Cloud Computing in Indian Higher Education

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Abstract

In developing countries, education plays a very important role in maintaining the momentum of economic growth. In a country like India with a population of over a billion, one of the biggest challenges that the government faces in providing education is the provisioning and maintenance of infrastructure. The infrastructural issue can be viewed from two dimensions: on one hand, the lack of investments and on the other hand, the difficulties in maintaining such infrastructures. This article focuses on the lack of investment and suggests the use of cloud computing as a form of possible remedy. This article uses Rogers' diffusion framework for the penetration of cloud computing in the higher education sector of India and proposes a cloud model for a higher educational institute.

Keywords

Cloud computing, higher education, human capital, diffusion of innovation

Introduction

Investments in human capital can be beneficial in the growth of any economy. According to Schultz (1961), expenditures on education, on-the-job training and health, etc., can improve the quality of human effort and can enhance the productivity constitute human capital. According to Becker (1962), investment in human capital constitutes 'activities that influence future real income through the imbedding of resources in people'. He pointed out that investment in schooling, on-the-job training, medical care and acquiring information about economic system can improve both the mental and physical abilities of individuals and that in turn can help in economic growth.

Human capital can further act as an engine for attracting other forms of capital typically in the form of investments (Benhabib & Spiegel, 1994). Moreover, as pointed out by Lucas (1990), owing to poor endowments of complementary human capital, capital in the form of investments fails to flow to poor countries (c.f. Benhabib & Spiegel, 1994).

As pointed out earlier, a very important aspect of investment in human capital is the improvement in the higher educational sector. One question may arise, as to how to show that the investment in education can spur growth. In a recent study by Mankiw *et al*. (1992), it is suggested that since education creates educated labour force, taking the average years of schooling of the labour force as input to the standard production function $Y = Y (K, L)$, where Y is the level of output that the economy produces, K is amount of capital invested and L is the labour force used, the output can be found (Benhabib & Spiegel, 1994). Further, Benhabib and Spiegel (1994) suggested that since education enhances technological progress, instead of taking it as a proxy for labour, it can be taken as a proxy for the level of technology in the output function $Y = (Y, K, T)$, where T is the level of technology used.

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From above, it can be assumed that higher education is one of the very important enablers for sustainable economic growth. But higher education requires enormous investments in the form of ever increasing costs of books, journals and educational software that form the backbone for imparting higher education in any economy (Kim & Bonk, 2006). These are some of the infrastructural issues that call for enormous amount of investments that not only the emerging economies, but even most of the highly developed economies, struggle to provide (St John & Parsons, 2004). Now the question arises that is there any way to achieve the required level of higher education with a reduction in investments in the above infrastructural issues. One way of reducing imminent needs for the infrastructure related funds is to spread the investment over the useful life of the investment. In other words, to turn the capital expenses into operating expenses. In this regard, the business principle of cloud computing is to utilize the power of computing in the form of a service and pay for the capacity used—much like the usage of gas or electricity. The entire philosophy of cloud computing is a revolutionary idea that has the potential to resolve the issues of mismatch between the required investment in higher education in terms of books, journals and software, and the actual investment. The usage of cloud computing can reduce drastically the investments required (Sultan, 2010).

This article uses Rogers' (2003) innovation–diffusion framework for diffusion of cloud computing in the Indian higher education sector and looks at how it can reduce the infrastructural investments to a great extent.

The article is organized as follows. The next section presents a brief overview of the higher education scenario in the developing world with a major focus on the Indian context. The third section introduces cloud computing; the fourth section describes cloud computing as a suitable match in higher educational sector. The fifth section presents the penetration of cloud computing as an innovation in the Indian higher education sector by using Rogers' diffusion framework. It also proposes a model which a higher educational institute can deploy while moving to the cloud. The last section provides concluding remarks.

Issues with Higher Education: Indian Context

The existence of inequalities in terms of access to higher education in both developed and developing economies have been identified by many authors including Bluntzer (2008), Usher and Cervenan (2005) and Altbach and Peterson (2007). Altbach and Balan (2007) recognize the challenges in developing and middle-income countries for funds to set up research universities. They argue that all countries need to coordinate in creation of the knowledge economy. Further, a widening knowledge gap in production of science and technology amongst countries has been identified (Meek, Teichler & Kearney, 2009). According to this report, international networking is one of the major challenges for the research environment across nations. The report also mentions that much of the scientific research at many institutions in developing countries is under-funded and investments in research and development in the majority of countries is low; most countries spend less than 0.4 per cent of GDP on research and development annually (Meek *et al.*, 2009). The cause of the decline in scientific publications per year is attributed to the decline in the allocation of investments in research and development.

