Promises and Challenges of Cloud Computing in Higher Education: A Practical Guide for Implementation

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Dynamic education environment have forced universities to adopt state-of-the-art practices to optimize both the cost and operational efficiency of their information technology platform. Cloud Computing Technology (CCT) has emerged as a meaningful technology that could contribute to this optimization by providing infrastructure and software solutions for the whole IT needs of a university via Internet. It is predicted that 2017 will mark the rapid proliferation of educational institutions transitioning to the cloud-based computing technology. This study presents the main principles and potentials of the cloud, as applied to the world of education. It discusses potential strategic benefits of this technology in education, and highlights its evolving trends. Furthermore, this study highlights key adoption factors and illustrates some of the routs that might be taken to implement cloud technology in education. Finally, this study highlights successful implementations of cloud based technology in two universities, Bryant and Roger Williams.

INTRODUCTION

Cloud computing is expanding and being adopted in numerous business domains. According to the November 2016 Forrester report, the cloud market will accelerate faster in 2017 than in previous years primarily because enterprises around the world are looking to the cloud as a viable place to run core business applications. The global public cloud market will be worth $146 billion in 2017, up from $87 billion in 2015, and is growing at a 22 percent compound annual growth rate (Boulton, 2016). Implemented properly, the technology has the real potential to enable accuracy, reliability, service enhancement, and cost reduction.

Cloud computing is different from other historical IT models in that it focuses mainly on services, rather than technology. Here, technology (storage, CPU, networking equipment) is not the service, but the building blocks for a service. The technical details are kept away from consumers of the service. Consumers can place service requests via self-service and are billed for what they use.

Universities are heavily dependent on information technology in terms of content delivery, communication, and collaboration. Today, students are demanding more information technology services from their respective institutions. Moreover, information technology is changing rapidly and has put an additional financial burden on the institutions. One of biggest challenges colleges and universities face in providing education is the lack of infrastructure, maintenance of that infrastructure (if available), and maintaining a wide range of hardware and software equipment. Cloud computing can help provide those solutions at a reasonable price.

Massive Open Online Courses (MOOCs) are cloud-based educational platforms with a promise of transforming higher education. What MOOCs demands is the need to scale services in ways that are not always predictable. MOOCs are having an impact on classroom education as well as education policies at the state and federal level. Higher educational institutions are also required to graduate more students more quickly. They must be able to service new populations and changing needs more effectively. Cloud based infrastructure provide a new ways to do just that – enabling universities to take advantage of economies of scale they could never achieve on their own.

Cloud computing is transforming the way institutions do business and serve constituents. Many higher education institutions are already taking advantage of the many benefits that cloud has to offer including cost savings, scalability**,** agility**,** and modernization. Cloud adoption in higher education institutions is considered widespread today. According to a survey of 470 higher education institutions reported on by Campus Computing in late 2014, nearly 1/3 reported having a "strategic plan" for cloud computing and about 50 percent have adopted a cloud-based collaboration system to improve information sharing across campus (Green, 2014). Those numbers are growing as more decision makers in higher education start to leverage cloud benefits.

According to a survey conducted by Edudemic, by the end of 2014, 80 percent of higher education students are expected to take coursework online. The study also reported a widespread application of cloud-based solution in higher education (Tate, 2014):

- 68 percent of institutions use (or will use) the cloud for conferencing and collaboration
- 65 percent of institutions use (or will use) the cloud for storage
- 65 percent of institutions use (or will use) the cloud for office and productivity suites
- 62 percent of institutions use (or will use) the cloud for messaging

There are huge benefits of using virtualization and cloud computing in education. For some institutions, the driving directive to "go all-in on the cloud" is a sure way to cut hardware costs. For others, the cloud will streamline operational efficiency and speed up development.

In their recent book, Cavas and Munyavi classified the various applications of cloud computing technologies in educational institutions and described the issues that needed to be solved in order to arrive at cloud education, including integration, ownership, security and assessment, and offered a holistic approach to cloud education (Cavus and Munyavi, 2016). Several other studies have identified many benefits of cloud technology in education. The shift towards cloud computing would enable educational institutions to save money and take benefit of the developing technology (Yadav, 2014, Boja , et al, 2013, Mathew, 2012, Wang and Yu Xing, 2011, Sultan, 2010). However, none suggested phases and or steps necessary for deployment of the technology in higher education institution.

Various deployment models of cloud computing make the adoption attractive for any type of educational institutions, depending on the need or usage. However, as with the introduction of other IT technologies, there are many issues to consider and overcome. It is not as easy or straightforward to "go to the cloud" as many users believe. The most impactful deployments require a detailed analysis of the users including the desired business outcomes (cost savings, speed to market, and increased service levels) and the services they need. This research discusses the three phases of cloud service adoption strategy and reviews top key factors to consider when choosing cloud services for education.

This research addresses different phases of cloud service adoption strategy and explores the many factors that may contribute to its success in the world of education. Section II provides a general

description of the technology and reviews its service models as well as its basic deployment models. Section III reviews advantages and disadvantages of CCT in higher education. Section IV discusses obstacles to rapid adoption and evaluates challenges facing educational institutions adopting this technology**.** In Section V, different phases necessary to develop and deploy the technology and key adoption factors are discussed. Section VI presents examples of two universities implementing the cloud successfully in their institutions. Finally, Section VII provides a summary and conclusion.

