reasons that affect the efficiency of the server in the local environment and takes space from the (RAM) and (CPU) is the tool that converts the computer into a server (Wamp server) in addition to the tool (JMeter) through which we perform tests and the operating system of the computer, as the readings showed that The percentage of RAM consumed (66%) and the percentage consumed by the processor (1%). Figure 4 shows the difference between on-premises and cloud.

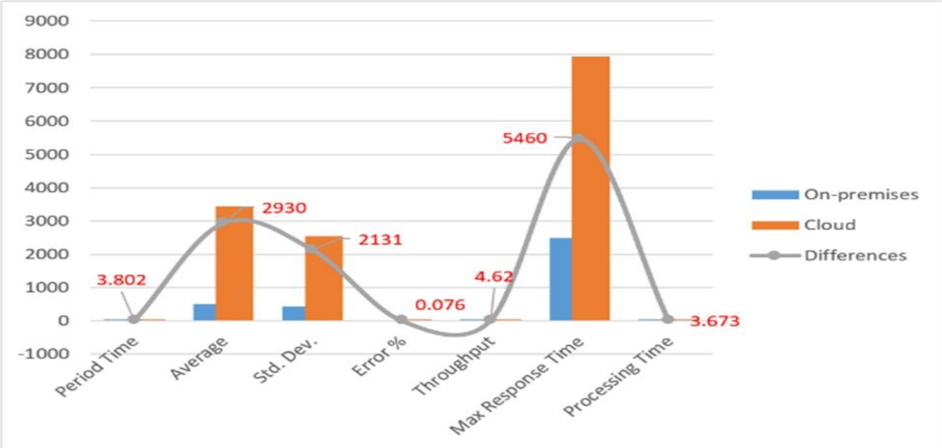


Figure 4: Differences between the two environments On-premises & cloud

7.2 Region Evaluation

Three cloud service providers will be selected, and we will run and test the Moodle system on two geographical locations for each service provider; for each stage of testing, we perform three levels each, and we increase the number of users (1, 10 and 20) with the same entry time in each provider. The most crucial factor that will be monitored at this stage is the latency time to ensure a difference in comparing every two regions.

7.2.1 AWS Provider

We chose two regions to host the server with the exact specifications: Ireland and Bahrain.

Ireland Region (EU-WEST-3): We perform three levels of tests (1, 10 and 20) on users, the period time constant in all levels (0.5 sec), and the result of tests shown in table 4.By observing the results shown in Table (4), there is a relative increase in the latency time for the completion of each user's tasks, in addition to a rise in the processing rate, and the standard deviation increases with the increase in the number of users. It is also noted that the maximum response latency rises gradually with the growth of users.

The amount of data processing per second (Throughput) gradually decreases with the increase in users, which is evidence of a decrease in server efficiency and an increase in the effect of the latency time on the results of users' processing. Figure 5 displays the variance between factors in each test.

Table 4: Ireland Report

Test	Average	Std. Dev.	Throughput	Latencies	MaxResponse Latencies
1	1248	916.18	0.08559	4975	1790
2	1341	995.62	0.04431	5052	1800
3	1589	1293.02	0.03981	5230	2700
AVG.	1393	1068	0.05657	5086	2097

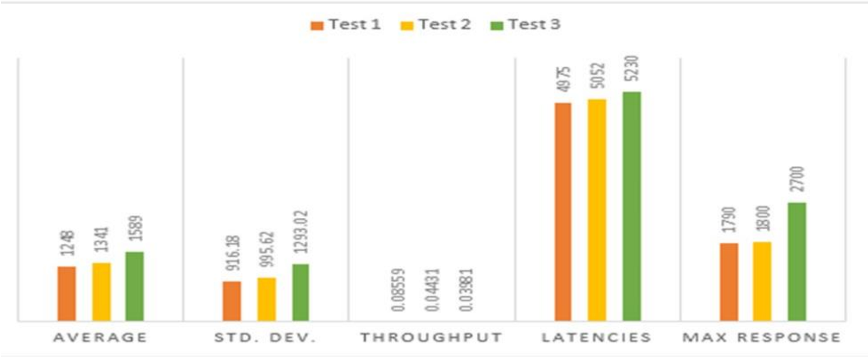


Figure 5: Differences in five factors between three test levels in Ireland

Bahrain Region (ME-SOUTH-1): We applied the same procedure in the first region of three tests (1, 10 and 20) with the same period (0.5 sec). Table 5 shows the results of the three tests. The results shown in Table 5 show stability in the readings for all factors. All the readings for the three test levels are relatively stable and close to each other if compared with the first region's results (Ireland). The results of the second region (Bahrain) show higher processing efficiency, higher response, less latency time, and the absence of a gap between tasks during processing. Figure 6 shows the summary result in the Bahrain region. The final comparison between the Ireland and Bahrain Regions is shown in Table 6.

