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Cloud-Based Learning Environment to Leverage Software Engineering Education

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Abstract: Cloud computing is already being used successfully in several sectors including education. In the education sector, the learning environment plays a vital role in enabling students to achieve successful outcomes during their programme of study. The scope of each learning environment depends greatly on the requirements of the particular study programme. This study looks at the advantages that cloud computing can bring to education generally and specifically to the practical provisions of the learning environment for software engineering. One of the key elements of that learning environment is the computing laboratory (lab) as this is where students hone their practical skills so that they are ready for the next step after graduation. The setup, configuration and use of the computing lab is very important for software engineering students, so finding a way to make lab facilities readily available to students would undoubtedly enhance their learning experience. In this regard, cloud computing can provide effective technological support to overcome the limitations of existing lab facilities for software engineering courses, particularly in developing countries. For instance, the requisite tools for lab courses can be hosted in the cloud and via a suitable networked system, students can access them to practise, build, develop and deploy applications. These tools can be distributed and managed across sites and also shared with more remote satellite institutions, thereby improving the quality of resources available to all students regardless of location.

Key words: Cloud computing, software engineering, learning environment, e-Technologies in education, new trends in education

INTRODUCTION

With the huge growth in educational content, resources and number of students, a suitable environment need to be adopted that can accommodate such an advancement in this sector. One of the key issues in developing a proper educational environment is to ensure the presence of reliable and scalable educational applications and tools. One of the technologies that would enable such an environment is termed as cloud computing and it is meant to aid in providing a highly scalable IT platform and infrastructure. Cloud computing infrastructure and services can add value to the existing learning environment of an educational system.

According to the technology experts most institutions and companies will move to the cloud by 2020 and this would help to eliminate the dependency on individual desktop based systems (Anderson and Rainie, 2010). When it comes to education, researchers argued that providing an effective learning environment in educational institutions is essential (Truong and Dustdar, 2011). Therefore, it is crucial to provide an effective learning environment for both faculty and students. Cloud computing has been used in different practices to resolve various issues. It is clear from the presented information that there are various ways of defining cloud computing. Cloud computing is an Internet based technology which provides computational resources via computer network and offers scalable, flexible and on demand services to the end users by centralizing the storage and network bandwidth besides the memory processing (Cubillo *et al*., 2011).

Cloud computing consists of large data centers which permit sharing of resources across hosted applications that lead to economies of scale at both hardware and software level (Venkatesa *et al*., 2016). Cloud technology has been receiving a lot of attention in various sectors. It is being used to eliminate various limitations and to resolve several issues in the public sector such as government and healthcare. Not only that, cloud computing in educational institutions has been getting a lot of attention as well. In this research, cloud computing will be explored in enhancing the learning environment of Software Engineering (SE) students via hosting the necessary tools of the laboratory courses on the cloud. As a result, SE students will be able to access the tools anytime anywhere without any restrictions such as the unavailability of labs.

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Cloud computing; an overview: Public sector organizations can gain enormous benefits by utilizing cloud infrastructure and services to deliver their Information and Communication Technology (ICT) environments. These organizations always aim to deliver better and improved services to their customers. Since, the global recession especially its financial impact has put additional pressure on the public sector, finding a way to overcome its challenges was a much needed task. CIOs of the various sections of the public sectors such as healthcare, government and education were quick to explore new approaches to increase the operational efficiency and productivity as well as lowering cost. From there, cloud computing emerged to aid in achieving their goals. Cloud computing would help the CIOs to perform the required balancing to resolve the critical tradeoffs (Macias and Thomas, 2011).

The researchers also mentioned that cloud technology and its services should be explored and adopted in various sectors such as government, healthcare and education. For instance, the US government established a cloud policy by devoting a large portion of the $80 billion ICT annual budget for future cloud solutions. In the next few year, the federal US Government plans to use the virtualization concept in their data centers to consolidate them from 2000 to about 1200 with their original number being 432 in 1998. Similarly, the Canadian Government announced that it would shut down more than 90% of their data centers in August 2011 (Macias and Thomas, 2011).