The worse is the scenario in a developing economy like India. Unprecedented changes in the global scenario have caused new challenges in university and higher education in India. As mentioned in the parliamentary report (172nd Report of Committee on Human Resource Development on University and Higher Education) on university and higher education in India, the General Agreement on Trade in Services (GATS) has made the challenges in higher education global. The key issues are commercialization and commoditization of education due to emergence of private players in the higher education arena, allowing foreign universities to set up campuses in India, equitable access, quality, excellence, funding to name a few. Promoting world-class research can be achieved only by establishing indigenous universities and laboratories with world class infrastructure. The population explosion and regional imbalances have resulted in more challenging demands in higher education in India (Dholakia, 2003).

In lines with the report (Commission, 1971) of the Education Commission (1964), the first National Policy on Education was formulated in 1968, wherein education was accepted as a major social investment for a better future. For the policy to be successful, expansion in higher education was must.

Education is a subject under Article 246 of the Indian Constitution. It is Entry 25 in the Concurrent List under the Seventh Schedule, that is, both central and state governments can set up higher education bodies in India. Universities can be administered by both central and state governments. In addition to these, there are Centres of

Excellence, like the Indian Institutes of Technology, Indian Institutes of Management, National Institute of Design, etc., which are set up by an Act of Parliament. There are bodies like All India Council for Technical Education (AICTE), National Council for Teacher Education (NCTE), Medical Council of India (MCI), etc., which are statutory bodies set up for coordination of higher education in India.[1]

The Indian parliamentary report[2] on university and higher education considers access and equity as the core concerns for expansion of higher education in India today. Greater access and equity require increase in the educational institutional capacity to provision for fair and equal opportunities to all deserving and desiring students for higher education. Funding is also a major concern which has led to rise in tuition fees and reduced the affordability of higher education.[3] A report[4] by the Planning Commission mentions that the major thrust of the Five Year Plans have been to develop infrastructure, improve the quality through several schemes and encourage research and development. It mentions that share of funds for higher education in Five Year Plans was very low—to the extent of 0.5 per cent in the Ninth Plan; it further plummeted to 0.3 per cent in the Eighth Plan. The decrease in funding is due to the diversion of funds to other sectors. It also mentions that the focus of the recent Tenth Plan was aimed at improving quality of higher education, promoting research and development, management of finance and use of information and communication technologies (ICTs).

The parliamentary report[5] has laid down research, faculty development and infrastructure creation as the major trust areas in the higher education sector. It has proposed upgrading the scientific infrastructure in universities and setting up of inter-university centres to facilitate research collaboration. Fully equipped and functional academic staff colleges in all the central universities are proposed. Under infrastructure development, the immediate task is the maintenance of the existing physical infrastructure and then setting up of new IT infrastructure to ensure connectivity and resource sharing across universities. In lieu of the rising costs of books, journals and computer equipments, there is a need to create online databases. Exploitation of ICT potential has been proposed for penetration to the remotest corner and for ensuring inclusion and sustainable growth.

Government has undertaken a centrally sponsored scheme[6] to leverage ICT potential in the higher education sector. The major components of this scheme are to provide broadband connectivity and access devices to the institutions and to help generate e-content. This mission aims to extend computer infrastructure and connectivity to over 25,000 colleges and 200 polytechnics in the country and across all departments of nearly four hundred plus universities. The INDEST–AICTE Consortium[7] is set up by the Ministry of Human Resource Development (MHRD) to enable access to electronic databases to centrally funded institutions. The Universities for Research and Innovation Bill, 2011, has been introduced in the Indian Parliament with the vision of setting up world-class universities for fostering higher research and innovation in the country.

The National Knowledge Commission (NKC)[8] has been constituted as an advisory body to the prime minister of India to restructure the educational set-up and create a knowledge network to meet the challenges of the twenty-first century. Providing equitable access to knowledge is one of the major concerns. The commission has recommended setting up of libraries and creation of a network or consortium of institutions. It has acknowledged the role if libraries in inclusive access to knowledge. Extensive educational infrastructure and resources are the key to producing skilled and trained personnel in the country. The excessive financial burden of setting up world-class educational infrastructure can be minimized only by sharing the existing educational facilities available in the limited educational institutions throughout the country. The NKC has explored the possibility of setting up a National Knowledge Network by interconnecting all universities, R&D institutions, health service facilities, agriculture research institutions and libraries in the country in a cost-effective way. The United States has initiated the National LambdaRail (NLR)[9] as a high-speed national computer network comprised of extensive fibre optic, super computing power and storage capabilities to link universities and research organizations for cutting-edge research. Similarly, GÉANT[10] is a pan-European data network. It along with Europe's national research networks connects over 40 million users in over 8000 institutes across 40 countries. The NKC in its report[11] has proposed for India that connectivity with an access bandwidth of 100 Mbps has to be provided to around 5000 nodes covering all higher educational institutions, R&D laboratories and libraries to set up the knowledge net. Research cannot be carried out in silos. It requires inter-institution and trans-country collaboration. This requires excessive investments in front-end infrastructure, which is economically unviable for a developing nation like India. Most of these investments come from the government. Data-sharing and resource-sharing must be facilitated collaboratively at reasonable costs. The major focus of higher education would be to increase the gross enrolment ratio to

at least 15 per cent by 2015. This necessitates expansion of existing infrastructure without diluting quality. Financing of higher education is a major issue as per the recommendations submitted to the prime minister by the NKC.