From Table 6, it is clear that the Average processing is faster by (513 msec) in the Bahrain site, the standard deviation rate is less by (418) in the second site, the amount of data processed (Throughput) in the second site is more significant by (0.02122 KB/ sec), the latency time in the second site is less by (1816 msec) That is, the Bahrain site has a faster response than the Ireland site by (1816), and finally, the Max response time is less by (857 msec), meaning that the second site also has a preference in this respect. Figure 7 shows the difference between the two regions.

Table 5: Bahrein Report

Test	Average	Std. Dev.	Throughput	Latencies	MaxResponse Latencies
Test 1	837	599	0.10707	3264	1195
Test 2	899	683	0.06810	3267	1225
Test 3	903	666.56	0.05820	3278	1300
AVG.	880	650	0.07779	3270	1240

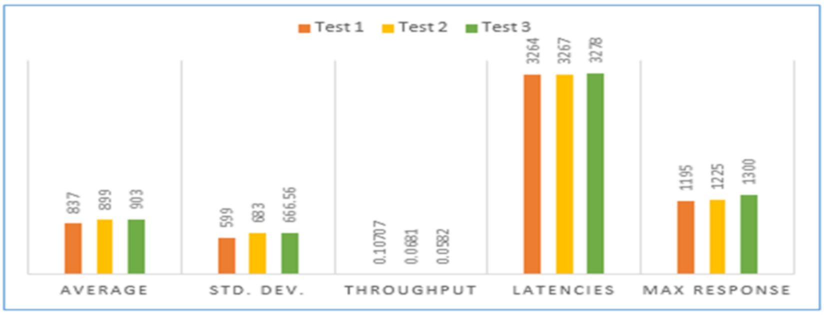


Figure 6: Differences in 5 factors between three test levels in Bahrein

Table 6: Differences between sites

Region	AverageProcess	Std. Dev.	Throughput	Latency	MaxResponse Latency
Erlinda	1393	1068	0.05657	5086	2097
Bahrain	880	650	0.07779	3270	1240
Difference	513	418	0.02122	1816	857

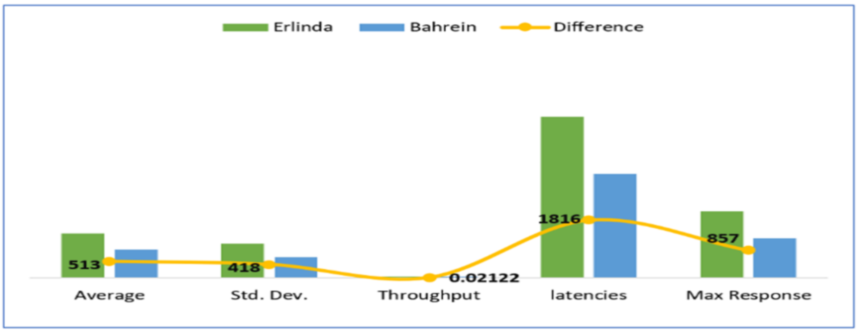


Figure 7: Difference and average between the two region Ireland & Bahrein

7.2.2 Azure Provider

We chose two regions to host the server with the exact specifications: the first region, Canada, and then the Qatar region.

Canada Central: These tests were performed for (1,10,20) users with the same period (1 sec). All results are shown in Table 7, and Figure 8 shows the summary result of the Canada region tests.

Table 7: Summary report for three tests in Canada

Test	Average	Std.Dev.	Error %	Throughput	Latencies	Max Response Latencies
Test 1	2440	1373.53	0	0.06204	9182	2030
Test 2	2713	1432.72	1%	0.05513	9195	2140
Test 3	2744	1558.88	0.5%	0.04162	9256	2210
AVG.	2632	1465	0.5%	0.05293	9211	2127

Qatar Central: We applied the same procedure in the first region of three tests (1, 10 and 20) with the same period (1 sec). Table (8) shows the results of the three tests, and Figure 9 shows the summary results of the Qatar region tests. The final comparison between Canada and Qatar Regions is shown in Table 8.

