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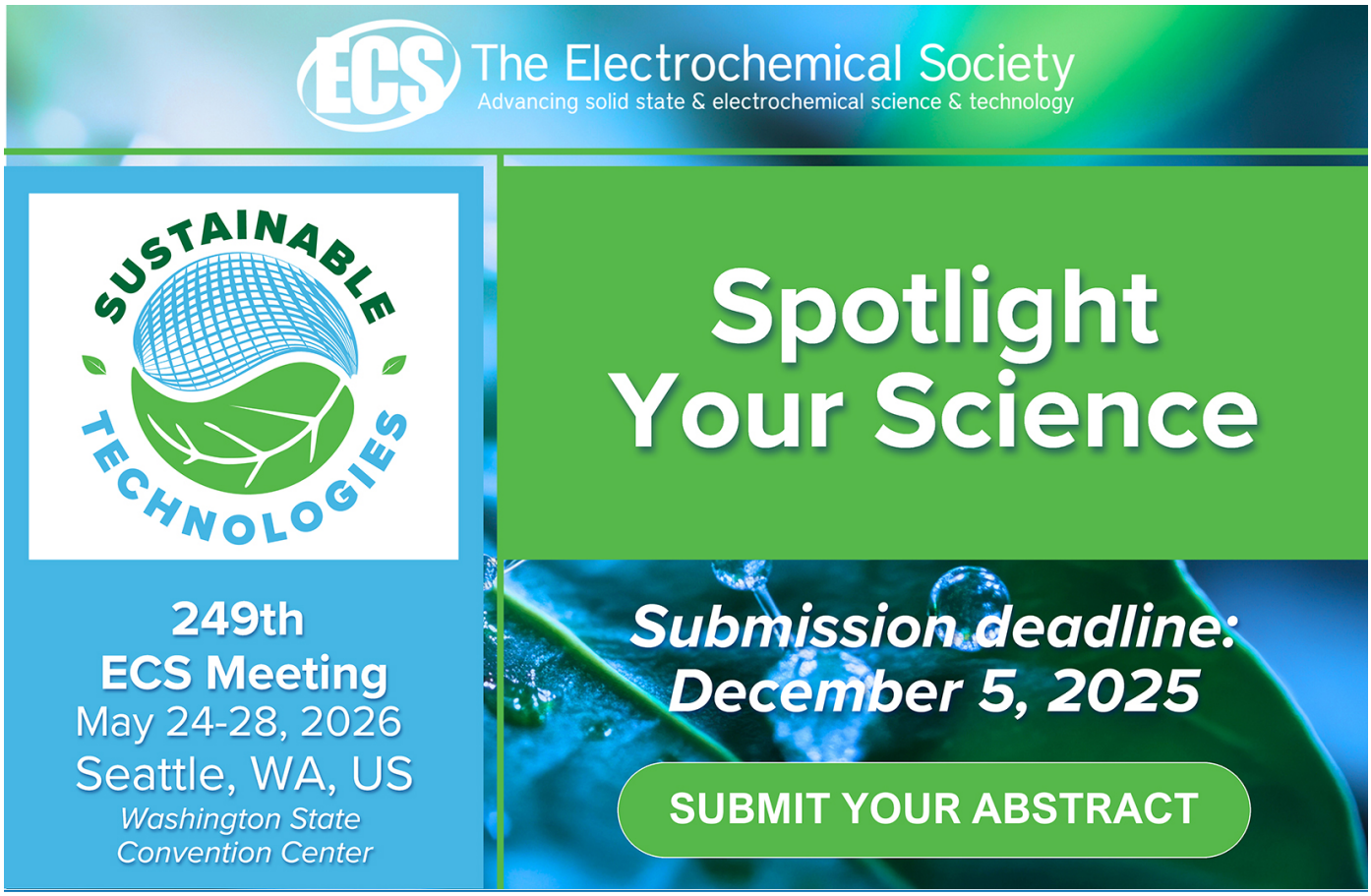

A Survey on Recent Applications of Cloud Computing in Education: COVID-19 Perspective