The HRD ministry as part of its Open and Distance Learning (ODL) system[12] to enhance access and equity to higher education on a distant learning mode, offers correspondence courses and modules over the Internet. Tremendous processing power is required for short instances during the progress of the sessions for teleconferencing and online chat sessions. These sessions can be recorded and stored in the cloud for future reference. The current pattern is mostly to store the modules in DVDs. The National Programme for Technology Enhanced Learning[13] is a joint venture of the MHRD, Government of India (GoI) and the IITs and IISc for providing virtual classrooms and e-content to the citizens.

All these necessitate the need for a new technology which is ubiquitous, so that the consumer can play its role anywhere such that the entire consumer behaviour can take place anytime. The main questions which comes to the mind are who uses this technology and who is it designed for? How is this technology a resource to the consumers? For the educational community, the Data Network and Access (DNA) for computing requirements should be in place all the time. The requirement of a new technology in higher education that gives meaning to online storage such that classroom lecture videos of professors from the premier institutes of higher learning can be stored online and a digital repository of e-books, e-journals, etc. created for access by the common citizens. Not only the storage, but even accessing these over the Internet requires upfront investments in computing storage and processing power which are used to the maximum limit only during peak demand when multiple access occurs across the country of the same content. So, having the DNA in place all the time requires tremendous investments which is not essential as people do not engage in usage behaviour always, so having fixed DNA capacity in place always is futile. Usage changes the need for technology—cloud as a substitute to heavy upfront investments in physical computing infrastructural needs of the educational community. This brings out the need for owning cloud services by the educational community. Cloud computing is a technology that can allow DNA up scaling and downscaling as per need and the pay per use facility to save upfront costs. The new technology should also cater to the user variety and the user frequency. Cloud has different service offerings catering to a wider educational community. The three service delivery models as proposed by the National Institute of Standards and Technology (NIST) (NIST Special Publication, US Department of Commerce The NIST definition of cloud computing (http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf) are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). SaaS is used for billing, customer relationship management, financial work; IT services management, project management to name a few. Salesforce.com, Oracle, NetSuite are the major providers of SaaS. The easiest implementation of SaaS is Google Docs which is used by the faculty and students on a regular basis. PaaS provides a platform for development and testing of new models, business intelligence tools, database designing and integration. Amazon RDS, Cloudant, MS Azure Services Platform, Amazon SNS are the major players in the market. IaaS is used for backup, storage, data recovery and computation. Amazon, Rackspace are amongst the major vendors for IaaS. Cloud computing also comes to the rescue by providing collaborating software and processing power for shorter instances. High capital investments in computing infrastructure can be avoided by moving to the cloud platform.

Cloud Computing

Cloud computing is a simple computing concept, which has emerged from distributed computing and grid computing. With the improvement in computer power and bandwidth, distributed computing has become a more practical area so that a complex problem can be solved in parts, across locations and distributed across computer terminals. A grid computer system can be as simple as a collection of similar computers running on the same operating system or as an inter-networked system comprised of every platform that can be thought of. Processing power, memory and data storage are all community resources that authorized users can tap into and leverage for specific tasks. In grid computing, the basic idea is to utilize the idle CPU cycles and storage similar to the way power companies share the electric grid. Another related term that is generally mentioned in the computing world is utility computing. It is a process of making IT infrastructure and resources available as a metered service similar to traditional public utility like electricity. Grid computing and distributed computing share the attributes of cloud computing but are subsets of cloud computing. Cloud computing as a utility involves renting on demand or pay per use.

The National Institute of Standards and Technology (NIST) of the United States Department of Commerce in its report (Plummer, Bittman, Austin, Cearley & Smith, 2008) defines cloud computing as,

> Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

The three service delivery models as proposed by NIST are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). SaaS is used for billing, customer relationship management, financial work, IT services management and project management to name a few. Salesforce.com, Oracle and NetSuite are the major providers of SaaS. The easiest implementation of SaaS is Google Docs. PaaS provides a platform for development and testing of new models, business intelligence tools, database designing and integration. Amazon RDS, Cloudant, MS Azure Services Platform and Amazon SNS are the major players in the market.

IaaS is used for backup, storage, data recovery and computation. Amazon and Rackspace are amongst the major vendors for IaaS.