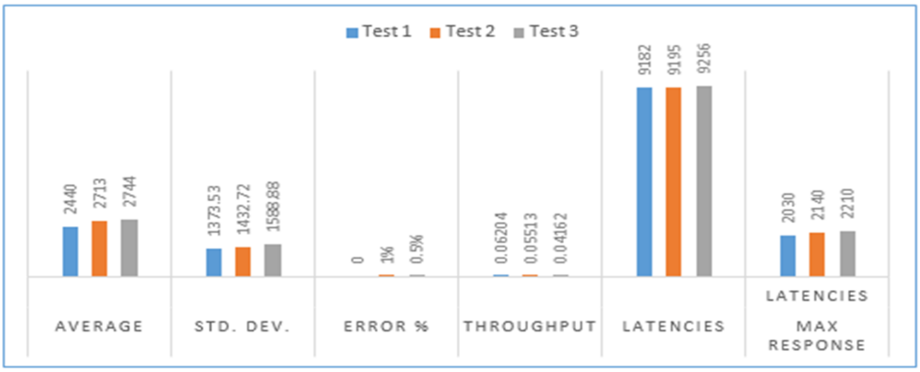


Figure 8: Differences between factors in Canada

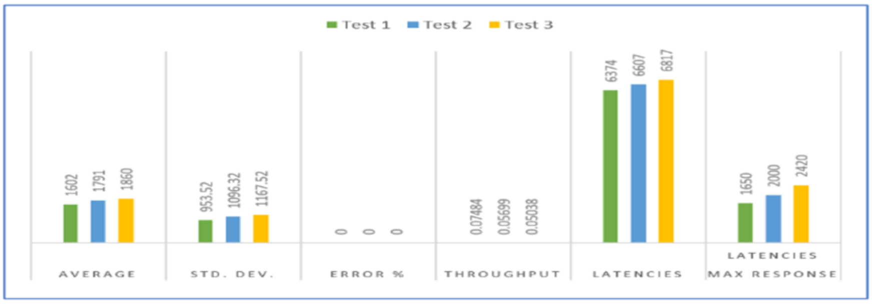


Figure 9: Differences between factors in Qatar

From Table 8, it is clear that the Average processing is faster by (881 msec) inthe Qatar region, the standard deviation rate is less by (392.55) in the second site, the amount of data processed (Throughput) in the second site is more significant by (0.0078 KB/ sec), the latency time in the second site is less by (2612 msec) That is, the Qatar site has a faster response than the Canada site by (2612), and finally, the Max response time is less by (104 msec), meaning that the second site also has a preference in this respect, we can note there are no errors on Qatar site while the Canada site there is (0.5%) errors. Figure 10 shows the difference between the two regions.

Table 8: Differences between the two regions

Region	Average Process	Std.Dev.	Error %	Through Put	Latency	MaxResponse Latency
Canada	2632	1465	0.5%	0.05293	9211	2127
Qatar	1751	1072.45	0	0.06073	6599	2023
Difference	881	392.55	0.5%	0.0078	2612	104

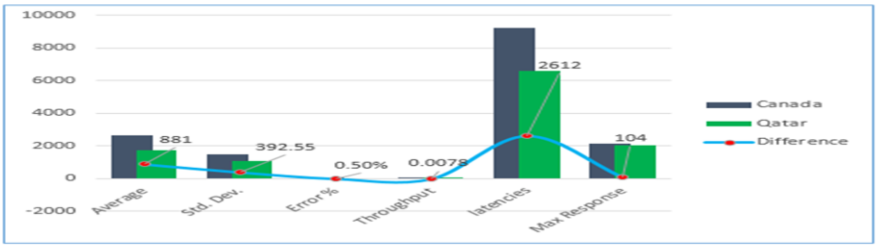


Figure 10: Difference and average between the two regions Canada & Qatar

7.2.3 Cloud Clusters Provider

We chose two regions to host the server with the exact specifications and run the Moodle system: the first region, West U.S., and then the Central U.S. region.
West U.S.: Three levels of tests (1,10,20) users with the same period (1 Sec), the result of testing shown in Table 9, and Figure 11 diagram shows the result of tests.
Central U.S.: We applied the same procedure in the first region of three tests (1,10,20) with the same period (1 sec). Table 10 shows the results of the three tests, and Figure 12 shows the summary results of the Central U.S. region tests.

Table 9: Report test for three tests in West U.S.

