

Revolutionizing Higher Education: A Critical Analysis of Cloud Computing's Impact, Suitability, and Challenges

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Abstract— This paper aims to overcome the lack of research focusing on the application of cloud computing in the higher education sector. Cloud computing is revolutionizing higher education by enabling virtual classrooms, cost savings, and enhanced security. However, challenges like security, privacy and compatibility concerns impede its wider adoption. This research, through a systematic critical review of post-2015 literature, explores the intersection of cloud services and pedagogical needs. It examines the suitability of various models (IaaS, PaaS, SaaS) and deployment options (private, public, community, hybrid) for educational institutions. Furthermore, it analyzes key cloud features like on-demand self-service, rapid elasticity, and measured service to identify their potential for empowering learning. Additionally, it critically reviews prominent cloud platforms (AWS, Azure, GCP) and identifies persistent challenges for its adoption in the higher education industry. Finally, it recommends future studies to investigate methods for overcoming these challenges, explore alternative cloud models, and analyze lesser-known providers.

Keywords—Cloud Computing, Higher Education, Cloud Services, Cloud Deployment Models, Virtual Classrooms, E-learning

I. INTRODUCTION

Cloud computing is a paradigm that involves the delivery of computing services, including storage, processing power, and applications, over the Internet [1]. Rather than relying on local servers or personal devices, users can access and utilize computing resources hosted by third-party providers. Cloud computing operates on a pay-as-you-go model, allowing organizations and individuals to scale their usage based on demand [2]. The key service models in cloud computing include Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). These services provide flexibility, cost-effectiveness, and accessibility, making it easier for businesses and users to manage and deploy applications without the need for extensive hardware or infrastructure investments [3].

Education refers to the process of gaining knowledge, understanding, and skills through formal and informal methods. Education is vital in maintaining a nation's economic and financial growth and it also provides innovation, empowerment, and creativity in the country's growth. To ensure high-quality service in the education field, both public and private institutions are constantly looking for areas for improvement despite the minimal resources allocated. One of the key components of education today is E-learning, which also can be known as online distance learning. Education has been gradually expanding and the teaching method from the traditional blackboard has been shifted to online platforms in recent years. However, traditional ways of education are still being applied in the classrooms and it is

especially prevalent in developing countries. According to Oluwayimika and Idoghor (2022), participation is limited by the typical classroom in the learning process as listening, reading, and answering questions are seen as more crucial and vital than being able to think outside of the box [4]. Students are not encouraged to voice out their unique opinions or conduct any independent inquiry in their respective classrooms. As a result, academic productivity and satisfaction are lowered for students. On top of that, most of the educator's work is still being done manually from student attendance to classroom teaching and the examination system [5]. Besides that, to participate in the E-Learning movement, institutions in the higher education field are becoming more dependent on information technology to service the requirements of E-Learning. To meet the requirements of E-Learning, the support and development of in-house IT infrastructures are expensive to maintain, and the infrastructures are required to be updated frequently [6]. Schools and universities are spending huge amounts of money on technical equipment, software, and hardware for these infrastructures. Moreover, a high expenditure is also needed to hire and train highly professional IT staff to support and develop the in-house IT infrastructure. Adding on, students will need to spend money to purchase e-books, personal storage devices, and software to facilitate their E-learning experience.

One of the gaps that this study attempts to fill is the lack of research focusing on the use of cloud computing in the higher education level. In addition, current studies have yet to provide a critical review on the features of cloud service providers that elevates the higher education industry. This study aims to fill in these gaps by investigating the application of cloud computing in the higher education sector. The objectives include examining the appropriateness of various cloud service deployment models for educational purposes, identifying the empowering features of cloud technology in education, critically reviewing the attributes of cloud service providers that contribute to transforming the education domain and exploring the challenges associated with implementing cloud solutions in higher education. The research specifically concentrates on cloud computing within higher education institutions. The data for this study will be sourced exclusively from journal articles and white papers. Key stakeholders addressed in this paper are limited to students, educators, and IT administrators. The temporal focus of this research spans from the year 2015, providing an up-to-date analysis of the state of cloud computing in the education sector.