The report (Plummer *et al.*, 2008) mentions the four deployment models: private cloud, community cloud, public cloud and hybrid cloud. In a private cloud model, the organization or the third party owns the cloud. It is provisioned for exclusive use by the organization and may exist on or off premises of the organization. A community cloud is used by organizations that share similar concerns like similar security requirements or similar missions. It is owned and managed by one of more organizations in the community or by a third party. It is provisioned for use for a specific community of users who share similar views and may exist on or off premises. A public cloud is for open use by the general public. It is owned and managed by the cloud provider and exists on the premises of the cloud provider. A hybrid cloud model is comprised of two or more distinct cloud infrastructures mentioned above. Table 1 shows the comparison amongst the deployment models.

As cloud computing moves into mainstream adoption, Gartner, Inc. has identified five attributes of cloud computing (Gartner, 2009). Figure 1 illustrates them.

The term 'massively scalable' which was initially used by Gartner (Plummer *et al.*, 2008) has been replaced by 'scalable and elastic' to indicate the ability to scale both up and down.

Cloud computing has spread across nations and across boundaries. According to Zinnov Research (Zinnov, 2010), emerging economies, especially the BRICS nations—Brazil, Russia, India, China and South Africa, and South Korea have shown a tremendous growth in terms of IT-related investments in the past one year. The growth

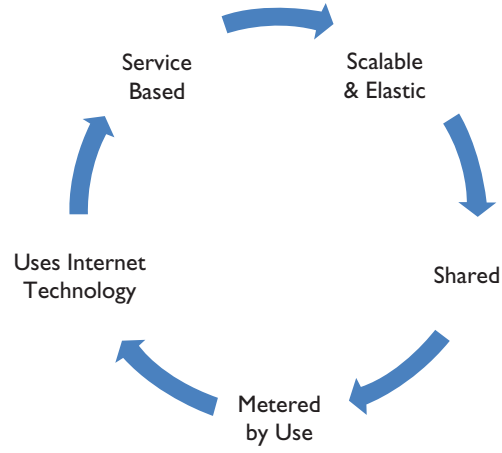

Figure 1. Key Attributes of Cloud Computing by Gartner (2009)

Source: Based on Gartner (2009).

Table 1. Comparison of the Cloud Deployment Models

Model/Category	Private Cloud	Community Cloud	Public Cloud	Hybrid Cloud
Ownership	Organization or third party	Organization(s) or third party	Third party	Organization or third party
Used by	Exclusive use by the organization	Organization(s) sharing similar concerns	General public	Combination of other models
Physical Location	On/off premises	On/off premises	Premises of the cloud provider	Combination of other models
Managed by	Organization or third party	Organization(s) or third party	Third party	Combination of other models

Source: Authors' research.

rates even exceed 15 per cent for China and Russia. Further, this growth of IT-related investments surpasses the growth in more developed economies like US and Japan. Not only the growth rate, but in terms of total IT investments across the world, the contribution of BRICS nations along with South Korea is around 11 per cent and amounts to $166 billion. Again, Zinnov Research points out various characteristics of IT-related investments in South Korea and the BRICS nations that include highly demanding and rapidly changing market, diversity, limited revenue and poor IT infrastructure.

Cloud Computing in Educational Sector

The computational requirements in educational institutions vary round the year. Computing-power requirements escalate while running computationally intensive algorithms. The computing infrastructure in laboratories in research institutions needs to deploy resources and prepare infrastructure for meeting peak-time demands. Cloud computing provides rapid allocation and dynamic provisioning of resources as and when required (Youseff, Butrico & Da Silva, 2008). Upfront investment in computing infrastructure can be prevented. Access to the cloud infrastructure will enable autoscaling up and down of the computational infrastructure during programme runtime (Mao & Humphrey, 2011). Amazon EC2[14] delivers resizable compute capacity in the cloud. It reduces the time required to allocate and boot the new server instances to few minutes, allowing to quick scaling capacity, both up and down, as the computing requirements change. Educational institutes may have confidential or non-confidential data which may require transmission over the internet (Karnik & Passerini, 2005). Email ids of professors and students, grades, etc., belong to the first category; whereas class schedule, professor notes belong to the later. Security requirements are generally low in the educational data compared to corporate. Unnecessary investments in purchase of licenses for dedicated software that are required for one-time use only and need periodic updating can be avoided. Similar software can be rented on the cloud at pay per use basis. The applications are not deployed in every machine, so maintenance is a concern of the cloud provider. Educational institutions are saved from hiring trained maintenance staff separately for looking after the infrastructure. Cloud providers take care of software update and maintenance (Foster, Zhao, Raicu & Lu, 2008).

Cloud computing provides on-demand scalable self-services. Most server access requests come from educational institutions (Block & Mire, 1996). Services in the cloud such as email-servers can be provided by integration via a common interface. The same interface in the cloud can provide access to both gmail and the dedicated email server simultaneously. Cloud computing enables faster online storage. Installation of optical fibres have led to broader network access and improved bandwidth (Kramer & Pesavento, 2002). Students require access to databases on the move. Storing these databases in laptops and carrying them becomes a daunting task. The onset of high speed 3G technology and the availability of affordable user interface devices like tablets, powerful mobile phones and personal digital assistants with touch screen sensitivity make accessing data on the move easier. Amazon S3[15] provides online secured storage. Dropbox[16] and Skydrive[17] are free online storage spaces that provide 2 GB and 7 GB online storage space respectively. They can be customized for Android, Windows and Mac platforms and can be accessed from anywhere. The educational infrastructure requirements vary round the year, peaking during the examination time or the processing of a computationally intense algorithm. Educational sector requires an interconnected pool of online resources which can be accessed across nations. Developing nations need access to the research happening in the developed world.