A study was conducted to show the status of using cloud computing in the public sector of the Asia Pacific region (Chandraasekaran and Kapoor, 2011). The report showed that cloud computing has taken firm roots in the Asia Pacific region. Within the report, a regional survey was presented that showed the cloud adoption in Asia pacific region. The survey showed that 21% of respondents have adopted cloud services in a variety of its forms. For instance, China was building a city-sized cloud computing and office complex as a mega data center and India had implemented some of the critical applications in the cloud to improve the nation's educational system including virtual learning environment and student information system. From the report, cloud computing has prompted the governments of Asia Pacific to access a new delivery model (Chandraasekaran and Kapoor, 2011). Cloud computing is one of the latest technologies that have had a significant impact on various sectors (Pandian and Kasiviswanathan, 2011). It is highly scalable and can be used to create virtualized resources. The interesting thing with the cloud is that the users are not necessarily required to have special knowledge to deal with the applications that have been hosted on them. They can easily communicate with the applications throughout the internet.

Considering the limited budgets, educators can gain benefits in many ways from utilizing cloud computing (Ghazizadeh, 2012). The services and storages of cloud computing can be provided over the Internet. The users would not need to install the software in their own computer, instead they just need the Internet to use the applications that are hosted in the cloud. Multiple servers might be utilized to store applications and data which can be accessed using the internet.

Cloud computing; important characteristics: Important characteristics of cloud computing technology can be articulated in the following points (Jadeja and Modi, 2012):

- The user can access data and the applications via browser's help anytime, anywhere especially as the cloud's infrastructure is generally provided by third parties
- Cloud allows for efficient resources utilization
- Maintenance of the applications in the cloud is easy
- Cloud is scalable
- Performance monitoring is easily executed
- Cloud is generally pay per use which makes it affordable
- The implementation of the cloud requires less IT skills
- Cloud's security can be better than the security of traditional systems

MATERIALS AND METHODS

Cloud computing services: The three main services offered by the cloud are:

Infrastructure as a Service (IaaS): It means renting computer hardware such as servers, storage, networking technology and data center space instead of buying and installing it in their own data center. The entire computer infrastructure such as virtual computers, servers and storage devices can be delivered through the internet (Pandian and Kasiviswanathan, 2011). This reflects the point that the users do not need to purchase infrastructure such as servers or network resources. The users need to pay only for the time duration that the resources are used for which means the users

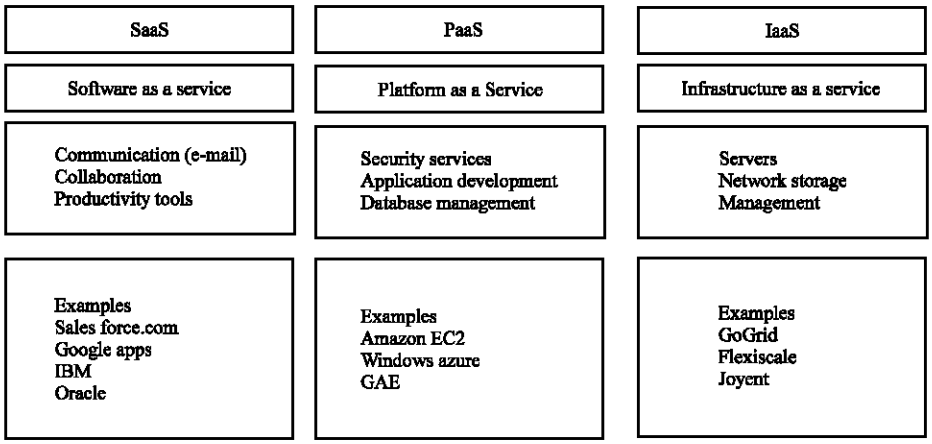

Fig. 1: Cloud computing services with associated examples

can achieve the service fast and with less cost (Jadeja and Modi, 2012; Venkatesa *et al*., 2016).

Platform as a Service (PaaS): There is a set of software and tools hosted on the servers of the cloud provider. PaaS is very useful for the developers, especially as it offers them an integrated environment that can be used to build their applications (Kuyoro *et al*., 2011). There are many services that can be delivered in PaaS such as operating system, database, development tools, web servers and other applications (Venkatesa *et al*., 2016).

Software as a Service (SaaS): This is a model of software distribution which means the applications are hosted by the service provider. These applications are made available to the customers over the internet (Kuyoro *et al*., 2011). The users are given the ability to access the hosted software through a web portal. There are various services that are available free of cost such as emails, calendars, contact lists, creation and sharing of documents and document storage (Pandian and Kasiviswanathan, 2011; Venkatesa *et al*., 2016). This point reflects the fact that these services can be easily adopted by educational institutions since many of these are free of cost as well as reliable and that would in turn give the students the motivation to enhance their ability to do more. Figure 1 shows these cloud computing services with associated examples.

