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Application of Cloud Technologies in Science Education

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Abstract

The use of cloud computing in science education is an emerging trend that enables access to online services anywhere, assuring scalability and cost savings in contrast to the conventional computational structure that requires both hardware and software to be physically kept on organizations' premises with requisite technical support. Cloud computing, accessible via a network, provides a variety of virtual resources (hardware, software, and services) to provide science teachers and students with tools to use virtual computing resources (Virtual Machines) for lectures and labs on demand depending on their needs. Universities are already using cloud computing to outsource email services and data storage, or adopt high scale massive open online courses (MOOCs), but it remains largely underused and can offer many other e-learning services that are computer-intensive and well-suited to online education (including video streaming, simulations or virtual worlds). Cloud computing also brings new technical risks related to security, compatibility and/or interoperability. Adopting cloud technologies in science education presents new challenges to educational institutions how to identify such opportunities for pedagogical uses. Cloud computing is a significant alternative for educational institutions that is still underutilized, but its advantages hugely outweigh the disadvantages and adopting the new applications in science education is an exciting opportunity not to be passed over. This presentation will define the basic cloud computing concepts, models, benefits and risks. We will explore some applications of cloud technologies in undergraduate STEM education at CUNY (City University of New York).

Keywords: science education, cloud computing, e-learning, online education.

1. Introduction

While information and communication technologies (ICT) applications for online and distance education have a long tradition and can hardly be defined as an innovation, the coronavirus outbreak in 2020 induced a paradigm shift in the entire educational system worldwide by reforming the teaching and learning practices practically overnight. Suddenly, the whole stream of education - a mix of traditional (in-class) and online education - became fully online. Both educators and learners had to learn new platforms, on the fly, and adapt the educational practices and pedagogy to match the new reality. Indeed attempts to use the Web as media for undergraduate, graduate and post-graduate education had been made since the late 1990s but it was the COVID-19 pandemic that made it a necessity. Nevertheless, the need for online schooling was formed by social and technological factors long before the pandemic. On the technological side, the main driving force was ICT development (Wi-Fi, 5G, Web 2.0) allowing the sustained transfer of large amounts of digital data and manipulation of these data in real time. In addition the availability of cheap and powerful Web-enabled devices gave life to the concept *Bring Your Own Device* (BYOD), liberating education from solely in-class format. On the social side the propel came from movement for liberating education by offering free online educational content via Massive Open Online Courses (MOOCs) and providing affordable and free educational materials via Open Educational Resources (OER) repositories. According to the National Center for Education Statistics, even before the pandemics more than 70% of American educational Institutions used some form of distance and online learning [1].

The support for intensive e-learning with OER requires educational infrastructure with high elasticity and agility. That is even more true for science education which is based on staged engineering design. In addition, science education benefits from real-time collaboration and peer-learning. However expanding local infrastructure is expensive and time consuming, while implementing cloud computing can add elasticity and agility to existing infrastructure by providing needed resources (computer power, storage) on demand, on-time, at reasonable price and under strict quality of service obligation. Consequently many educational institutions seek to establish hybrid local-cloud learning environments, in which the cloud guarantees expandability of the infrastructure, but the steering of the educational process remains the university's obligation. In this paper we will review the main characteristics and features of cloud computing and the applicability of various cloud frameworks for science education in a context of principles of STEM education.

2. Cloud computing concepts

Cloud computing is a business-oriented model of computing in which the users rent or subscribe for the needed resources (computational power, storage and applications/software) from the cloud provider, who in turn ensures the quality of service (QOS) necessary to guarantee reliability, availability and performance of rented/subscribed resources. That feature is fundamental for technology heavy-learning, when the success of a course depends on stable and educational infrastructure. In the core of the cloud are virtualization of necessary resources and virtualization of implemented services. The latter are the handlers which allow users to access the cloud resources: storage/disk space, computational power, applications/software. Consequently, cloud services include: Software as a service (SaaS) - allowing users to apply software installed on virtual computer by vendor and not locally; Platform as a service (PaaS) - permitting users to employ different hardware and software platforms; Desktop as a service (DaaS) - providing local desktops; Big Data as a service (BDaaS) - allowing virtual storage; and Infrastructure as a service (IaaS) which is an analog of Data Center on-demand. According to Metz [2], four different deployment models for cloud computing have been outlined by NIST: Private cloud, Public cloud, Hybrid cloud, and Community cloud. In higher education the mostly widely used services are DaaS, PaaS and SaaS along with data services.