This study relies on journal articles as its primary data source, shaping the methodology around the systematic identification, selection, and analysis of these articles. The

search strategy involves utilizing specific search queries and keywords, namely "Cloud Computing," "Education," "E-learning," and "Higher Education." To enhance the credibility and reliability of the research, a rigorous filtering process is applied to the selected journal articles, focusing on those published from the year 2015 onward. This temporal criterion ensures that the information incorporated into this study is not only recent but also relevant, credible, and trustworthy.

II. ASSOCIATION OF CLOUD COMPUTING WITH THE HIGHER EDUCATION DOMAIN

The association of cloud computing with the higher education domain represents a transformative shift in the way educational institutions manage and deliver services. Cloud computing offers a scalable and flexible infrastructure that enhances accessibility, collaboration, and efficiency within higher education. It facilitates the storage and retrieval of vast amounts of data, supports collaborative learning environments, and enables institutions to streamline administrative processes. The adoption of cloud services in higher education contributes to cost-effectiveness, as institutions can leverage shared resources and eliminate the need for extensive on-premise infrastructure. Additionally, cloud computing supports innovative teaching methodologies, such as online courses and virtual classrooms, promoting a dynamic and inclusive learning experience for students. This integration of cloud technology in higher education is reshaping traditional approaches, fostering a more connected and technologically advanced academic landscape.

A. Virtual Classrooms

According to Simon, Lotte, Sine, and Khalid (2017), students can have outstanding educational experiences with the availability of virtual classrooms [7]. Educators can communicate with students in person regardless of the location that they are in thanks to cloud-based software. To achieve the same level of engagement in a physical classroom study, Simon, Lotte, Sine, and Khalid (2017) stated that the best method to keep students engaged in online classrooms is to create small virtual break rooms with a limit of 8 students and a coordinator in each room [7]. The facilitator will ensure that each student is given the chance to engage and contribute their viewpoints and thoughts on a particular subject. Besides that, with virtual classrooms, educators can deliver lectures, labs, assignments, and exams on the cloud [4, 5]. This will make it possible for students to access a wide array of learning resources through a web browser from an electronic device anywhere and anytime they find most beneficial. Besides that, virtual classrooms allow higher education institutions to reach more and more diverse students. The cloud has uncovered a world of modern probabilities for students who are not served well by the traditional method. Lecture halls and physical classrooms are being crowded daily. Universities have limited budgets and resource allocations, which means that these universities may not be able to take in the growing number of student enrolments every year. However, if these universities adopt the cloud, they will be able to take in the growing number of students and provide them with high-quality learning resources if the students have internet access.

B. Cost Saving

According to Hartmann, Braae, Pedersen, and Khalid (2017), the use of cloud computing is a low-cost method to increase the potential for productivity and collaboration in educational institutions [8]. With the advent of cloud

computing, students and administrators are not required to install software locally on their computers because the software is outsourced to the cloud service. Hence, these students and administrators are not required to purchase software licenses and are not required to pay for the maintenance. Thus, the cloud presents a more economical method to acquire and utilize IT services. Besides that, the public knows that learning resources such as textbooks, E-books, and video materials at higher education levels are expensive. The price of textbooks in higher education has far exceeded the price of textbooks in other levels of education. Consequently, many students in the higher education field are not willing to purchase these textbooks. Instead, this challenge can be overcome by cloud computing as students will get access to the learning materials uploaded by their educators in the cloud server in addition to spending less money [9, 10]. Furthermore, with the streamlining of routine procedures such as student enrolment and academic tracking to the cloud, higher education institutions can significantly cut administrative expenditures. Notwithstanding that, the institutions will only need to pay for the services that they have used, which makes cloud computing an economical option for the education domain [11].