Cloud computing deployment models: The main concern for deploying cloud applications is to decide what type of cloud to implement. There are three main types of cloud models that can be deployed which are public cloud, private cloud and hybrid cloud (Jadeja and Modi, 2012).

Public cloud: It provides its users the ability to access the cloud via web browser. With public clouds, users need to pay per use which means that they need to pay only for the time duration in which they use the cloud services. This is pretty much similar to the home based electricity systems where payment is only made for the amount of electricity used. This approach helps in reducing IT staff as well as operation costs.

Private cloud: It is implemented within the internal data center of organizations. The main advantage is that its management is easier, especially as the applications, data and resources will be under the organization's control compared with the public cloud where the resources and applications are managed by the service provider.

Hybrid cloud: It involves both public and private cloud. It can be adopted within any organization, especially for organizations that need intensive computing resources. These organizations can deploy a private cloud to serve their usual needs and can use the public cloud for their occasional need for the intensive computing resources.

Education for all in the cloud: In cloud-based education students have access to an e-Learning environment and online educational tools and apps. This e-learning environment complements traditional face-to-face learning and this combined approach is considered to improve student's results, learning experience, skills acquisition and knowledge (Gudanescu, 2010). Thus students who have access to a cloud-based education system benefit from the advantages offered by a blended learning environment. Thus cloud computing can introduce improvements to many existing learning environments. There are several advantages to using cloud computing

in the education sector. Yet, it would seem that scant research has been undertaken by those working in the field of education on the potential benefits of this relatively untapped resource. Many educators do not have a complete understanding of the capabilities of the growing range of new technologies that could be utilized to enhance educational infrastructure, strategies and practices, especially in relation to the learning environment itself, student's skills and the overall teaching and learning experience (Conole and Culver, 2010).

A cloud-based education system can enhance learning because it provides access to additional resources in the cloud, a virtual environment that can be accessed via a range of electronic, internet-enabled devices. The ability to use extra resources is of benefit not only to students but also to educators. In the case of students, they can access information, download teacher-created content as well as upload assignments into a cloud storage facility. Thus, there is no need to print off the assignments and this saves paper. In fact, cloud-based learning could potentially eliminate the need for paper and pen entirely as the applications available have progressed way beyond email to include a plethora of cloud-based apps that are already available and the list is growing.

As for teachers, a cloud-based learning management system can facilitate the creation of learning content, the sharing of lecture notes and other documents. Teachers can also contact students via the cloud-based educational portal and vice versa with the click of a mouse. The cloud also offers advantages to the educational institutions themselves as these organizations need to store a lot of computationally expensive information and confidential data and must be able to access and manipulate it quickly and effectively for management purposes. The cloud is secure and it can be accessed with ease from anywhere at any time by anyone who has the necessary authority to do so. Thus, cloud computing can provide important support for the educational environment.

There is evidence that users with Internet access are keen to adopt the cloud for teaching and learning. This is reflected in the findings of various studies that have been conducted based on different parameters such as ease of use, learnability, error, satisfaction, memorability and efficiency to assess the acceptance of the cloud learning environment particularly from the student's perspective. The results of these studies reveal that most students are in favour of using a cloud-based learning environment (Razak, 2009). Cloud computing allows them to share educational material, information, expertise and thoughts peer to peer. Moreover in developing countries, the shortage of lecture halls, laboratories (labs), multimedia hardware and software, skilled and capable educators and ICT-based facilities leads to an unequal distribution of quality education. The adoption of the cloud as a learning environment can help to resolve these issues. At the moment, well-known providers such as Google, Gmail, Hotmail and Yahoo are playing an important role in the education sector (Truong and Dustdar, 2011).

Several noteworthy studies in the field of cloud-based education are discussed briefly to provide a flavour of the work taking place in this exciting area of learning. For instance, Al-Noor *et al*. (2010) proposed a cloud-based educational model that can be used for ubiquitous access to educational resources throughout Bangladesh. This approach resolves some of the issues facing the current educational system in the country such as uneven access to computer-based educational resources, financial constraints and data transfer hurdles as well as management, data protection and distance education infrastructure. To mitigate similar issues in Turkey (Conole and Culver, 2010) proposed a cloud-based educational architecture that can be used across separate university buildings as shown in Fig. 1. This distributed system efficiently solves problems pertaining to delivery of resources, ease of access, ease of use, safety, finances, administration and control.