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Abstract. Due to the outbreak of coronavirus pandemic (COVID-19) in recent times, almost all countries have been affected in a drastic way, impacting delivery mode of education in world everywhere. Several schools, colleges and universities are under lockdown or have been forced to provide online education. To meet the existing challenges due to COVID-19, it has become highly critical that educational institutes become more efficient in virtual delivery of quality teaching services. In here, cloud computing provides an excellent platform for educators to improve their teaching practices and productivity. Cloud computing presents an ideal opportunity as it not only saves costs, but also power, due to the simultaneous usage of infrastructure by several stakeholders for the purposes of teaching, learning, and research. This is a short survey paper which explores the applicability of cloud computing within the context of educational settings. It also describes a few applications such as cloud rendering, gamification and collaborative e-learning technologies. In the end, a few challenges have also been presented.

1. Introduction

Higher Education Institutions (HEI) that provide degree-level and tertiary education, will have to remain updated with the advancements in technology. In the past, these institutions invested huge amounts of money in Information Technology (IT), but were expected provide education services to the community at an affordable price while still maintaining excellent quality [1]. Coronavirus 2019 (COVID-19) pandemic in recent times has impacted several countries, altering the delivery mode of education in the world everywhere. There is an urgent need for incorporating new technologies to deal with challenges risen due to this pandemic [2]. To meet the existing challenges due to the outbreak of COVID-19, it has all the more become very critical that HEIs focus on the providing quality services. The sustainability of HEIs also has become in danger due to the pandemic. Therefore, it is important to search for unique methods to leverage infrastructure in order to retain the quality of services. For example, the sustainability of the institutes can be realized by fitting the prerequisite software, hardware, and storage with deployment of cloud computing [3]. Moreover, considering user's willingness and intention to adopt and leverage new technologies is also very important [4]. The main benefit that cloud computing offers is virtual collaborative learning, which makes it useful for teachers and students, aiming to incorporate computer-based technologies in pedagogies to enhance cooperative learning styles [5] offering more motivation to students. Cloud computing also provides e-learning platforms, capabilities such as monitoring and archiving data on cloud [6].

In the presence of COVID-19, several schools, colleges and institutions are under lockdown or have been forced to provide online education. In here, cloud computing offers an idyllic prospect to drop the

IT expenses of HEI. Cloud computing provides an excellent platform for educators to improve their teaching practices and productivity [7]. Cloud computing technology not only saves costs, but also the power, due to the simultaneous usage of infrastructure by several stakeholders for the purposes of teaching, learning, and research [8]. However, the first-hand requirement for the HEIs is to understand the successful implementation of cloud computing and provisioning of cloud-based education [9]. In the past, several studies on successful deployment of cloud computing have been tried, implemented and tested in developing nations. Interestingly, research on cloud computing in HEI settings in emergent countries are limited [10], such as in Taiwan. Cloud computing technology offers benefits to both teachers as well as students. It enables technology to archive data, cooperate on projects and distribute resources in a virtual manner [11]. Thus, it can be used remotely by users and they can access online resources on devices irrespective of time, and location. The COVID-19 pandemic has affected education in 188 nations as of April 2020. Cloud computing, part of the 4th industrial revolution (Industry 4.0), as a technology has the power to enable education notwithstanding the pandemic difficulties [12]. Thus, cloud computing acts as an essential solution for HEIs in such times.

2. Cloud Computing, It's Service Delivery and Deployment Models

The conventional processing infrastructure is becoming pricier and tougher to manage, with a substantial rise in data size and online users. Past computing techniques are inefficient for retrieving data everyplace and at any time. That is why, a need has risen to archive data using an external storage infrastructure. Moreover, with the increase in the number of users on Internet, video conferencing, and related technologies, the user data cannot be handled using traditional computing [13]. This is where cloud computing comes into picture, using which it has become possible to manage the volume, variety and availability of data in a more efficient and scalable way. Cloud is a huge multifaceted system which is made up of numerous end users, cloud service providers, physical hardware machines, internet latency, service brokers, bandwidth, scheduling algorithms, and storage capabilities etc. [14].