3. Application of cloud technologies in science education

In this section we will explore some cloud frameworks used in science education. Since the type of education is a governing factor, we will evaluate cloud frameworks in terms of their response to the principles of STEM education to integrating technology, reaching across disciplines, and bringing project-focused tasks [2].

3.1 Via basic cloud frameworks and video conferencing communication tools

Many large cloud providers support specifically developed educational cloud frameworks combining popular tools and services suitable for education. The simplest frameworks are in fact expansions of already popular office suite software enriched with features that enable support sharing and collaboration. Google's GCP offers Google Workspace (previous G-Suite). Microsoft Azure offers Office 365 Education with similar functionality. Other popular cloud office type frameworks are Zoho Office suite, Hancom Office, LiveDocuments and some others. These frameworks support manipulations of documents, presentations, data sharing, communication, team work, and some assignments and class management. Because of the native support for sharing and collaboration, these frameworks are appropriate and often used for learning when students work on individual assignments as part of group projects and the results are summarized in a shared report. For example, Weibel [3] describes the use of Google Drive for an online physical chemistry learning laboratory to communicate basic data and applications and to support a shared lab journal; in addition students can assess the final results and make comments on the content. E-mail is used for submission of final lab report. Apart from their simplicity and gentle learning curve the main advantage of office-like frameworks are their applicability to basic education in different science disciplines, support for project-based tasks and direct integration of technology in education. However office like frameworks are not the best match for high tech models of learning like inquiry-based learning, game-based learning or flipped-class learning.

Video conferencing software has emerged as a worldwide standard for conducting remote lectures. The most popular are Microsoft Office Education level 2 Teams, Cisco's WebEx, and Zoom Video Communications. Their learning curve is not steep, but may require training to use such features as whiteboard and break rooms to name a few. However, apart from factors like insufficient network their main shortcomings are security issues, background noises, and limited pedagogical resources [4].

3.2 Via advanced cloud educational frameworks

The STEM learning principles mentioned above require project-based lab work, strong collaboration among peers and engineering design of learning process. The central challenges for online hands-on science education are how to assess the learning outcomes beyond using quizzes and how to present a wide scope of lab activities. For the latter, the cloud frameworks focused on virtualization, such as Amazon Virtual Computing Lab (VCL) or Apache VCL are the best suited. For instance Ali and Ullah explored the features of different 3D virtual lab for theoretical chemistry courses [5]. In biology, Abramov and his colleagues use virtual reality for biotechnological lab development [6]. Other services such as Data Simple Storage Service (DS3) and Elastic Compute Cloud (EC2) are often used in design of online courses in computer science and mathematics. IBM's education frameworks InfoSphere and BigInsights support Apache Hadoop on cloud and are being used in courses in Big Data.

3.3 Via third party advanced frameworks

Third party frameworks are specialized implementations designed to support different models of advanced education. The most popular cloud application is JupyterHub which plays a significant role in democratizing research-based post-graduate education. Many research universities have already adopted JupyterHub to provide access to high performance computing resources via cloud for graduate and undergraduate education. For instance Georgia State University has deployed JupyterHub for their instructional cluster, Data Intensive Computing Environment (DICE), which was adopted into Big Data Programming and Scientific Computing courses [7]. Ngo and colleagues used JH framework to design cloud classes in parallel and distributed computing on the undergraduate level [8]. A similar project called "Open Research Infrastructure" is in progress at the CUNY High Performance Computing Center.

4. Application of Cloud Computing at CUNY

Application of cloud technologies is vital to increase collective leaning and improve quality of education across the City University of New York (CUNY), a conglomerate of 26 colleges and more than 100 institutes and research centers. Apart from Office 365 Education, CUNY provides Dropbox, Dropbox Paper, and Adobe Creative Cloud to all CUNY students, faculty and staff. The distance teaching CUNY switched to at the end of March, 2020, uses Zoom for Education to allow faculty to conduct lectures. In addition the different campuses use basic cloud frameworks for the needs of online education and research. The flagship City College of New York (CCNY) received an NSF grant to develop a cloud processing of latency- and capacity-sensitive mobile applications across network domains and testbeds. A cloud-based lab is a pilot project currently developed at the e-Learning Center at the Borough of Manhattan Community College (BMCC). The College of Staten Island (CSI) developed a *Physics For Everyone* cloud assisted course - lectures, problem-solving exercises, and labs - to be launched in Spring 2021.

5. Conclusion

Cloud based science education can provide teachers and students with tools for lectures and labs on demand depending on their needs. Adopting cloud computing in science educations - via office-like suites, virtual labs and/or specialized frameworks – is an emerging trend that enables educational institutions with new opportunities for pedagogical use and tools to provide e-learning.

6. References

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