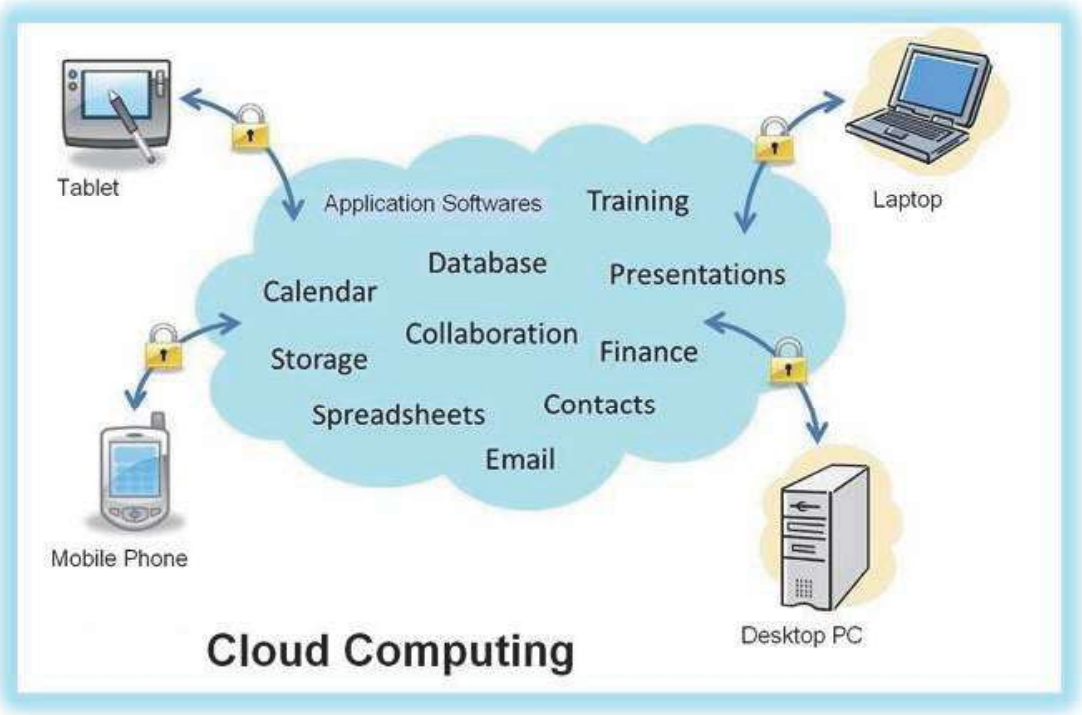
CLOUD COMPUTING

This section provides a general description of cloud computing, including the definition, its characteristics, its advantageous and disadvantageous over traditional IT, its service models, and its basic deployment models.

A. Overview of Cloud Definition

Cloud computing, in its many forms, has become an integral part of IT. The term 'cloud' has been used to refer to platforms for distributed computing- a cluster of servers, network, software, interface, etc. which are required for the user to execute a particular task. 'Computing' refers to the delivery of this cluster as a service to the user where the user can use it as and when required. The user is relieved from owning a massive computing infrastructure and requiring upfront investment in it. Rather, it allows the user to use a similar infrastructure owned by another party at his/her own discretion and pay only for the time it is being used. This pay-per-use model enables convenient and on-demand network access to a shared pool of configurable computing resources such as servers, storage, applications, and services. Clients can connect to existing physical or virtual environments using different connectors. The user readily accesses all information online in a 24/7 format and from various types of devices – desktop, laptop, tablet, and smartphone. Cloud infrastructure is an umbrella that covers both the software and the hardware necessary to provide 24/7 pay-as-you-go service. The software (applications) are delivered as services to users in a software-as-a-service (SaaS) model via the web. The hardware and system software (cloud) are used to run applications that user access and use online (Figure 1).

FIGURE 1
CLOUD COMPUTING



Source: Retrieved from Information Technology & Systems

B. Cloud Deployment Models

NIST Special Publication 800-145 identifies four Cloud Computing Deployment models (Mell and Grance, 2011):

1. Public Clouds: The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services. Public cloud services are sold on-demand, typically by the minute or hour. Customers only pay for the CPU, storage, or bandwidth they consume. It is a cost-effective way to deploy IT solutions, especially for small or medium sized businesses. Google Apps is a prominent example of a public cloud that is used by many organizations of all sizes. Leading public cloud providers include Amazon Web Services (AWS), Microsoft Azure, IBM SoftLayer, and Google Compute Engine.
2. Private Clouds: The cloud infrastructure offers many of the benefits of a public cloud computing environment and is operated solely for an organization. It may be managed by the organization or a third party and may exist on premise or off premise. Private clouds provide greater control over the cloud infrastructure, and are often suitable for larger installations.
3. Hybrid Clouds**:** A composition of a public and private cloud models with orchestration and automation between the two. A Public cloud is used for non-critical information and bursting workloads that must scale on demand, while mission-critical workloads or sensitive data and applications are kept within private clouds under the control of the organization. Hybrid cloud computing strategy enables users to capitalize on the flexibility of the cloud while still realizing value from traditional infrastructure.
4. Community Clouds**:** The cloud infrastructure is a shared cloud computing service environment that is available to a limited set of organizations or employees (such as banks or heads of trading firms). The members of the community generally share similar security, privacy, performance, and compliance requirements.

C. Cloud Service Models for Education

Cloud computing is delivered via different service model architectures. The most common models for education are: SaaS, PaaS, and IaaS. The following summarizes definitions and gives examples of each model (Matsumoto, 2012):

1. Software as a Service (**SaaS**) – Applications are deployed over a network (Web) and are accessible via browser or program interface. Since applications are offered through software on demand, they can be deployed quickly which bring ease of use and financial benefits. Examples of companies providing this type of platform are Google Apps (email, calendar, and documents), Salesforce.com, and Intuit-QuickBooks.
2. Platform as a Service (**PaaS**) – This platform provides an agile development environment that makes it easier for the user to develop applications quickly and adopt it instantly. The wait for deployment of suitable hardware and software for application is eliminated. Users can use the platform to build applications using languages, libraries, services, or tools supported by provider. Examples of companies providing this type of platform are Google App Engine, Windows Azure, and Force.com.
3. Infrastructure as a Service (**IaaS**) – This platform provides general purpose support services including infrastructure services such as database, storage capacity, networking, and other computing resources. The user has control over operating systems and deployed applications. This model is referred to as utility computing. Examples are Amazon Web Services, CenturyLink, and Rackspace.