National Institute of Standards and Technology (NIST) described cloud computing as a technology model which facilitates "convenient, resource pooling, ubiquitous, on-demand access which can be easily delivered with different types of service provider interaction" [15]. It follows a simple simple "pay as you go (PAYG) model, where one needs to only pay for the services they've used [16]. Using this approach, the costs can be highly reduced by providing infrastructure. The end user has the option to select all the hardware specifications from the type of CPU, memory, hard ware, OS, networking, access control, to any supplementary software that might be needed in the infrastructure. Therefore, the infrastructure is provisioned on an on-demand basis to the stakeholders. Cloud computing uses virtualization to provision infrastructure to the end users. Some of the main features of cloud are its feasibility, availability, and scalability, which is also cost-effective, convenient, permeating, multiuser, elastic, and stable. The deployment models and the service delivery models are described in the table below (Table 1) [17-19].

Table 1. Service delivery models and the deployment models.

Service delivery models	Four deployment models
Infrastructure as a Service (IaaS) – It is cloud based system which provides the users virtually with infrastructure components such as storage, power processing and networking elements [19].	**Public** – This model gives open access of infrastructure unrestricted to the public. Several corporations, education, or government bodies own public clouds. Therefore, multiple stakeholders may own or use public cloud at the same time [17].
Platform as a Services (PaaS) – It is applicable for users who intend to deploy their own applications [19].	**Private** – When computing operates within the data center of a corporation, it is private cloud. The business units of the organization are given have exclusive rights to access the infrastructure only within that organization [17].

Software as a Service (SaaS) – It is a cloud-based system, where users are presented with the application(s) only [19].	**Hybrid** – It is the integration of two or more clouds (public, private or community) [17].
Computing as a Service (CaaS) – It is a cloud-based system which provides access to raw computing power on virtual servers such as EC2 service, Amazons [20].	**Community** – In this model, the cloud resources are shared and used by several organizations at the same time [17].
Security as a service (also called as (SECaaS)) – It includes data security services such as anti-malware and spam filtering for email (ex. Google's Postini) and filtering of Internet content [21].	**Virtual private cloud** – It is a semi-private cloud deployment model, which has less infrastructure. It is based on virtual private network (VPN) [17].

Cloud server stacks are used where the end user is at the front end and server lies at the back end. The services exist in middleware of the cloud server stack. The application lies at the top level, which delivers the application virtually to the client on the front end. The end users do not need to install any software, and need to pay on the go as per their usage [18]. The cloud computing services model shown in Figure 1 is adapted from the works of Mathew [20].

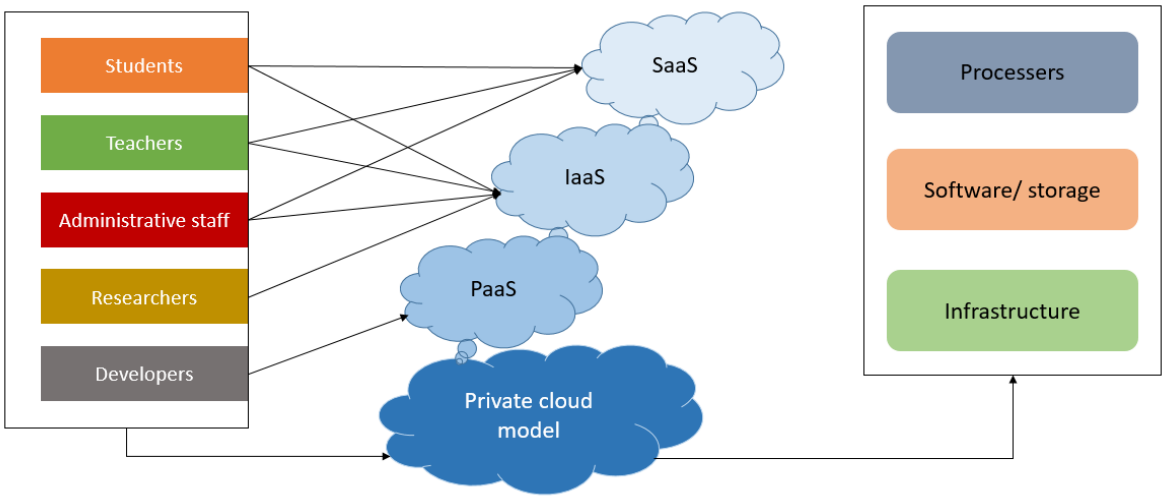

Figure 1. Cloud computing service models suitable in a university setting (adapted, Mathew, 2012).