Test	Average Process	Std.Dev.	Error %	Throughput	Latency	Max Response Latency
Test 1	2775	1408.96	0	0.14457	11795	3170
Test 2	3226	1742.84	0	0.10266	11845	3130
Test 3	3740	2571.22	0	0.08599	12926	2760
AVG.	3247	1904	0	0.11107	12187	3020

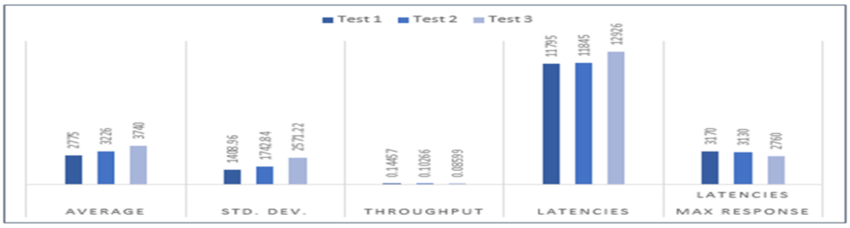


Figure 11: Differences between factors in West U.S.

Table 10: Results of three tests in Central U.S.

Test	AverageProcess	Std.Dev.	Error %	Throughput	Latency	Max Response Latency
Test 1	2679	2174.49	0	0.08155	11173	2400
Test 2	3529	2458.22	0	0.60746	10745	2400
Test 3	3388	2425.6	0	0.90112	11405	3150
AVG.	3199	2353	0	0.53004	11108	2650

The final comparison between West U.S. and Central U.S. Regions is shown in Table 11From this table, it is clear that the Average processing is faster by (48 msec) in the Central U.S. region, the standard deviation rate is less by (509) in the second site, the amount of data processed (Throughput) in the second site is more significant by (0.41897 KB/ sec), the latency time in the second site is less by (1079 msec) That is, the Central U.S. site has a faster response than the West U.S. site by (1079), and finally, the Max response time is less by (370 msec), meaning that the second site also has a preference in this respect. Figure 13 shows the difference between the two regions.

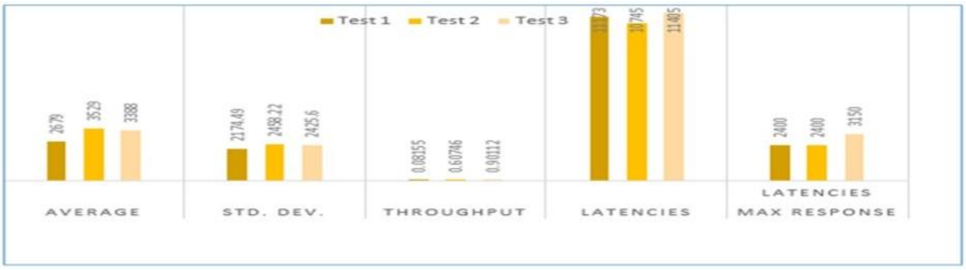


Figure 12: Differences between factors in Central U.S

Table 11: Differences result between the two site west U.S. & central U.S

Region	Average Process	Std.Dev.	Error%	Throughput	Latency	MaxResponse Latency
West U.S.	3247	2862	0	0.11107	12187	3020
Central U.S.	3199	2353	0	0.53004	11108	2650
Difference	48	509	0	0.41897	1079	370

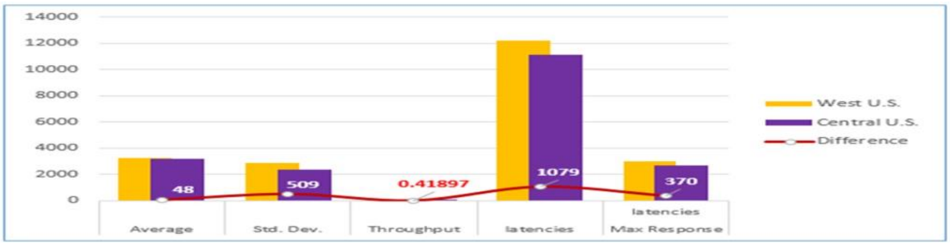


Figure 13: Difference and average between the two sites

7.2.4 Statistical Analysis (Usage Preferences)

In the cloud environment and through the tests that were conducted in 5 states from 100 users to 500 users, the results showed that the best number of users entered the server was 200 users, where the server was able to process all user requests without any errors and with the lowest possible response time. As for the local environment, where the server showed the best performance during the 100 user entry stage, which is the first stage of the testing stages, where the results showed the lowest possible response time with the highest amount of data processed (Throughput), and in comparison with the cloud environment, there is a significant superiority in response time as well as the amount of data processed, so we recommend that when using the cloud environment, the number of users does not exceed 200 users to obtain the best possible performance, but when using the local server, it is preferable for the number of users to be less than 100 users, and the following graph represents a comparison between the two environments as shown in figure 14.