There have also been studies in Kenya, India, the Kingdom of Saudi Arabia (KSA) and China which reflects the worldwide interest in leveraging the capabilities of the cloud. For instance, Jobe (2013) proposed the Massive Open Online classes for e-Learning in the Kenyan Cloud School (KCS). The KCS offers a web-oriented instructional system for tertiary education. The proposed solution is designed to address numerous problems such as the accessibility of academic material, student's failure rates, examination assessment and management of e-Learningin the KCS. In India, a cloud-based solution known as a Collaborative Educational Management System (CEMS) is used in the education sector. This CEMS enables institutions to maintain student's academic records and personal details in a centralized database (Macias and Thomas, 2011). Cloud computing has also been providing enhanced effectiveness, elasticity, efficiency, consistency and cost-efficiency benefits in the e-Learning education system of the KSA (Tashkandi and Al-Jabri, 2015). Moreover, in China, Google has launched a technical support initiative to establish an academic cloud by entering into partnership ventures for large-scale data processing activities in the university sector in the country. One such initiative is at Tsinghua University in Beijing which acquires cloud services from Google and manages these resources by providing lab facilities (Sultan, 2010; Kalpeyeva and Mustafina, 2013; Taweel, 2012).

Cloud computing and teaching from primary to tertiary: As briefly indicated above, cloud computing has a lot to offer and this virtual network mode can facilitate all types of services (Gaur and Manuja, 2014) and bring about substantial changes in the education sector. It is anticipated that an 'education cloud' will lead to some key areas of change. Firstly, students will experience a fundamental change in their learning environment which will become more personalized. A learning management environment that is more focused on the individual can promote each student's own learning style and needs. Also, access to a cloud computing education system can improve student's independence and innovation and their ability to fully interact with their courses. It can also enhance their ability to gather information, analyse data, process their acquired knowledge and better adapt to today's information society.

For teachers, the most obvious change that will take place will relate to teaching methods and strategies. As the cloud services provided by the education cloud become more suitable for student's autonomous learning, this will make pedagogy refocus to become more student-centred and student-directed. It follows that with the support of the cloud, a cooperative networked platform will lead to the inquiry-teaching model and the collaboration model being more extensively applied. There will also be a change in the nature of the exchange between teachers as it will enable them to work anywhere and allow them to more easily cooperate and share their data and documentation via various devices. The cloud will also bring about change in the management of education at the intra and inter institutional level. Education management can use a cloud service suite of applications to build a more proficient and responsive teaching and management system. Not only can such a system facilitate communication between teachers as mentioned above, it can also facilitate communication between managers and teachers and enable schools in remote areas to establish good communication and support links with schools in developed areas which will of course be of indirect benefit to students and their families as well as teachers.

The last two related changes to mention will also be of benefit to students and teachers alike and these changes relate to resources and funding and investment. Due to the imbalance in economic development, investment in education in many remote areas is much lower than that in areas that are more urbanized. Thus education resources in economically underdeveloped areas are often completely inadequate whether that be equipment, infrastructure or expertise. However, by implementing education cloud applications, it should be possible for economically developed regions to share such resources with their economically underdeveloped counterparts. In this way, the education cloud will further promote impartiality in the provision of education resources. Moreover, using an education cloud can reduce the purchase and maintenance costs of hardware such as computers and networks for schools and other educational institutions. Also, educational organizations could enter into agreements with firms that can provide cloud services at reasonable cost; even a bottom-end configured computer can run a huge amount of calculations for the purposes of scientific computing. Indeed, scientific and lab-based education is where the cloud can come into its own.

The cloud and the college computing lab: The ability to conduct lab-based hands-on experiments is an essential part of many courses such as software engineering as it enables college students to improve their practical skills and make them job-ready. Since lab rig resources are often in scarce supply, a lot of attention has focused on finding ways to make such resources available online to students, educators, administrators, etc. so that they can book, collect data from or manage a lab. Indeed in recent years, the importance of experiment-based teaching and learning has been recognized by more and more universities and colleges in China. Many labs have been set up with similar rigs simultaneously but they are then usually managed in a non-joined-up way. As they are often located in different rooms or buildings this means that they are managed without due attention being paid to resource sharing and integration. Although, computing power can be shared up to a point among labs through features such as file sharing, remote login access, etc., the performance of the system and thus the user experience, especially for those teaching and studying multimedia, are still inadequate overall due to incomplete data, non-real-time delivery and inconsistent user interfaces. Also, when administrators have to deal with upgrades to hardware or software and need to rapidly counteract cyber attacks, they have to spend a lot of time and energy to restore the experimental teaching environment (Zhang *et al*., 2015).