To use the services provided by cloud technology, the universities and HEIs first need to identify their requirements. There are several cloud services which can deployed in the education settings. Figure 1 shows the private cloud architecture that can be applicable for educational settings. HEIs can deploy their own private cloud by leveraging their existing resources. Interestingly, it is also possible that several universities come together and deploy a hybrid cloud called as 'educational cloud'. In this kind of model, all these universities can share resources from various universities which choose to be a part of the hybrid cloud. Private cloud can utilize the local network, while the educational cloud can use public networks to access the functions provided by both the cloud models [20].

3. Applications of Cloud Computing in Education

3.1. Cloud Rendering

Conventional modes of online education such as live instruction and multimedia are proving inadequate for modern experimental education needs. The aim of experimental education is to upgrade observation and operation through practice – *'learning by doing'* approach. This method enables students to remotely conduct experiments at the educational facilities using Virtual Reality technology [22] such as the Virtual Chemical Vapor Deposition (CVD) Learning Platform [23], RoboUALab [24, 25] etc. Virtual reality (VR) is a simulated environment in which a realistic looking virtual world that can respond to a user's input is created with the use of computer graphics. Unfortunately, traditional end-computing techniques have seen to largely increase the computational costs. Real-time 3D rendering and interaction are very crucial for virtual reality (VR) experimental education. As there might be several complex experimental scenes in a fully capable education system, there is a need for a dynamic universal system which is able to support mobile devices and terminals with limited storage capacities and low level of processing power. Zhang et al. [26] proposed a cloud-to-end rendering and storage system to mitigate these issues and provide high-quality educational experiences with low latency. They divided the experimental scenes into two parts: background and interactive models. Thereafter, using cloud rendering technology [27], they rendered the background simulations. The computational results from the rendering process are then transferred to the end terminal using real-time message protocol (RTMP) [28]. For the interactive models, they used lightweight rendering. Lastly, both the rendering results are combined at the end terminal. The lightweight rendering made use of a terminal-oriented adaptive algorithm to transfer the models after rendering, based on the processing power and network latency. They also proposed an enhanced version of 3D-warping and hole-filling algorithm that significantly enhanced the image quality when the user's viewpoint changed at the time of conducting experiments. The results of their study indicated that their proposed system rendered 3D experimental education scenes with high image fidelity and low latency [26].

3.2. Gamification

Gamification has gained an immense attention in new teaching methods due to its ability of improving the process of learning among students. The use of game-like environments enhances the motivation for learning and improves problem solving abilities in students [29]. In the near future, gamification will surpass benefits of the traditional way of learning leading to technical challenges such as upgradation of learning modules and scalability. Hakak et al. [30] in their work have attempted to mitigate these issues using the cloud computing technology. It can leverage the infrastructure for creating games with motivational and learning outcomes [30]. To enhance the educational learning, Simões developed an architecture based on K-6 learning [29]. The K-6 environment offered internet-based services to HEIs. Morschheuser and Hamari [31] carried out a study, in which they offered strategies. The main goal was to introduce the big picture of developing a gamification environment. In all, 7 requirements were identified, that were supposed to be used for educational purposes, which are motivation, clarity of goals, testing ideas, monitor cheating scenario, optimize tasks for long-term progress, and overall lose/win results of games. Similarly, Hakak et al. [30] identified five key elements of motivation, small tasks, reward incentives, task design and game identity for incorporating gamification in education. They proposed that several cloud computing platforms can transcend gamification to a higher level and enhance its effects on individuals. Some examples are affective computing, distributed computing, and cloud computing. It was also found that almost all of the game content was related to Maths and Treatment. They introduced a one application that served as an authentic foundation for gamification.

3.3. Collaborative E-learning

Cloud computing has profoundly facilitated the use of online collaborative learning engagements in the field of education. Al-Samarraie and Saeed in their review of literature categorized the collaborative tools as Learning Management System (LMS) tools, synchronized tools, and social media tools [32].