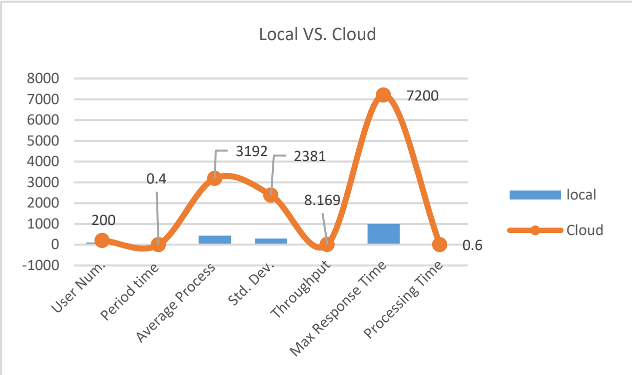
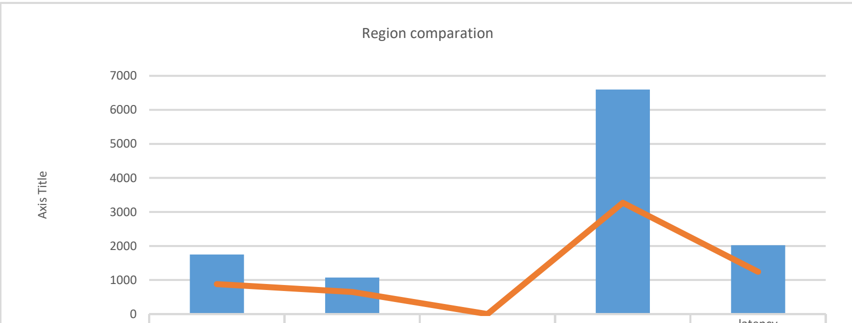


Figure 14: Local and Cloud Comparison

The second part of the research focused on evaluating the performance of the Moodle system by hosting it on different service providers and on different locations to prove whether the closest location is the best, and through the tests we can also conclude which of the tested service providers is the best. Among the three tested providers, (Cloud Clusters) will be excluded because it does not have data centers close to the test area, unlike the other two that have data centers in the Middle East. When comparing (AWS) and (Azure) as the best and fastest service provider, it becomes clear that (AWS) outperforms its competitor (Azure). The following table shows the test results with a graph comparing (AWS & Azure).



	Average Process	Std. Dev.	Throughput	latency	latency Max Response
Azure	1751	1072.45	0.06073	6599	2023
AWS	880	650	0.07779	3270	1240

Figure 14: Region Comparison

8 Conclusions

The performance of the Moodle system in various situations was assessed during two critical stages of the research. An internal and cloud-based server with identical specifications was used to evaluate the system in the initial phase. Load testing was used to assess system capacity and user processing times. The results showed that while the local server performed better in some parameters due to faster data transfer times, the cloud-based Moodle system surpassed it in terms of period time, throughput, and processing speed. The Moodle system was tested on several cloud providers and geographies in the second step to identify performance disparities by region. The study discovered that hosting the system nearby produced quicker and better results. Cloud providers displayed variable performance, with nearby locations generally outperforming those farther away. This pattern was seen with service providers like AWS, Azure, and Cloud Cluster, highlighting the importance of a provider's closeness to the active area of the educational institution in getting the best system performance. In the future, the researcher can apply the test steps to a different LMS and take a different study case, the Blackboard system, and compare it with the Moodle system to make a comparison between two systems that work on the cloud environment and give any educational institution advice if it wants to choose a specific system. In addition, the researchers can use different scenarios, for example, the user's behaviour while submitting a quiz within the system, recording the script for this scenario, and applying several tests on the JMeter tool to determine the size of the server that any educational institution needs, because the quiz work needs significant processing and requires the entry of a large number of users at one time. Therefore, the system will be placed at the maximum possible load through the test steps applied in our study to determine the appropriate server size that accommodates all users.

9 Future Work

In the future, we seek to apply the test steps to a different (LMS) and take a different study case, the Blackboard system and compare it with the Moodle system to make a comparison between two systems that work on the cloud environment and give any educational institution advice if it wants to choose a specific system. In addition, we will prepare a scenario for the user's behavior while submitting a quiz within the system, recording the script for this scenario, and applying several tests on the JMeter tool to determine the size of the server that any educational institution needs, because the quiz work needs large processing and requires the entry of a large number of users at one time. Therefore, the system will be placed at the maximum possible load through the test steps that were applied in our study to determine the appropriate size of the server that accommodates all users.

Acknowledgment

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