C. Security

According to Mishra, Panda, Pati, and Mishra (2019), cloud computing offers a high level of security for sensitive and confidential data such as student personal information, exam questions, and exam results [12]. One of the ways cloud computing offers a high level of security for confidential data is through improved improbability [13]. If these data are stored in the cloud, hackers cannot locate the machine that stores student personal information, exam questions, and results. It is also not possible to locate the physical infrastructure that needs to be hacked to obtain the confidential data. Besides that, virtualization through the cloud allows for the immediate replacement of any affected cloud server without severe damage. Cloud downtime also is anticipated to be reduced to a minimum as it is easy to create clones of virtual machines to store confidential data. If any sensitive data is lost due to any technical failure of the machine, the lost data can be retrieved easily as the data will be saved in the cloud. Furthermore, higher education institutions can monitor data access more easily since only one location should be monitored and supervised instead of hundreds of machines belonging to the institution [13, 14]. Moreover, any security changes can be easily tested and applied because the cloud is a unique entry point for all institutions. Also, if required, the data can be erased remotely. As a result, such a high level of cloud security has removed barriers to cloud computing so that educational institutions can achieve the educational benefits of the cloud [15].

III. SUITABILITY OF CLOUD SERVICES AND DEPLOYMENT MODELS FOR THE EDUCATION INDUSTRY

A. Infrastructure as a Service (IaaS)

According to Zaharescu and Zaharescu (2012), the IaaS service model provides clients with the needed resources as a cloud service [16]. The resources provided include virtual server space, load balancers, network connectivity, IP addresses, and bandwidth. According to Mary and Rose (2019), IaaS in the education domain provides higher education institutions with the virtual infrastructure to establish and distribute software such as applications and

operating systems [17]. In the higher education domain, the computer labs are the main elements of the domain. IaaS satisfies the infrastructure needs of infrastructure architects. Therefore, higher education institutions do not need to purchase computer resources as they are only required to pay for what they use in the cloud [18]. Furthermore, Margianti and Mutiara (2015) stated that with IaaS, infrastructure architects of higher education institutions do not need to manage or control the cloud infrastructures [5]. However, they do have control over the applications and operating systems. Moreover, limitations may also be placed on the control over networking components such as host firewalls. Adding on, computing resources can be used to provide a scalable amount of memory, bandwidth, and other tools that were explored in cloud-based learning [19]. As a result, this characteristic is vital in cloud-based education as virtual classrooms and virtual labs can be set up and torn down when required.

B. Platform as a Service (PaaS)

According to experts, PaaS gives programmers in higher education a virtual development environment to build, test, and deploy applications created using programming languages and tools supported by the cloud service provider onto the cloud [5, 20]. The distributed applications and the application hosting environment are controlled by the programmers. However, the programmers do not have control over the cloud infrastructure which includes networks, servers, storage, and operating systems. Besides that, Mary and Rose (2019) have mentioned that educators in the higher education field can create customizable virtual labs for students [17]. Furthermore, Rajaei and Aldakheel (2012) asserted that PaaS is very useful in the higher education domain as PaaS alleviates students' concerns about not having the necessary hardware for Computer Science courses [18].

C. Software as a Service (SaaS)

According to past studies, the SaaS model allows clients to utilize applications of cloud service providers that are running on cloud infrastructure [5, 18]. In the education email, students can access these applications from various devices such as laptops and mobile phones through an interface such as web-based emails. Students, educators, and administrators using the SaaS model do not have control over the cloud infrastructure such as networks, storage, and operating systems. Besides that, they are also not allowed to control and manage the individual application capabilities of the software applications. Moreover, the SaaS model allows users to use software applications through the cloud at a low cost, almost free [21]. Furthermore, users from the education domain can use the application without the hassle of installing and running the application on their own devices [17]. This is because the applications will be run on the cloud instead. In addition, according to Samyan and Flour (2021), the types of features that cloud service providers offer to the education domain include access to learning resources, virtual classrooms, and facility interaction between students, educators, and administrators [14].

D. Private Cloud

According to Margianti and Mutiara (2015), the private cloud exists only for one organization which may be controlled by the organization or a third party. The private cloud may also be located on or off the organization's premises [5]. One of the benefits of the private cloud is the high level of security offered as the required resources will

only be under the control of one user. However, one of the disadvantages of the private cloud is the increased cost compared to public cloud options. Besides that, Mary and Rose (2019) stated that the private cloud satisfied the needs of a higher education institution [17]. To satisfy the security requirements, communication to authorized users is required for confidential information such as the grades and academic progress of students. According to Mathew (2012), the researcher supported the idea that a private cloud model for education is necessary [22].