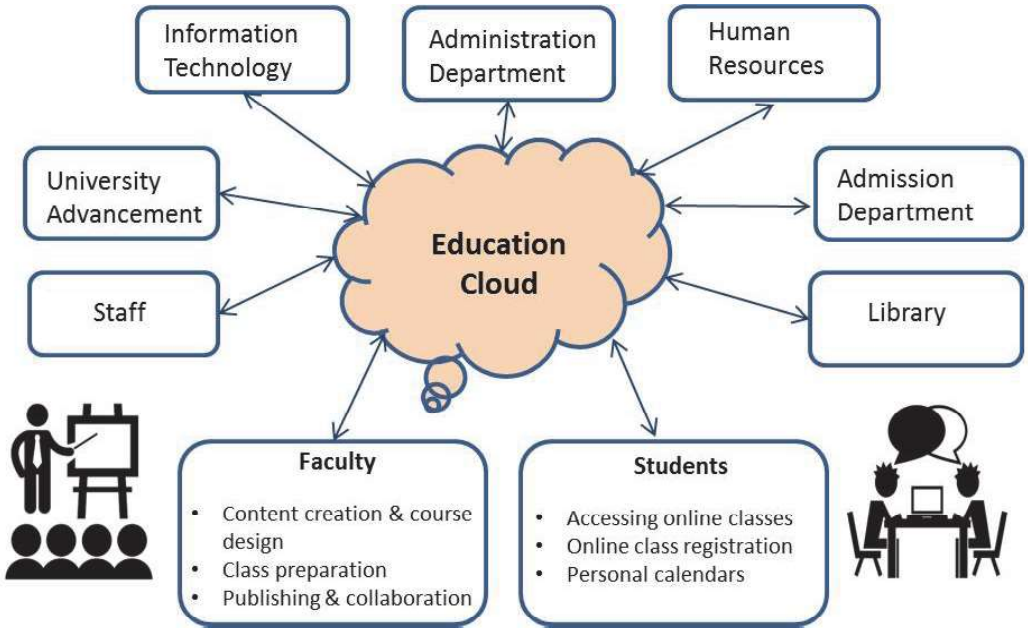
CLOUD PROMISES IN HIGHER EDUCATION

The world of education and training has always embraced new teaching methods and tools. Most of the higher educational institutions have become highly dependent on information technology in terms of content delivery, communication, and collaboration. These services are increasingly provided using Internet technologies to faculty and students and accessed from web browsers.

Traditionally, higher educational institutions comprised of bloated IT infrastructure costs, highly stressed IT Departments, and rigid software solutions that consumed time and money. In the past few years, cloud computing enabled educational institutions to offer many services cheaply or freely, often with much higher availability than can be provided by the distributed information technology infrastructure. Free or low-cost cloud-based services are used daily by learners and educators to support learning, social interaction, content creation, publishing and collaboration. Examples of cloud-based services include Google Apps, YouTube, Twitter and Dropbox. Figure 2 shows services that could be attached to education cloud.

Consumer acceptance of Web-based cloud services for everything from e-mail to video is of course becoming universal, and educational institutions are following suit. Software as a service (SaaS), which enables institutions to access fully functional applications such as Microsoft Office, Adobe, and Auto Cad Suites are growing at an unprecedented rate. Many higher educational institutions, for example, use Google Apps for e-mail and to create documents and spreadsheets, bypassing capital investments in servers and software licenses. This development has created a wave of cloud computing capabilities delivered as a service, including Infrastructure as a Service (IaaS), platform as a Service (PaaS), software, applications, and content as a Service

FIGURE 2
CLOUD SERVICES FOR HIGHER EDUCATION



(SaaS). Cloud vendors are competing, with innovation and new business models to match the needs of different colleges and universities. Figure 3 shows how different departments and university users may consume services from cloud computing architectures.

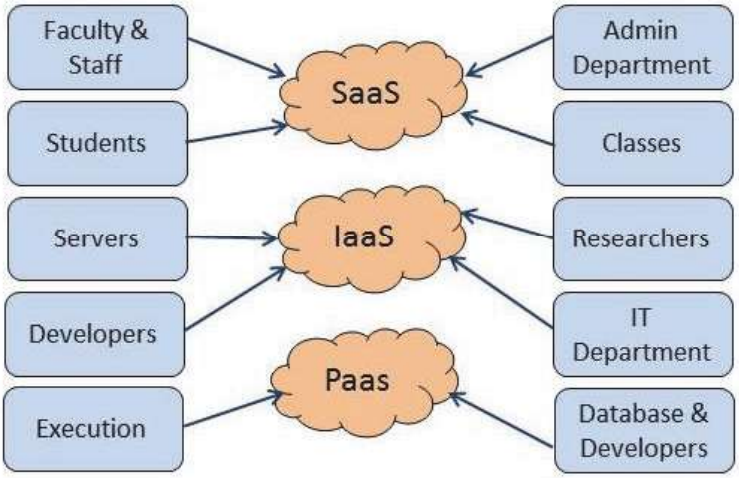
A. **Advantages and disadvantages of CCT in Higher Education**

Cloud computing is an easy to adopt technology with simple and the latest architecture. There are many benefits of cloud technology in education sector as described in several research studies. Cloud was mostly implemented in higher education institutions because of learning management system and student information system. (Boja et al., 2013; Ellucian, 2014; Gonzalez et al., 2012; Hirezone, 2015; Lin & Chen, 2012; Mathew, 2012; Mell & Grance, 2011).

Cloud computing dramatically lowers the capital investment in hardware and software infrastructure for higher educational institutions. These institutions can acquire IT capacities that were not possible in past. The technology enables colleges and universities less resource-intensive ways to get the programs that they need to run their business. Furthermore, cloud-based services reduce carbon footprint and has less environmental impacts.

The replacement of on premise solutions with the cloud computing model has the potential to deliver several immediate benefits to higher educational institutions including no server to maintain, no IT infrastructure to set up, no upfront license fees, and no software programs to buy, install and maintain on premise. Getting more IT storage traditionally requires more hardware and more expense. In the cloud, there is more flexibility. One is able to store massive amount of data cheaply and acquire resources on demand. Institutions can scale up as computing needs increase and scale down again as demands decreases, which eliminate the need for massive investments in local IT infrastructure. Managing resources are easier in the cloud. Computing resources can be deployed very quickly which bring ease of use and financial benefit. The technology provides the ability to choose the IT resources needed in a way that can grow over time or instantaneously as needs change. Cloud based services also reduce margins - hosted services have recurring, predictable and affordable fees. Furthermore, moving to cloud removes typical IT constraints -- such as long lead times for infrastructure improvements, limited resources for maintenance, incompatibilities between systems and tools and maintenance of old, costly equipment.

FIGURE 3
USERS OF AN EDUCATION CLOUD SERVICES



Cloud offers opportunities for greater student choice in learning. Students can access a wide array of resources and software tools that suit their learning styles and interests. Students, faculty, and staff can use office applications for free without having to purchase, install and keep these applications up to date on their computers. Colleges and universities are now free to focus on their goals that are making more research facilities available to the students and faculties.

Cloud computing architectures have a positive impact upon e-learning solutions development**.** e-learning is an emerging aspect of distance education offered by many institutions of higher education. e-Learning systems usually require many hardware and software resources. Cloud computing environment is the best answer for many educational institutions that cannot afford such investments. Cloud Computing environment not only provide support to e-Learning systems but also for the implementation of data mining techniques that allow exploring the enormous data bases generated from the e-Learning systems.