Moreover, lab management systems for college labs are usually intranet-based so they cannot provide a 24 h service to their users and the service that is provided has to be carefully scheduled. The support staff of each lab have to produce a blank calendar at the start of every semester that they give to lecturers who need to determine the schedule of experiments and book slots. When the schedule is agreed, the students need to be informed. This process is laborious for both support staff

and lecturers and the nature of the process means that when amendments to the schedule are made, the information given students can quickly become out of date. In light of the foregoing issues there has been a growing trend since the beginning of the last decade to make labs more open and easier to access and several research studies have been undertaken to this end.

For instance, a conceptual model and technical design for an online rig booking system for scarce rig resources was presented by Gallardo *et al*. (2011). Several solutions to improve access to online virtual labs were discussed by Mateos *et al*. (2012) and the authors then proposed their own solution based on the SCORM standard SCORM in 2015. However, neither of the proposals have been implemented, so it is not possible to evaluate their actual effectiveness. Some Learning Management System (LMS) frameworks have been proposed such as those in (MIT, 2016; MOODLE, 2015; MRBS, 2016) and plenty of systems have been created as modules or plug-ins based on these frameworks during the past decade or so. Such frameworks can serve as the basis for basic LMSs but it is difficult to connect them seamlessly to an existing lab environment. The design and implementation of a virtual lab for network security education was proposed by Xu *et al*. (2014) and a virtual system for network administrator education was presented by Tateiwa *et al*. (2008). Special-purpose systems can be a good fit for particular courses or training objectives but this of course means that are not going to be suitable for a general-purpose situation. An experimental teaching and management system called Open Laboratory Access (OLA) which is based on cloud computing has been designed and implemented (Zhang *et al*., 2015). By using OLA, lecturers can plan experiments and issue schedules. The students can then book the experimental rigs they need online and gain access to the lab on schedule then power up their reserved rig by using their student ID card to authenticate their identity and start their experiment. After the students have finished their experiment, the lecturers can get access to the results and any statistical data entirely online and then evaluate and grade the assignments. In the OLA, thin-clients are used as terminals for software-based hands-on experiments instead of a PC to reduce the cost of the lab setup and maintenance and this strategy also provides a consistent user experience.

Leveraging cloud computing for education: The deployment of traditional computing services in the cloud can benefit the education sector in several ways as explained by Gaur and Manuja (2014). Essentially, cloud computing can be leveraged to the advantage of the education sector in four key ways. Firstly, it can be used to streamline and lower the capital expenses associated with the provision of Information Technology (IT). The shifting of the deployment model from an on-site to a cloud model can simplify a lot of convoluted processes involved in running an IT infrastructure and thus reduce overall capital expenditure which would then enable educational institutions to use their limited financial resources to better provide and improve their core educational services. Secondly, the use of the cloud can facilitate the aggregation of the demand for and the sharing of services. Indeed, the economies of the cloud rely entirely on aggregation. This is particularly the case for the large public cloud players that pool huge amounts of computing, storage and networking power and then allocate the same to meet customer demand which is growing exponentially. The multi-tenant model of cloud computing helps cloud service providers to reduce the overall costs involved in the provision of resources and to offer them on a pay-per-use basis which is of ultimate benefit to the end-user.

Thirdly, the cloud can be leveraged to improve institutional responsiveness by enabling the distribution of IT facilities throughout a campus and beyond. If a lecturer sets his/her students the task of analysing the efficacy of a novel algorithm on different platforms, performing this assignment by using an on-site IT infrastructure is very likely to be a burdensome process that will use up a lot of time and resources so the platform as a service or PaaS model of cloud computing is an ideal way to resolve those issues. Last but not least, the cloud can help to make IT greener. Cloud computing can help to reduce energy use through economies of scale and the well-managed intensive use of hardware. For instance, in the multi-tenant model of the cloud, processing capacity can be shared efficiently across many end-users which can help to reduce the carbon footprint.

RESULTS AND DISCUSSION

Recommended learning environment for software engineering studies: In the 21st century, students can no longer be restricted to traditional teaching methods. An example of this is the lecturer lecturing and the student listening in the classroom. This statement is also supported by other researcher who stated that "The classical mode of teaching may not entice all the types of learners. In addition to this, making the physical presence mandatory in the class may not contribute towards achieving the teaching objective and learning outcome" Patil *et al*. (2011) Would these claims be true for Software engineering majors? This is a concern that has to be addressed.