However, the basic limitations are the need for constant and fast Internet connectivity, frequent power cuts and lack of foolproof security. Most countries in the developing world for Internet still rely on dial-up connectivity. There is no cloud without Internet. Saving data and retrieving data from the cloud requires heavy uploads and downloads. Power failure midway can result in data loss. A real threat is the susceptibility of educational data on the cloud to theft. Educational data like patented algorithms and unpublished research papers are not suitable for storing in the cloud.

Diffusion of Cloud Computing in Indian Higher Education

Everett M. Rogers in the book *Diffusion of Innovations* (Rogers, 2003) mentions the innovation–diffusion process for a new idea to pass through the stages of knowing about an innovation to forming an attitude towards it, to a decision to adopt or reject, to implementation of the new idea and its confirmation. Higher education is considered as an innovator in networking and high performance computing, whereas it is a late adopter of IT applications and support (Katz, Goldstein, Yanosky & Rushlo, 2010). The study also suggests that cloud computing has a transformational

capability. Institutions have already started virtualizing parts of the IT infrastructure and services, especially student emails. Most of the interviewees in the study believe that although the cloud service provider market will mature over a span of five years or less, adoption pattern in higher education will be different. The study mentions that cultural, organizational and regulatory considerations, and not technical glitches, will slow adoption.

Cloud computing satisfies all elements of the technology acceptance model (Katz *et al.*, 2010). According to a paper (Katz *et al.*, 2010), the key determinants of adapting to a new technology are the perceived usefulness and the ease of use. The improvements in the existing job on the adoption of a newer innovation and the minimal effort required for the transition to this new technology are the key concerns.

With changing roles of technology where gratification has become immediate from delayed, cloud computing is seen as an innovation. Cloud services can be provisioned immediately and with ease to meet the requirements of the users. The main entry path into the educational institute is through play and work. Cloud services cater to a wider educational audience. The buyers, that is, the educational institutes can save upfront investment costs and the users, the students can develop different applications on the cloud platform using software and resources from the cloud. There is no need to purchase the licenses to the software for one time use. They can easily be hired on the cloud using pay per use facility. Technology requirements have changed from fixed to being mobile. Miniaturization of technology devices and changing user traits of relying on online storage which is easily accessible from mobiles through the android platform have led to the demand for cloud services in the educational community. Latest technologies like 3G connectivity have increased the network speed. Ownership of the technology is not an issue now, usage is. Cloud computing allows usage of different products positioned for use by the educational community to suit their different needs at different times of both pleasure and work.

The annual savings in investments in an educational institute can easily be seen as the returns would increase in terms of research output and savings on fixed costs of software license purchasing and updating. The investments for cloud would be requirements and service based. Fixed upfront investments will not be required on subscribing to the cloud offerings.

Table 2 identifies the key vendors for the various delivery models that an educational institute can contact depending on the functional requirements.

We use the Roger's innovation-diffusion framework in the Indian scenario to penetrate the new technology, cloud computing in the Indian higher education sector. Figure 2 illustrates the stages of the Innovation-Decision Process.

Table 2. Cloud Vendors and Service Offerings Across the Delivery Models

IaaS	Backup	Backupify, JungleDisk, Mozy, Online Backup, SpiderOak, Zmanda Cloud Backup
	Computation	Amazon EC2, AT&T Synaptic Cloud, Cloud Servers, CloudSigma, GoGrid, LayeredTech, Navisite, Verizon CaaS, Rackspace Cloud Servers
	Content delivery	Amazon CloudFront
	Cloud management	enStratus, New Relic, RightScale, Standing Cloud
	Services management	CloudWatch, Scalr, ylastic
	Storage	Amazon EBS, Amazon S3, At&T Synaptic, EMC Atmos Online, Rackspace Cloud Files, Zetta
PaaS	Business Intelligence	Birst, Clario Analytics, Cloud9 Analytics, ColdLight Neuron, Datameer, K2 Analytics, Oco, PivotLink, Quantivo, Sterna, Vertica
	Database	Amazon RDS, Amazon SimpleDB, Cloudant, Database/MS Azure, Rackspace Drizzle
	Development and testing	BrowserMob, CollabNet, Keynote Systems, LoadStorm, Rational Software Delivery Services, RhoHub, SkyTap, SOASTA, WhiteHat Sentinel
	Integration	Amazon SNS, Amazon SQS, Apigeee, Appian Anywhere, Boomi, IBM Cast Iron, Informatica Cloud, SnapLogic
	General purpose	Caspio, Engine Yard, Etelos, Force.com (Salesforce.com's PaaS offering), Google App Engine, Heroku.com, InfoDome, LongJump, MS Azure Services Platform, OrangeScape, Qrimp, Rollbase, SmartPlatform, Vmforce.com (Salesforce.com's PaaS offering)
SaaS	Billing	Aria Systems, eVapt, Redi2, Zuora
	Collaboration	Acrobat.com, Box.net, ExpanDrive, IBM Lotus Live, MindQuilt, MS OfficeLive, NetDocuments, SocialText
	Content management	Clickability, Crown Peak, Mosaic, NetDocuments, SpringCM
	Financials	AstoriaSoftware, DocLanding, NetDocuments, SpringCM
	Personal productivity	Google docs, MS Office Web Apps