Cloud computing technology also improves collaboration by allowing dispersed groups of faculty to meet virtually and share information. Another big advantage of cloud is providing reliable services delivered through data centers and built on servers. The Cloud often appears as a single point of access for all institutions' computing needs. Furthermore, cloud storage provides a better business continuity planning by protecting data and systems. The providers of cloud services have advanced strategies to ensure that mission-critical data is backed up and protected in a secure and safe location. Cloud storage gives the ability to conduct business that minimizes downtime and loss of productivity.

Cloud computing helps educational institutions realize major benefits in two main categories of performance and technology efficiency. However, moving to the cloud hosted systems has inherent risks and challenges to go along with the benefits that must be managed in order for the transition to be truly successful for the institution. These evolving cloud technologies and approaches can create security gaps and human errors. With the cost of cyber security crime projected to quadruple over the next few years reaching $2 trillion by 2019 (Nielson and Donovan, 2016), there is a concern that education cloud architectures could be a successful avenue of attack for cyber criminals. There are other disadvantages that have been attributed to implementation of cloud computing architectures in organizations including platform inconsistency, network vulnerability, data unreliability, business discontinuity, lack of confidence, and standard adherence. Table 1 summarizes the findings.

TABLE 1
ADVANTAGES AND DISVANTAGES OF CCT IN HIGHER EDUCATION

Categories	Advantages	Disadvantages
Performance Efficiency	• Provides greater student choice in learning • Facilitate a Stronger Learning Environment • Cost proficient: pay per use, based on resources consumed • Improves administrative efficiency • Enables full users self-service • Release resources when no longer needed • Facilitates eLearning and distance education • User friendly – easy to understand and operate • Reduced cost – take advantage of economies of scale across users of cloud • Reduced margins • Rapid development/improved mobility • Can be provided by 3rd party (e.g. Amazon) or on in-house network • Leverage on big data analytics and mobile computing • Easy customization, continuous improvement • Enables dispersed groups of faculty to meet virtually and easily share information	• Business discontinuity • Performance inconsistence due to sharing of resources with various other companies • Not all applications run on Cloud • Transparency: not getting a whole lot of insight into your network • Dissemination policies • Fewer options • Standard adherence • Lock-in • Lack of confidence • Organizational support
Technology Efficiency	• Reduced system administration overhead: automated provisioning • Increased utilization through sharing of resources • No need for design deployment environment to meet maximum load • Increased/matched reliability and security • More flexibility: acquire resources on demand • Better alignment of IT resources • Elastic Scalability • Ability to mix and match public and private cloud as well as co-located and on-premises physical infrastructure • Built-in disaster recovery capabilities and expertise • Choice and agility – 24/7 availability • Little to no maintenance • Less environmental impact- fewer data centers worldwide and more efficient operations, less real estate required	• Network vulnerability • Platform inconsistency • Availability of features • Lack of control and options for scalability • Reliability and security • Security gaps & human errors • Standard adherence • Intellectual property

OBSTACLES TO RAPID ADOPTION

There are numerous challenges in applying cloud computing technology in education in a way that would allow for its significant and rapid growth. The biggest challenges for rapid adoption of technology by educational institutions are lack of resources/expertise, security and compliance. As more colleges and

universities are placing more workloads in the cloud, the need for expertise has grown. Training of IT and development staff will be critical in helping address this challenge. Although data centers do take strong security measures, concerns about the cloud's security remain. There are broad span of concerns in cloud computing security including network security, data security, compliance, governance, and more. Gonzalez et al. surveyed the state of the art in cloud security and concluded that the top three major security problems facing organizations in cloud adaptation are legal issues, compliance and loss of control over data (Gonzalez et al, 2012). Other studies identified top cloud security threats as listed below (Winkler 2011, 2012; Raguram, 2014):

- Trusting vendor's security model
- Loss of physical control
- Data dispersal and international privacy laws
- Quality of service guarantees
- Potential for massive outages
- Malicious Insiders and Abuse Of Cloud Services
- Service Traffic Hijacking — Phishing, buffer overflow attacks, and loss of passwords
- Reliability of cloud service provider's service
- Governance — data control, security control, and lock-in
- Network security — transfer security, firewalling, and security configuration
- Data security — cryptography, redundancy, and disposal

The cloud infrastructure is always, to a certain degree, an open and shared resource. Therefore, it is major targets for cyber attackers. Cloud computing systems and services are subject to malicious attacks from both insiders and outsiders. Side-channel attacks, identity hijacking, and distribution of malicious code have all been observed. Therefore, management of security in cloud environments needs to be carefully analyzed and maintained by.

There are other challenges facing rapid adoption, including the costs of managing the cloud and the speed of uploading files. The cost in the cloud could increase rapidly such as for certain customizations to meet education needs. Large files can take a long time to upload causing frustration and inconvenience for day-to-day business. Other challenges include governance and control, complexity of building a private cloud, defining What Services Should Move to cloud, and performance issues.

CLOUD DEPLYMENTS IN HIGHER EDUCATION

Higher education institutions are rapidly embracing the potential of cloud technology to reduce cost of IT services, to respond more rapidly to new opportunities, and to realize the full potential of their data to better inform strategic decisions about the future. However, higher education institutions have a unique culture and mission that affects how decisions about cloud computing are made. For example, reaching consensus takes time, especially when administrators are dealing with decisions about where to allocate limited resources. Administrators need to fully understand the benefits of cloud-based services models. Defining a strategic approach to the cloud will help any higher educational institutions determine what cloud-hosted services and systems to adopt and will help to make integration as smooth as possible. An effective cloud strategy requires creating a framework built around the needs of the unique stakeholders – from students to faculty, and board members to alumni. Stakeholders must be involved early in the process to ensure development of an institution-wide cloud strategy that addresses IT challenges specific to higher education.

Implementing a successful cloud computing strategy in education takes time and effort. Many parts of the educational institutions will be affected, there are complex decisions to be made, and various stakeholders must be involved. Many organizations have not been successful with deployment of cloud computing due to the failure of developing a cloud strategy rooted in the delivery of IT services linked to their outcomes. Often a school has competent IT staff and a vision of IT requirements. But there is a gap between the strategic vision and understanding of available technologies versus budgets available to

deliver on that vision. Furthermore, many institutions do not know how to initiate their cloud projects. Before deploying cloud service in a college or a university, the need to determine where cloud services will add value need to be identified. Then a scalable deployment approach must be planned.