Since, this research is focused on software engineering majors, the main issue which this research is trying to address is related to the availability of lab software and tools, especially as Software engineering programme requires their intensive use. This point can be elaborated by using a scenario in which a lecturer tends to use the latest version of any programming environment. The very first concern is the licensing of this application. Secondly both student and the institution's lab must be privileged with the required hardware specifications to run the application. Moreover, even if they do have the proper specifications, there is still a possibility that their operating system might not support this application. If the operating system is able to run the application, the earlier problems may still arise whenever there is an update or if a newer version of the application is to be issued. Fortunate enough, no stated issues, there is still a possibility that availability of the labs for the students and lecturers might be an obstacle as the administration has to carefully assign the lab with given specifications to a given class, let aside managing and maintaining the lab.

There is always a need of establishing a proper mechanism and availability of hi-tech facilities that allows for easy adaptation of any technological change, especially as there are rapid advancements in the software engineering field. An environment well-suited the needs of increasing number of students, lab facilities to adapt to the requirements of the new software, number of terminals meeting the needs of students and lecturers at any point of time is not easy to establish and execute. It also requires the maintenance activities to be controlled and within the estimated budget and scheduling constraints to overcome. All of these facilities require considerable investment, utilization of resources and maintenance costs for any university or institution to ensure.

Therefore, universities thinking about creating an effective teaching and learning environment for software engineering students need to consider aspects like number of required terminals, the space to place the computers, the network aspects, electricity considerations, maintenance requirements and of course the necessary hardware specifications. All of these issues should be looked carefully and definitely will consume a lot of resources like money and man power.

Clearly creating and setting up the proper learning environment especially for software engineering students is highly demanding. The scope of the SE learning environment is quite broad, however in the subsequent section we will focus on the computing laboratories and how their utility can be enhanced using cloud technology as a solution.

Cloud based education for software engineering programme: As described in one of the recent studies, computer science student's enrollment has dropped dramatically over the last few years mainly because the graduates did not match the industry's needs (Vegso, 2006). While mapping the findings, it can be safely said that since the educational sector did not advance as per expectation and that students are not satisfying the industry's needs, these issues should be addressed by applying the new approaches of teaching and learning to narrow down the gap.

One proposition to overcome this issue is to use cloud infrastructure and services. By the year 2013, cloud computing and its services would grow by six times (Ahuja and Mani, 2012). However considering the fact that future era is the era of the cloud, by integrating cloud in teaching and learning approaches, the familiarity of students to cloud technology would grow rapidly and the benefits of the cloud would thus lead to the enhancement of education.

Without a doubt, the learning environment would gain benefits from using the cloud services. One of the benefits is the privilege of hosting various types of lecture resources on the cloud such as lecture slides, tutorials, sample assignments, course notes and related videos etc. by using the SaaS services of the cloud. Software engineering learners and educators would also gain benefits from PaaS services, especially as they can build, develop and deploy their applications on this layer. An example of benefiting from PaaS is using a distributed database source easily. So it makes it clear that the cloud can certainly enhance student's understanding and outcomes as well as improve their overall learning experience.

The use of the cloud can offer highly available, accessible and reconfigurable resources. However, the software engineering learner would be prevented from dealing with the complexities of hardware and software when acquiring and managing the underlying infrastructure. North Carolina State University is a prime example when it comes to look at the advantages that would be gained by using cloud computing in a learning environment. They constructed a virtual computing laboratory while using the IBM cloud solutions. The lab gave the students the ability to allocate and access virtual machines as a specific application image such as Matlab (Vouk *et al*., 2008).

CONCLUSION

Cloud computing is emerging as an extremely useful resource in various fields not just in education. In fact, the

education sector was among the pioneers in adopting cloud computing. However, for all the stakeholders in the education sector in all parts of the world to truly gain the maximum benefit from the advantages that 'cloud education can bring, a more standardized approach is required in its application. By adopting appropriate strategies the benefits of cloud computing can be used to enhance the learning environment of all students. Moreover, the learning experience and outcomes of a typical software engineering student can be improved significantly through access to the cloud given the nature of the components of a software engineering course. For instance, the lab requirements for some such courses are highly resource-intensive so access to the cloud infrastructure would be very useful, particularly in developing countries as it could be used to host a multitude of the requisite, often expensive, tools that are essential for success in lab-driven courses. By tapping into the power of the cloud, students will be able to use the tools they need without any constraints of time, place or cost.

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