E. Public Cloud

According to Margianti and Mutiara (2015), the infrastructure using the public cloud model is easily accessible to the public [5]. Some of the advantages of using the public cloud model are scalability and lower costs. However, as the infrastructure is a form of shared asset, many customizations are not able to be provided by the cloud service providers to higher education institutions. In terms of security, the level of security provided largely depends on the provider. Thus, it is recommended that a thorough evaluation must be conducted on the reliability of each public cloud provider before using the public cloud model. It is also believed that the security of the public cloud model is inferior to the private cloud as everyone can access the public cloud easily. Furthermore, Mary and Rose (2019) found that the public cloud provides data storage for texts, images, audio, video, and other multimedia content that are suitable for educational purposes [17]. The public cloud will be suitable for students and educators to upload and retrieve learning materials if the materials are arranged properly.

F. Community Cloud

Margianti and Mutiara (2015) define the community cloud model as a shared cloud server between several clients and it supports a specific community that shares the same goals, interests, and concerns [5]. Clients or third parties either manage or oversee the community cloud. In addition, the community cloud may exist either on or off-premises. According to Mary and Rose (2019), in the education domain, the community cloud has various universities with international standards putting in a collaborative effort to share their syllabus [17]. It is a good opportunity for the higher education domain to amend its syllabus according to the ever-changing technology.

G. Hybrid Cloud

The hybrid cloud model combines two or more cloud deployment models that remain unique entities [3]. Mary and Rose (2019) state that hybrid cloud uses services from a private cloud and a public cloud [2]. In the education domain, the sending of student progress reports, examination results, and attendance reports to parents through E-mail was one of the ways the hybrid cloud model was used. Mathew (2012) also supported the idea that universities should use the hybrid cloud model where learning contents and materials can be shared over the network [22]. With the hybrid cloud model, students and educators are allowed to utilize the wide range of information and storage capacities for educational activities to their advantage.

IV. CLOUD FEATURES THAT EMPOWER THE EDUCATION INDUSTRY

A. On-Demand Self Service

One of the cloud features that empowers the education industry is on-demand self-service. According to previous studies, students and educators can access their education resources stored in the cloud from a computer, laptop, or mobile phone at home, school, library, or some other place at their convenience [9, 20]. Using cloud services and applications, mobility can be achieved by students and educators because the learning materials and resources are made available and accessible through computers, laptops, mobile phones, and other technologies. To illustrate, classes can be carried out outside school premises or students can complete their educational tasks at any location with Internet access [23]. Besides that, students can also perform different educational activities such as achieving rapid and effective communication, collaboration, exchange or sharing documents, contacts, audio and video presentation, and other activities regardless of the time and location that they are in [21].

B. Rapid Elasticity

Another cloud feature that empowers the education industry is rapid elasticity. It describes the capacity of a cloud application, platform, or infrastructure to accommodate an increasing or decreasing user demand [24]. Education institutions can easily scale up the learning software, applications, and experiences due to the cloud. According to Margianti and Mutiara (2015), scalable cloud systems and applications help to provision big data platforms and research for student's research and analysis [5]. This means that cloud services can be provided at a lower cost in educational institutions compared to in-house data and computer infrastructure. The rapid elasticity feature also enables usage peaks and traffic surges to be controlled by educational users. These usage peaks and traffic surges are usually the results of occasions such as course enrollments and online exam submissions. At the same time, educational users can reduce cloud usage immediately during a time of low activity to reduce cost wastage [25].

C. Measured Service

According to recent studies, measured service represents the automatic control and optimization of cloud resources by metering down the cloud capabilities with a pay-as-you-go pricing model [12, 24]. Tarandeep, Abdulkadir, Sharma, and Muhammad (2021) also supported that one of the advantages of cloud computing is that users are only required to pay according to their usage [11]. Generally, in the education domain, students can use office applications without having to purchase these applications. For applications that require payment, cloud service providers provide the facility of pay per use which reduces the cost for students with a tight budget [5]. According to Mary and Rose (2019), many higher education institutions pay for the specific software applications that they use from the cloud, and it helps the institutions to reduce expenditures [17]. Mhouthi, Erradi, and Nasseh (2017) also added that the emergence of online learning systems with its pay-as-per-usage model has been promoted by cloud computing which has adapted to all scales of budgets and requirements [26]. Thus, cloud computing was viewed as one of the most low-cost options for the requirements of higher education domains.