Gartner conducted a 12-month long research of enterprises with cloud management strategies and identified the three phases of cloud service adoption strategy (Smith, 2016). We have modified the findings of this survey and identified the three phases of cloud service adoption strategy for successful implementation of cloud in higher education. These phases are described below and are summarized in Table 2.

In the **elementary phase**, colleges and universities should begin to learn about cloud technology and perform detailed analysis of their applications and the services they need. Cloud computing focuses primarily on services, rather than technology. The services offered can range from automated IT tasks, IT services and automated business processes. The delivery of cloud computing services to students, faculty, and staff should be based on what they need. Consumers of the service place service requests via self-service and are billed for what they use. The most impactful deployments start with users fully understanding the desired outcomes and then identify the services that will be offered via the private and/or public cloud. Questions such as what services students, faculty, and staff need, how much of the service will be consumed, when the service will normally be consumed, which users consume the service, and what is a reasonable price for the service needs to be answered.

In **Phase II**, schools need to document and analyze the internal processes that will be affected by the chosen cloud services. The traditional deliveries of curriculum and administration network within the school system need to be considered. Moreover, other services such as delivering data outside of the physical network in a secure way to allow students access to files for homework need to be analyzed. During this analysis, the users should study the internal IT processes involved with offering the services. This might highlight a need to flatten, reconfigure, realign, refine or eliminate inefficient processes and target manual repetitive processes to be automated. The types of security that will be applied to cloud deployment also need to be addressed. Finally, schools need to look beyond their own IT staff for assistance and partner with expert solution providers that can provide both initial and ongoing assistance. As schools consider wider impacts such as data protection and security, the support of outside providers will become even more important.

In **Phase III**, users should map applications and workloads to the associated cloud services. Each workload should be reviewed for its applicability to cloud computing and its location environment. Next, a detailed review of the overall architecture of the workloads that make up the application is required. Finally, users should determine the security profile for each workload — for example, can it reside off-premise and must it be encrypted? After the user analyzes the workload, decisions should be made regarding what cloud computing deployment model is best for the organization's applications and workloads. Should the workload run in a public cloud, an on-premises private cloud, or should it be run on a combination of on-premises and public cloud. For schools with sizeable investment in infrastructures, decisions to migrate to cloud based service should be based on maximizing the computing, networking and storage resources that they already have. Another crucial decision at this stage is selection of a storage system for ever increasing education data that offers the right balance of security, high performance, network connectivity and cost efficiency. Cloud storage is becoming one of the most important and fastest growing segments of the enterprise IT industry. Answering the following key questions can help the school's IT team decide if cloud storage is right for the institution:

- What are the primary benefits you hope to gain from cloud storage?
- How will your use of cloud storage change over the next 12 months?
- What are significant challenges in providing long-term storage in cloud?

TABLE 2
CLOUD COMPUTING DEPLOYMENT PHSASES

Adoption Phases	Recommended Activities
Phase I **Elementary Phase: Identify your cloud computing IT services**	• Begin to learn about cloud technology • Perform detailed analysis of applications and the services needed • Identify which services are wanted and/or needed • Identify which service should be offered, procured and/or supported? • Determine how much of the service will generally be consumed • Determine what is a reasonable price for the service?
Phase II **Intermediate Phase: Document the internal processes that will be affected by the cloud services you choose**	• Study the internal IT processes involved with offering the services • Revise or eliminate inefficient processes • Target manual repetitive processes to be automated. The goal should be that any action that can be automated should be automated • Look for synergies to be built across the infrastructure that support a given service or application • Determine how the environment will be monitored and maintained after it has been provisioned • Determine what security will be applied to cloud deployment
Phase III **Final Phase: Map applications and workloads to the associated cloud services**	• Study the internal IT processes involved with offering of the services • Analyze each workload for its applicability to cloud computing and its location environment • Determine the overall architecture of the workloads that make up the application • Determine the security profile for each workload — for example, can it reside off-premises, and must it be encrypted?

Cloud vendor selection is also an important task that needs to be handled with care. The following criteria should be used to find a cloud solution that offer secure, reliable, and flexible infrastructure.

- Protection - No-compromise approach to data protection and preservation
- Management - Secure services for backup, replication, archive and recovery
- Integration - Framework for on and off premise solutions - Rapid development/improved mobility
- Security and Trust - Highest data integrity, reliable backup and recovery, trusted advisor
- Flexibility - Facilitates eLearning and distance education

A. Key Factors to Consider

The role of central IT teams in cloud deployment has been evolving over the last few years especially within larger organizations. As applications of cloud based services increased, central IT began to take the role as a broker of cloud services to ensure appropriate management, governance, and control. In 2016, business units within the enterprises increasingly agreed that central IT should play a role in selecting, brokering, and governing cloud services. They also agreed that central IT should set policies for cloud use and select public and private cloud technologies (RightScale, 2016). The IT team must discuss the challenges and the questions that must be considered in order to succeed in the new cloud era. New players and new offerings constantly enter the scene. With so many options—private clouds, public clouds, hybrid cloud, and "multi-cloud"— deciding how best to move forward can be overwhelming for the IT teams. The top three key factors to consider when choosing cloud are: performance, cost and agility as described below (Turbonomic, 2016):

1. **Performance –** Application performance is responsibility of the users in the cloud and it largely rests on central IT teams' ability to predict resource needs and understand the real-time application demand. You have performance issues if you underestimate the size of instances your applications need. Over-estimate and you waste budget. The real work of your IT team is making sure the applications get the resources they need to perform and that instances are performing as expected.
2. **Cost –** Using economies of scale, cloud providers can offer a lower cost per transaction or service. Yet operating VMs in the cloud is not cheap or simple. Costs can quickly rise depending on how many VMs are being hosted in the cloud. Over-sizing instances is a costly decision. With any public cloud, you do not "pay for what you use." Instead, you "pay for what you think you will use." Your IT team needs to decide on number of instances you are running in a public cloud. They also need to make sure that you are using only the resources you need in the public cloud. The performance benefits and the cost savings are considerable if your instances are appropriately sized based on real-time application demand.
3. **Agility –**Most cloud services provide two types of agility to their customers. First, the agility offered to developers for creating business applications more quickly. Second, the agility of their infrastructure and operations teams to empower developers, managing the use of those resources, while continuously maintaining performance. There are often tradeoffs on both ends. What enables developer agility challenges infrastructure and operations teams' agility. Agility does not come without a thoughtful approach to the cloud platform you choose. The cloud makes agility possible, but does not guarantee it. More importantly, without guaranteed performance agility is useless.