Source: Authors' research.

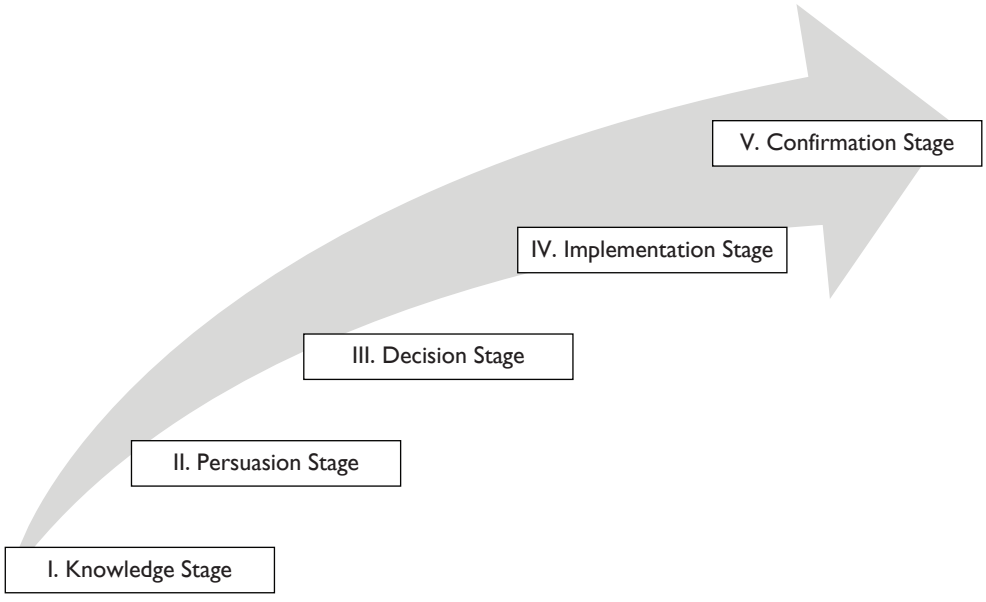

Figure 2. Five Stages in Roger's Innovation-Diffusion Process
Source: Based on Rogers (2003).

The *Knowledge Stage* is when the educational institutions are made aware of the existence of cloud computing, its pros and cons, its functions and applicability in Indian higher educational sector. The MHRD, GoI should conduct orientation programmes to educate the academic staff and students to make them aware of the basic principles and the utility of cloud computing. In the *Persuasion Stage*, a top-down approach can be followed. To start with, the directors of the Institutes of National Importance (INIs), preferably the IITs, IIMs and IISc of the country, need to be convinced of the adoption benefits. IIMs and IITs are the premier management and technical institutes respectively of the country; they form the opinion leaders and benchmarks of higher education in India and their adoption will persuade the other higher educational stakeholders to follow suit. For the process of adoption to become self-sustaining, a threshold critical mass should be attained. Other institutes will be willing to adopt only when they find that those which have adopted are satisfied with the innovation and reaping the benefits. Setting up of a new highly computationally intensive lab may be easier with the advent of cloud as the initial capital expenditure is lesser. The most important concern even here will be security which has to be addressed. During the *Decision Stage*, some educational institutes can be asked by the GoI to shift some of their infrastructure to the cloud on a pilot basis. Monitoring of the savings and benefits accrued will allow a suitable choice for adoption to be taken. The *Implementation Stage* occurs when some of the daily necessities of the educational institutes are shifted to the cloud. To start with, email servers can be moved to the cloud. Once the pilot project involving the INIs is successful, the scale of implementation may be increased to signal acceptance towards the *Confirmation Stage.*

For a country like India, there is a well earmarked hierarchy in higher education with central and state universities having affiliated colleges under them. The control is top-down and decisions are taken by the government and administration. Top administration decides which innovation is to be diffused. The universities can decide to introduce cloud computing in their affiliated colleges in intact groups and in departments where members are supposed to be more innovative, for example, Research and Development wing of the colleges. Incentives for early adoption may be provided by National Assessment and Accreditation Council (NAAC).[18] The NAAC grades colleges on the basis of quality status on all facets of education and innovation. Moving to the cloud actually does not necessitate unnecessary installations of servers and physical computing infrastructure, which can be seen as a move towards green computing which can fetch higher points on the quality assessment scale for the colleges.