They found cloud computing tools were indeed used for collaborative learning tasks under the umbrella of editing, sharing, discussion, and communication. A survey was carried out on 170 IT students in a private Malaysian university also supported the student's willingness to continue using cloud e-learning application in their studies [33]. The students were tested for one trimester to assess their experience of using Cloud e-learning applications. Cloud based e-learning incorporates the usage of cloud computing in the field of e-learning where all the processing infrastructure resources can be engaged as e-learning offerings [4]. In another study, it was anticipated that Google Apps aids collaborative learning process through evaluations carried out by group members' during discussion. It also facilitated coordination between group members through the techniques of idea sharing, case studies, presentations, team problem-solving, and role playing. When less restrictions are placed on team discussions, such tools can improve the learning effectiveness of students as they explore concepts and monitor their individual progress on their own [32]. It was also found that social networking tools mitigate barriers coupled with students' coming from varied experiences and educations when using LMS tools alone. Moreover, e-learning platforms based on cloud technology in schools has transformed into a shareable, flexible, content-reusable, and scalable learning methodology very user friendly for students [33].

3.4. Mobile Cloud Computing

Due to the incorporation of mobiles [34] in everyday lives, individuals can fetch information at their fingertips anytime, in anyway irrespective of their location [35]. The exponential advancements in mobile technology and developments in cloud computing have created new opportunities for mobile learning (m-learning). M-learning is a part of the learning process in education which enables accessible learning and is a viable solution for a substantial value addition in the field of education. M-learning facilitates the learning process by provisioning ubiquitous cloud services, using which the learners can access information using handheld devices, including mobile phones and personal digital assistants [36]. In their paper [37] developed a multimodal, interactive, cloud-based m-learning software using which students are able to interact based on their specific preferred learning styles. This tool improved the learning capabilities of students with special needs by around 30% using customizations in the functionalities to meet their learning goals. Using cloud computing and mobile platforms, it was possible to integrate them with the mobile environment to mitigate the limitations of mobile [38]. Mobile cloud computing is often termed as "an integration of cloud computing technology with mobile devices to make the mobile devices resource-full in terms of computational power, memory, storage, energy, and context awareness" [39]. M-learning technology based on cloud computing standardizes the learning processes of individuals [40] as well as individuals with special educational needs [41]. Therefore, mobile technologies have opened new avenues that HEIs can leverage to provide unique modes of learning. Recently, several educational bodies have started incorporating m-learning services as essential parts of their teaching systems.

4. Challenges of Cloud Computing in Educational Settings

Even though cloud computing offers several benefits for improving the efficiency, cost and convenience for the universities and HEIs, it does not exist without some limitations [42]. For example, the main challenge of cloud computing is the risk related to data protection, security and retaining its integrity. Security and protection of sensitive data is very important to the specifically the Research and Development department of universities, which deals with a lot of intellectual property, patents, etc. Moreover, it is not possible to run all the applications on cloud systems. Also, there is a lack of complete information and not all the universities are totally aware of the benefits that cloud computing has to offer. So, the readiness of the universities in terms of cloud computing, still remains questionable. It also adds up to the lack of confidence in the end users who are part of the universities in different capacities such as students, teachers, teachers, administrative staff, etc. Lastly, speed and lack of suitable Internet facilities present in the universities can affect smooth functioning of the working methods [43]. Therefore, cloud computing in the context of educational settings and HEIs is still in its nascent phase and has a lot of future potential [42].

5. Conclusion

In this paper, we looked at how cloud computing technology can be applied in the education settings. It has become an urgent due to the COVID-19 pandemic, as many schools, colleges and universities have been forced to provide online education. Cloud computing plays an ideal role here which lowers the IT costs of HEI. Cloud computing also provides an excellent platform for educators to improve their teaching practices and productivity. It can also motivate the students by following an experiential education approach, using unique gaming techniques or collaborative e-learning platforms. Cloud computing technology saves IT costs and also the energy output. Moreover, the same cloud infrastructure can be exploited by a several universities for the purposes of teaching, learning, and research at the same time by deploying an educational cloud model. We also looked at some of the challenges that the educational settings might face while deploying cloud computing models in their schools, colleges or universities.

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