B. Cloud Services Available to Educational Institutions

There has been a huge growth in low cost and free cloud based technology for social interaction, publishing, collaborating, editing, content creation, computing, etc. For example, students can use office applications for free without having to purchase, install on their computers.

Several companies are providing cloud services in the education sector including Microsoft, Google, and Amazon. Almost all colleges and universities are using Microsoft products including Office 365, office Web Apps and Business productivity online suite for more than two decades. Similarly, most colleges and universities are using Google Apps (email, calendar, and documents) for communication and collaboration. Amazon cloud is being used for creation of flexible IT infrastructure in these institutions. Finally, collab9's Cisco powered Unified Communications as a Service (UCaaS) platform has a solution tailored specifically for the higher education industry. Higher education institutions can use this communication and collaboration platform for seamless real-time interactions throughout their campuses.

TABLE 3
CLOUD SERVICES AVAIABLE TO EDUCATIONAL INSTITUTIONS

Cloud Service Providers	Cloud Services
Microsoft	• Office 365 • Exchange • Office Web Apps • CRM online • Microsoft Dynamics
Google	• Google Apps for Education – email, calendar, and documents for collaborative education • Chromebooks
Amazon	• AWS cloud – provides storage resources and IT infrastructure for institutions
Cisco	• Unified Communications as a Service - Collab9's UCaaS platform • Communication and collaboration platform
Open Source	• EdX – Mooc provider, offering high-quality courses

By unifying communication in the cloud under UCaaS platform, higher education institutions will be able to improve administrative efficiency, boost security, and facilitate a stronger learning environment. Finally, EdX, an open-source platform founded by Harvard University and MIT in 2012, is trying to transform education. It is an online learning destination and MOOC provider, offering high-quality courses from the world's best universities and institutions to learners everywhere. Table 3 has the summary of these services.

CASE EXAMPLES OF SUCCESS

In this section we discuss case examples of two higher education institutions that have successfully migrated to cloud-based infrastructure and have been using various cloud services throughout their institutions. Our first example is Roger Williams University located in Bristol, R.I., – a leading independent, coeducational university with programs in the liberal arts and the professions (RWU, 2017). Our second example is Bryant University, a private New England university distinguished by an integration of business and the arts and sciences with a global perspective.

Case I - Roger Williams University

Roger Williams University (RWU) has been utilizing cloud services in an increasing number of ways in the past few years (Table 4). For example, RWU students have been utilizing an online learning system called "Bridges" where all of their course materials have been hosted on an external cloud hosted by Amazon Web Services (AWS). Bridges allows faculty and students to upload, view and download lectures, assignments, grades, and much more over the Internet using a variety of personal devices from anywhere with an Internet connection.

TABLE 4
CLOUD SERVICES AVAIABLE TO ROGER WILLIAMS UNIVERSITY

Categories	Example RWU Solutions
Instructional Technologies	• **Bridges** is a collaborative learning environment powered by Sakai. It is an open-source course management system that facilitates the creation of sophisticated web-based instructional materials (Roger Williams University, 2013). • **rCloud** is a virtual desktop for faculty and students to access a variety of software and cloud file management options from any device anywhere with an internet connection. • **Gotomeeting/Gototraining** are web conferencing tools currently supported at RWU for live (synchronous) web classes & meetings (Roger Williams University, 2013). • **Panopto** is a video content management system for recording lectures, and managing and sharing video and audio files (Panopto, 2016). • **VeriCite** is a cloud-based tool that identifies plagiarism by comparing submitted work against an ever-expanding database of sources (Vericite, 2016). • **Qualtrics** is a cloud-based survey tool that allows any RWU faculty, staff member or student to create, distribute and share surveys electronically.
Library	• **HELIN** is an academic library consortium including six Rhode Island and one Massachusetts academic libraries. HELIN has recently went live with **WorldShare Management Services (WMS)** which is a cloud based library services platform that offers all the applications needed to manage a library (OCLC, 2017).
Email/Calendar/ Office	• **Google Apps** is a package of online applications that makes communicating and collaborating easier and more efficient. All RWU students are assigned Google's web-based e-mail program, which integrates with Google Docs, for creating and sharing documents, and Google Calendar, for coordinating schedules. All of these services are hosted on the cloud, so e-mail, documents and calendars are always accessible from any computer (Roger Williams University, 2015). • **Office 365**, powered by Microsoft Cloud services, is a suite of office applications that are available to RWU faculty, staff and students so they can work and collaborate from anywhere on any device.
Human Resources	• **Interview Exchange** provides flexible, customizable, and feature-rich applicant tracking and hiring management tools online (Hirezone, 2015).
Institutional Data & Operations	• **Colleague** is a cloud-based fully integrated student management system that provides secure, easy access to the information to manage assets more efficiently and allocate resources more effectively (Ellucian, 2014) • **Portal** is a role-based portal and online experience for students and faculty. The RWU Campus Portal provides students the ability to check class schedule and register for classes, and display important campus news and announcements (Roger Williams University, n.d.). • **Curricunet** is a cloud-based online curriculum management system for development and approval of new courses as well as course and program modifications.

In addition to the Bridges platform, in 2013-2014, RWU started to gradually roll out a virtual desktop system offering students and faculty access to all software programs via the cloud. The initiative was launched in collaboration with Samsung Americas, which is an organization led by an RWU alumnus. The rCloud is a virtual desktop for RWU faculty and students through which they can access a variety of software and cloud file management options. Each rCloud user is assigned a profile based on their school affiliation within the university. For example, students in the School of Engineering, Computing and Construction Management (SECCM) have access to a platform which supports construction management and engineering instruction, including all MS Office, Adobe and Autodesk Suites in addition to other software applications that are specialized to SECCM courses. On the other hand, students in the Gabelli School of Business have a separate virtual profile that gives them access to specific business related software applications. Students from different schools within RWU can access their particular profiles and the associated software through the Internet on any personal or school computer or mobile device. RWU lists some of the other benefits of the rCloud as follows (Roger Williams University, 2013):

- Every space becomes a collaborative learning/work space.
- Consistent desktop environment and computing power regardless of local hardware/software.
- Easier backup and recovery of full desktops and personalized settings.
- Ability to stream to peripherals on the network such as printers and scanners.