Here we propose a model of cloud implementation in a higher education institute. In our proposed model we have identified the key actors (stakeholders) in a higher education institute who interact with the IT division of the institute. We

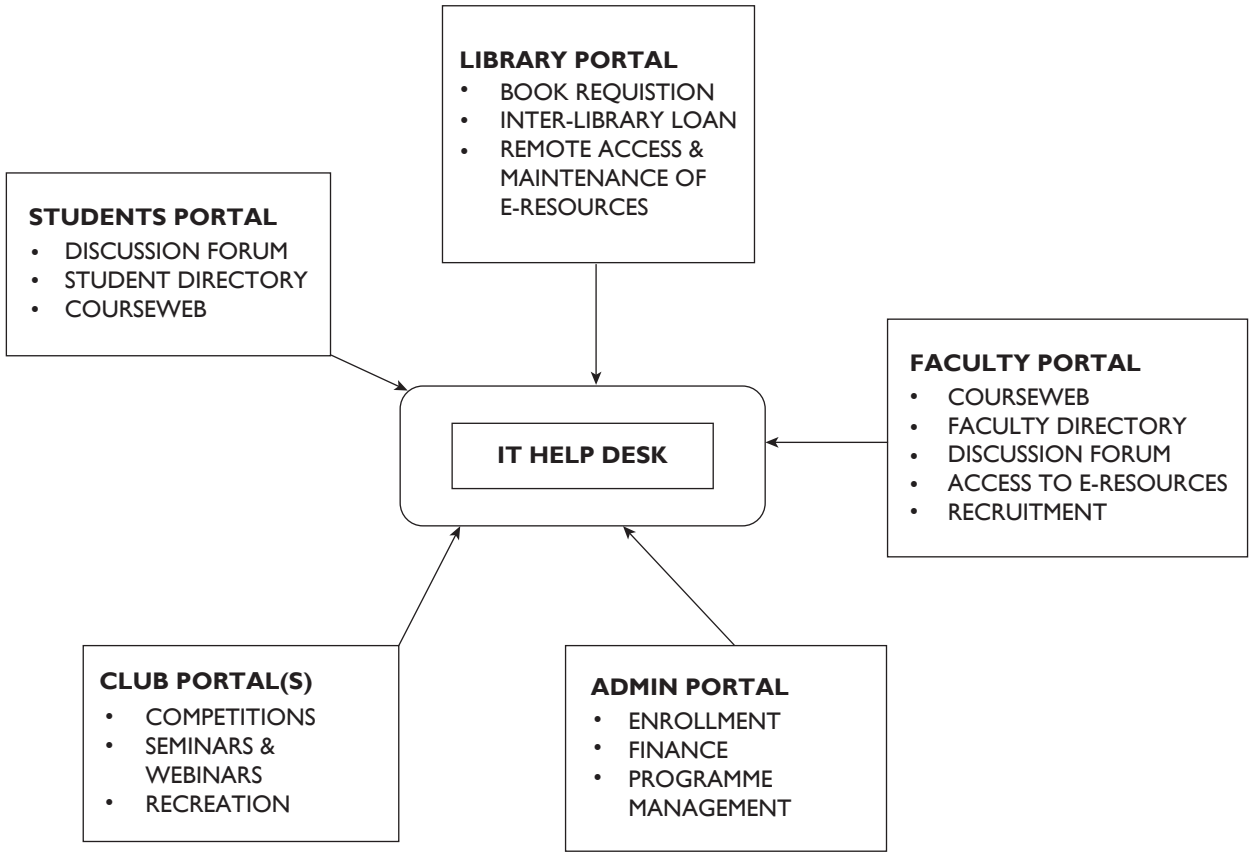

Figure 3. Main Stakeholders Using IT Services in a Higher Educational Institute

Source: Authors' research.

have named the IT division as the IT Help Desk. Figure 3 illustrates the roles which are dependent on the IT division.

Further, we have identified how these stakeholders can be assigned the various delivery models of the cloud. For example, students need access to Google documents for project preparation which comes under the PaaS model. Also, students need access to word processors and other software over the net for their projects, which comes under the SaaS delivery mode. Similarly the linkage for the other stakeholders has been shown in Figure 4.