V. CRITICAL REVIEW OF CLOUD SERVICE PROVIDERS' FEATURES TO IMPROVE THE EDUCATION INDUSTRY

In this Section, three major players, namely Amazon AWS, Microsoft Azure, and Google Cloud Platform, are examined for their distinctive features and contributions aimed at enhancing the education industry.

A. Amazon AWS

According to Williamson, Gulson, Perrota, and Witzemberger (2022), Amazon has provided cloud services to more than 9,000 customers from the education sector [27]. The facilitation of migrating an educational institution's deployed applications, servers, and databases to the cloud is one of the main goals of AWS in the education sector. A package of AWS Migration services performs the transfer, and functionalities of data analytics, artificial intelligence, and machine learning are given to the education institutions. With the AWS cloud migration, education institutions are promised better capabilities to utilize data to make more intelligible and actionable processes, events, and activities [28]. Therefore, AWS does not only govern the data collection and usage of education institutions but also the way they can govern their students and educators. The AWS Cloud also allows education institutions to be free from the troubles and hassles of managing infrastructure and they can also gain access to the newest technologies at a low cost, regardless of the scale [27].

B. Microsoft Azure

According to Zainab and Dhaka (2014), Azure can provide developers of educational institutions with on-demand computing and storage to deploy, scale, and run applications on the interest using the data centres of Microsoft [29]. Considering the scenario at educational institutions where data continuously grows rapidly each semester, Azure's storage feature is very important. As the load on educational institutions will vary significantly during busy times such as the release of examination results, the institution's websites will crash most of the time when examination results are released. Thus, more machines are required to run the application with occasional spikes in website traffic. If the application is running on Azure, the number of instances running can be increased during usage peaks and reduced back to a lesser number during times of lesser traffic by institutions. Besides that, tables, blobs, and queues for cloud storage are provided by Azure. Azure tables are not relational as the tables hold data in the form of entities and properties. This characteristic is beneficial to educational institutions because some colleges are associated with a single university. As every college will have various branches, branches' names and branches will be different for every college. Therefore, the Azure table feature is the best choice for data storage in the education domain.

C. Google Cloud Platform

According to Alqahtani (2019), there are many benefits to using Google Cloud Platform in the education domain [30]. Its multiple cloud applications provide students with collaboration and real-time editing, also providing students tools for easy sharing to communicate and share knowledge regarding a subject or topic. Google Cloud Platform also has features to help students with tasks such as writing articles and arranging classes that are suitable for educators [7]. Google Docs also allows students to work together on tasks, and the students can see real-time changes in the documents. With that, students do not need to wait to receive the changes

through email notification. As a result, students can save time that can be used for studying [32]. Besides that, the “Class Assignment” feature is one of the most distinguished features of Google Classroom. This feature allows students to access their class assignments, complete them, submit them to their educator, and receive their results [33]. In addition, Google Cloud Platform allows its applications to be run on mobile phones, enabling easier and faster access for students and educators. This helps students and educators to save time as they can access and enter classrooms through their smartphones.

VI. POTENTIAL CHALLENGES OF THE CLOUD FOR THE EDUCATION INDUSTRY

While the adoption of cloud technology in the education industry brings numerous advantages, it also presents potential challenges that institutions need to navigate. One major concern is the issue of data security and privacy. Storing sensitive educational data on external cloud servers raises questions about who has access to this information and how it is protected. Educational institutions must ensure robust security measures and compliance with data protection regulations to safeguard student and faculty data. Another challenge is the dependence on internet connectivity for accessing cloud-based services. In regions with unreliable or limited internet infrastructure, this reliance may hinder seamless access to educational resources, impacting the learning experience. Additionally, the cost implications of migrating and maintaining cloud services can be a concern for institutions with budget constraints. Striking a balance between reaping the benefits of cloud technology and addressing these potential challenges requires careful planning, implementation, and ongoing monitoring in the dynamic landscape of the education sector.