Case II-Bryant University

Bryant University entered the cloud space in 2014 to improve agility, cost and reliability. At Bryant University, all students receive laptops and are encouraged to use smartphones and tablets in their classrooms to collaborate with each other and faculty. According to NaviCloud (2014), the proliferation of devices and application endpoints required to support it led to a 300 percent increase in the amount of data stored and managed by the university, in just four years. Bryant uses Actifio's Copy Data Virtualization platform for on premise backup, and was looking to eliminate tape back-up, which can be costly and time-consuming to access, from their infrastructure and secure their data at an offsite datacenter. NaviCloud Vault provided the service solution needed to reduce the amount of replicated storage produced without any loss of data.

Bryant University utilizes cloud services in many other ways (Table 5). Recently, Bryant University transitioned its course planning software, Blackboard®, from a self-hosted environment to a cloud-based service offering. With Blackboard, all faculty have a fully functional website for each of their courses online. Faculties are able to share their lecture slides, assignments, submit grades, and much more over the Internet. Students are able to view submit their work, view their grades, and work in teams in this collaborative space. Notably, Blackboard offers an option called Blackboard Collaborate where faculty can hold lectures online from anywhere in the world with an Internet connection. Students join the course through their Blackboard site and can join the main classroom or be placed in "workrooms" to work on team projects. Faculty can jump in and out of each "room" to give feedback and then ask the class to join the main class for further discussion. Blackboard also offers a mobile application for its users.

Students use Google Apps for email accounts, which allow large capacities of storage throughout their four years in college. Students increase efficiency in their coursework by using Microsoft Office applications for group collaboration. For example, students can use Google Docs (similar to Microsoft Word) or Google Sheets (similar to Microsoft Excel) to simultaneously work on a document with a team of students from multiple computers, tablets, or even mobile phones. Part of the app suite, Google Docs increases efficiency for student work and even allows faculty to provide real time analysis and feedback.

Bryant University also provides access to Citrix Presentation Server, a virtual desktop through which they can access a variety of applications through one website. This option provides access to various applications from any desktop connected to the server, such as the data analysis software, SPSS.

TABLE 5
CLOUD SERVICES AVAIABLE TO BRYANT UNIVERSITY

Categories	Example Bryant University Solutions
Instructional Technologies	• **Blackboard** is a collaborative learning environment course management system that facilitates the creation of sophisticated web-based instruction. • **Qualtrics** is a cloud-based survey tool that allows any faculty, staff member or student to create, distribute and share surveys electronically.
Library	• **HELIN** is an academic library consortium including six Rhode Island and one Massachusetts academic libraries. HELIN has recently went live with **WorldShare. Management Services (WMS)** which is a cloud based library services platform that offers all the applications needed to manage a library (OCLC, 2017).
Email/Calendar/ Office	• **Google Apps** is a package of online applications that makes communicating and collaborating easier and more efficient. All Bryant University students are assigned Google's web-based e-mail program, which integrates with Google Docs, for creating and sharing documents, and Google Calendar, for coordinating schedules. All of these services are hosted on the cloud, so e-mail, documents and calendars are always accessible from any computer. • **Office 365**, powered by Microsoft Cloud services, is a suite of office applications that are available to Bryant University faculty, staff and students so they can work and collaborate from anywhere on any device.
Human Resources	• **PeopleAdmin** is a software-as-a-service (SaaS) cloud-based talent management solution to streamline the hiring process; onboard new employees; efficiently manage positions and employee performance; develop compliant, defensible audit trails; and utilize industry-leading reporting and metrics (PeopleAdmin, 2014).
Institutional Data & Operations	• **Portal** is a role-based portal and online experience for students and faculty. The Bryant University Campus Portal provides students the ability to check class schedules and register for classes, and display important campus news and announcements • **NaviCloud Vault** NaviCloud Vault, part of NaviSite's Storage-as-a-Service solution, is built on Actifio's CDS solution with patented Dedupe-Async replication technology to significantly reduce the amount of replicated storage a business produces without any loss of the underlying data (NaviCloud, 2014). • **ERP** Enterprise Resource Planning is the integrated management of core business processes, such as product planning and purchase, in real-time.

Bryant University also uses Gioculusit for Oracle® managed services, such as Banner® (Wilson, 2016). Banner® is Bryant University's enterprise resource planning (ERP) platform, which provides the integrated management of core business processes, such as planning and purchase, often in real-time and mediated by software and technology.

SUMMARY AND CONCLUSION

Cloud computing is now a mainstream technology that is recognized as a huge benefit to higher educational institutions. Cloud solutions deliver high levels of capability and reliability while lowering administration and operational costs. Students, teachers, parents can access information using any device

from anywhere. What's more, they do all this with pricing that is often significantly lower than that of equivalent on-premises solutions. Many higher educational institutions implement cloud based technology because of learning management system and student information system. Advantages such as availability of low cost and free technology, personalized learning, 24/7 accessibility, openness, and increased functional capabilities all are contributing to the rapid acceptance of this technology in higher education. An entire world of knowledge can now be made available to faculty and students that can be accessed anytime, anywhere, from any device.

Like all the new technologies, cloud computing also faces certain challenges which need to be understood, mitigated, and overcome in order to fully exploit its benefits in higher education. Security, compliance issues, reliability, and lack of interoperability are some of the implementation challenges to overcome.

Moving to cloud based services is a sea change for any institution. Managing that change requires a partner who understands higher education and the benefits the cloud can deliver to the constituents and to the mission of the institution. By partnering with a cloud service provider on the provision of central administrative functions, higher education institutions can reorganize their workforce to focus on unique, high-value tasks and provide a higher level of service to key stakeholders than would otherwise be possible. Moreover, administrators and staff must collaborate to ensure the solutions are right for the institution. Implementing cloud solutions in higher education will require certain conditions to be fulfilled. In most colleges and universities there is a gap between the strategic vision and understanding of available technologies versus budgets available to deliver on that vision. The first step in cloud deployment in higher education is determination of where cloud services will add value. Then a scalable deployment approach must be planned. This study identified the three phases of cloud service adoption strategy for higher education.