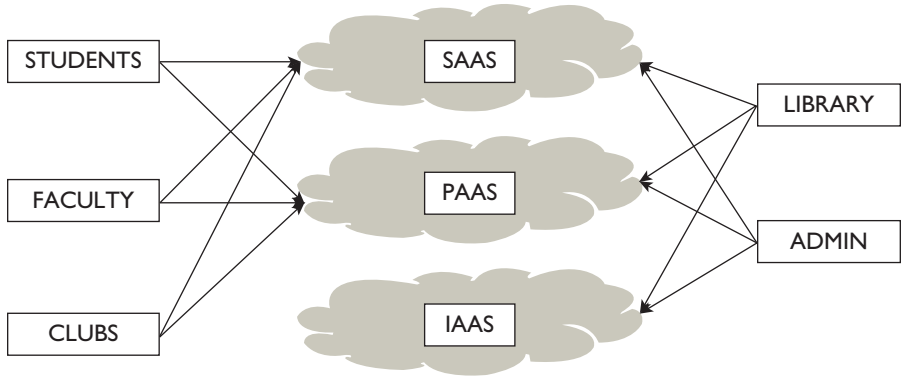

Figure 4. Cloud Delivery Models Across Main Stakeholders of IT Services in a Higher Educational Institute

Source: Authors' research.

Table 3. Cloud Deployment Model Selection Criteria for Higher Education Data

Functions	Critical (Private/ Community)	Non Critical (Public)
Book requisition		•
Inter library loan		•
E-Resources	•	•
Discussion forum		•
Student/faculty directory	•	
Courseweb	•	•
Recruitment		•
Enrolment		•
Financial	•	
Programme management	•	
Recreation		•
Seminars and webinars	•	•
Competitions	•	•

Source: Authors' research.

Table 2 identifies the key vendors for the various delivery models that an educational institute can contact depending on the functional requirements.

On the basis of the criticality of data and functions, deployment models can be selected to be either private or community (users sharing similar concerns) or public. Table 3 illustrates this. The key differences for the various deployment models have already been shown in Table 1.

Conclusion

This article addresses an important aspect of human capital development through investment in higher education and how the scarcity of funds acts as a hindrance. Cloud computing has been shown to be a proper fit for the requirements of the higher education sector. The move towards cloud can lead of change in macro-level policy decisions by the government. More institutes of higher learning can be set up at a much faster pace by the government as the infrastructural costs for installing permanent computing facilities is lowered. The allocation for funds in the educational sector can be lowered and instead used for improving healthcare facilities in the country. Major national universities can set up their campuses in other parts of the country and abroad and access the same e-resources over cloud. Cloud promotes connectivity across institutions of higher learning and equitable sharing of resources and access to the faculty and students. Cloud computing can lead to lowering of the carbon emissions as requirements for installing dedicated servers decreases. This article further uses the Rogers' diffusion framework of innovation in the context of cloud computing implementation for higher education which can be seen as a remedial for reduction in infrastructural investments in higher education sector. It then proposes a model for cloud implementation in a higher educational institute. However, this article has certain limitations as it only provides a theoretical framework without any empirical evidence and thus, it provides a scope for future work where the same can be established.

Notes

1. 172nd Report of Committee on Human Resource Development on University and Higher Education (http://164.100.47.5/newcommittee/reports/EnglishCommittees/Committee%20on%20HRD/172ndreport.htm).
2. Ibid.
3. Ibid.
4. Report of Working Group on Higher Education-11th Five Year Plan, Planning Commission, Government of India. (http://planningcommission.nic.in/reports/genrep/index.php?repts=b_repgen.htm).
5. 172nd Report of Committee on Human Resource Development on University and Higher Education (http://164.100.47.5/newcommittee/reports/EnglishCommittees/Committee%20on%20HRD/172ndreport.htm).
6. National Mission on Education through Information and Communication Technology (http://www.aicte-india.org/downloads/National%20Mission%20on%20education.pdf).
7. Indian National Digital Library in Engineering Science and Technology, An Initiative of Department of Secondary Education and Higher Education, Ministry of Human Resource Development, Government of India (http://paniit.iitd.ac.in/indest/downloads/brochureforcoremembers.pdf).
8. National Knowledge Commission, Government of India (http://www.knowledgecommission.gov.in/).
9. National LambdaRail, The Network for Advanced Research and Innovation (http://www.nlr.net/)
10. GÉANT (http://www.geant.net/pages/home.aspx).
11. National Knowledge Commission, 'Report to the Nation 2006–2009' (http://www.knowledgecommission.gov.in/reports/report09.asp).
12. Distance Learning, Department of Higher Education, Ministry of Human Resource Development, Government of India (http://mhrd.gov.in/overviewdl).
13. National Programme on Technology Enhanced Learning, Ministry of Human Resource Development, Government of India (http://nptel.iitm.ac.in/).
14. Amazon Elastic Cloud Compute (EC2) (http://aws.amazon.com/ec2/).
15. Amazon Simple Storage Service (http://aws.amazon.com/s3/).
16. The Dropbox Blog (http://blog.dropbox.com/).

17. Microsoft Skydrive Live (http://windows.microsoft.com/en-US/skydrive/home).
18. National Assessment and Accreditation Council (http://www.naac.gov.in/).

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