A. Security Concerns

One of the top concerns for education institutions to adopt cloud computing is data security [17]. The drawbacks of efficient encryption algorithms are one of the reasons contributing to the lack of data security. Besides that, another reason is the residual data left behind by users of educational institutions which becomes accessible to unauthorized parties. In cloud computing, the probability of unauthorized parties accessing information has increased due to the number of parties that are sharing the same cloud resources such as similar networks and similar data storage. In addition, storing sensitive and confidential information in the cloud may be unsafe because education institutions are unable to safeguard the boundaries of the cloud. Samyan and Flour (2021) asserted that this information requires developers and cloud administrators to continuously monitor and have control over the information [14]. According to Islam, Kasem, Khan, Habib, and Ahmed (2017), educational institutions need an expand of trust boundaries to cloud service providers for the remote usage of cloud resources [9]. A security architecture that can measure such a trust boundary without being exposed to vulnerabilities can be difficult to set up. Singh and Chatterjee (2017) also stated that cloud services use the Internet to transfer data from one source to another [34]. The data will need to travel from one point to another, which is unsafe. Threats such as malware injection and IP Spoofing may appear during the transfer of student data over the internet. Moreover, as data in cloud computing is stored on the cloud server, huge chunks of data are divided into smaller portions and stored on multiple servers. This will make it

difficult for education institutions to recover important data if the data is lost as it is difficult to have a backup since the data is stored on third-party servers.

B. Privacy Concerns

According to Margianti and Mutiara (2015), the protection of data is a major challenge for higher education institutions [5]. These institutions may believe that their data will be more protected if it is hosted privately within their institutions instead. This is because educational institutions must treat sensitive student data confidentially. A risk is presented to education institutions when they transfer their data to a cloud service provider for hosting in a remote data center. This is because the data is no longer under the control of the institution and the data center’s location may be unknown. This scenario can result in data leakage leading to the loss of trust in the education field. Furthermore, they added that the provision of cloud services via only one vendor is a single point of failure due to vendor lock-in. Another security concern for the education industry is unsolicited advertising. Cloud providers can target students with less technological expertise with unsolicited email or advertising.

C. Compatibility Concerns

According to Mahmood and Iftikhar (2018), the technical aspects and customization of existing infrastructure migration to the cloud is a challenge that needs addressing [35]. Besides that, migration to the cloud requires a team of IT experts with a certain level of skill and expertise to perform the migration which is not common [36]. In previous research, one of the IT experts that they interviewed argued that the compatibility problem has caused a lot of trouble to the technical team of the education institution [23]. As an example, Auto CAD software can only be used inside the institution and cannot be used outside the institution. Adding on, this system requires a specific configuration on the student’s and educator’s machines that can only function in a specific situation. Not only that, due to a deficiency of well-established industry standards within the cloud computing field, public clouds are commonly ownership to some extent [37]. For education institutions that have custom-built solutions that are highly dependent on these ownership environments, switching from one cloud service provider to another can be challenging. Thus, this will lead to a vendor lock-in scenario. Cloud computing compatibility with any device as well as the ability to integrate with in-house infrastructure is one of the challenges of cloud computing that the education domain must overcome.

VII. CONCLUSION

This research illuminates the intricate relationship between cloud computing and the education industry. Our findings showcase the potential of cloud services and deployment models in enhancing access, cost-efficiency, and security within educational institutions. We provide a framework for selecting suitable models based on internal and external factors, empowering institutions to make informed decisions. Additionally, our review of leading cloud features and provider offerings highlights their potential to revolutionize pedagogy and learning experiences. However, overcoming identified challenges in security, privacy, and compatibility remains crucial for broader adoption. Future studies should investigate innovative methods for addressing these concerns, explore emerging cloud models like CaaS and FaaS, and focus deeper into the features and potential of

lesser-known providers. By embracing the transformative power of cloud computing while meticulously addressing challenges, the education sector can unlock a future of accessible, engaging, and effective learning for all.

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