Higher education institutions can use the implementation phases, key deployment factors, and two cases discussed in this paper to find and implement a cloud solution that offer secure, reliable, and flexible infrastructure for their institutions.

REFERENCES

Angela Lin,Nan-Chou Chen, (2012). Cloud Computing as an Innovation: Perception, Attitude, and Adoption, *International Journal of Information Management*. Retrieved from: http://dx.doi.org/10.1016/j.ijinfomgt.2012.04.001.

Boja, C., Pocatilu, P. and Toma, C. (2013). The Economics of Cloud Computing on Educational Services. *3rd World Conference on Learning, Teaching and Educational Leadership*, 93 (21) October, 1050–1054.

Boulton, C. (2016). 6 New Trends That will Shape Cloud Computing in 2017. January 17, 2017. Retrieved from CIO.com - Tech News, Analysis, Blogs, Video: http://www.cio.com/article/3137946/cloud-computing/6-trends-that-will-shape-cloud-computing-in-2017.html.

Cavus, N. and Munyavi, R., (2016). *Adoption of Cloud Computing in Higher Education*, LAP LAMBERT Academic Publishing, ISBN: 978-3-659-95349-1.

Ellucian. (2014). Software and Services for Higher Education Management. , May 29. Retrieved from: http://www.ellucian.com.

Green, K. (2014). The 2014 Campus Computing Survey. The Campus Computing Project. Retrieved from: http://www.campuscomputing.net/item/campus-computing-2014.

Gonzalez, N., Miers, C., Redígolo, F., Carvalho, T., Simplicio, M., Näslundy, M., and Pourzandiy, M., (2012). An quantitative analysis of current security concerns and solutions for cloud computing. *Escola Politécnica at the University of São Paulo (EPUSP),* São Paulo, Brazil..

Hirezone. (2015). June, 4. Retrieved from Hirezone Web site: http://www.hirezon.com.

Mathew, S. (2012). Implementation of Cloud Computing in Education –A Revolution, *International Journal of Theory and Engineering*. Vol.4.

Mell, P. and Grance, T. (2011). The NIST Definition of Cloud Computing. Special Publication 800-145. Retrieved from: http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf.

Matsumoto, R. (2012). SaaS Does Not Necessarily Equal Cloud. Retrieved from: http://www.rickmatsumoto.com/saas-does-not-necessarily-equal-cloud/.

NaviSite's NaviCloud. (2014). NaviSite's NaviCloud ® Selected by Bryant University for Remote Storage. Retrieved from: https://www.timewarnercable.com/en/about-us/press/navisites-navicloud-vault-selected-by-bryant.html.

Nielsen, T. and Donovan, P. (2016). Addressing Cyber Security Concern of Data Center Remote Monitoring Platform. Schneider Electric. Retrieved from: http://www.forbes.com/sites/stevemorgan/2016/01/17/cyber-crime-costs-projected-to-reach-2-trillion-by- 2019/#45018db93bb0.

OCLC. (2017). HELIN Library Consortium now live with OCLC WorldShare Management Services, January 20. Retrieved from OCLC: https://www.oclc.org/en/news/releases/2017/201704dublin.html.

Panopto. (2016). Panopto, April 2. Retrieved from Video for Education: https://www.panopto.com/panopto-for-education/.

PeopleAdmin. (2014). SelectSuite® for Higher Education., January 25. Retrieved from PeopleAdmin: http://www.peopleadmin.com/wp-content/uploads/2014/01/SelectSuite_HighEd_Final.pdf.

Raguram, S. (2014). Performance of Ring Based Fully Homomorphic Encryption for securing data in Cloud Computing. *International Journal of Advanced Research in Computer and Communication Engineering*.

RightScale 2016 State of the Cloud Report. 2016. Retrieved from: http://www.mcit.gov.eg/Upcont/Documents/Reports%20and%20Documents_1252016000_RightScale-2016-State-of-the-Cloud-Report.pdf.

Roger Williams University. (2013, January 5). Tutorials: University Libraries. Retrieved from Roger Williams University Web site: http://library.rwu.edu/lib/learning-commons/id/tutorials.

Roger Williams University. (2013, September 1). rCloud. Retrieved from Roger Williams University Web site: http://rcloud.rwu.edu.

Roger Williams University. (2015, October 7). Student Services. Retrieved from Roger Williams University Web site: http://rwu.edu/about/university-offices/it/student-services.

Roger Williams University. (n.d.). Student Services. Retrieved from Roger Williams University Web site: http://www.rwu.edu/about/university-offices/it/student-services#portal.

Roger Willimas University. (2017, January 3). About Roger Williams University . Retrieved from Roger Williams University Web site: http://rwu.edu/about.

Smith, D. (2016). Cloud Computing Deployments Should Begin With Service Definition. Gartner Report, Retrieved from: https://www.gartner.com/doc/reprints?id=1-3G2H8FE&ct=160826&st=sb.

Sultan, N. (2010) Cloud computing for education: A new dawn? *International Journal of Information Management,* 30(2), 109-116.

Tate, A. (2014). Five ways Cloud is Enhancing Higher Education. IBM, Retrieved from: https://www.ibm.com/blogs/cloud-computing/2014/08/five-ways-cloud-is-enhancing-higher-education/.

Turbonomic. (2016). New Clouds, Same Challenges – Public Cloud Guide. Retrieved from: http://docs.media.bitpipe.com/io_12x/io_128571/item_1279146/483452_Turbonomic_Public-Cloud-Guide.pdf.

Vericite. (2016, September 28). Overview. Retrieved from Vericite: https://vericite.com/overview/.

Wang, Bo, and Yu Xing, H. (2011) The application of cloud computing in education informatization. *Computer Science and Service System (CSSS*), International Conference on. IEEE.

Wilson, Lisa. (2016). Bryant University (A Banner® User) Selects GIOculusIT for Oracle® Managed services. Retrieved from: http://www.gioculusit.com/bryant-university-selects-gioculusit-for-oracle-managed-services.

Winkler, V. (2012) Cloud Computing: Virtual Cloud Security Concerns.*Technet Magazine*, Microsoft. Retrieved 12 February 2012.

Winkler, V. (2011). Securing the Cloud: Cloud Computer Security Techniques and Tactics. Waltham, MA USA: Elsevier. p. 59. ISBN 978-1-59749-592-9.

Yadav, K., (2014) Role of Cloud Computing in Education. *International Journal of Innovative Research in computer and Communication Engineering,* Vol.2.