Can Cloud Computing Bridge the Digital Divide in South African Secondary Education?

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Abstract
Cloud computing is a relatively new concept that holds significant promises for the future development and delivery of computer resources to secondary or basic education in South Africa, especially in schools most affected by the digital divide. The aim of this paper is to briefly review the extent to which cloud computing applications and services currently used by secondary education systems in developed countries around the world can be used to help breach the digital divide that currently exists in the secondary (basic) education sector in South Africa. The authors believe that South Africa has the required technology and skills to breach the digital divide in secondary education and by doing so set the pace for the rest of the African continent. All it lacks is the political will and determination to do so.

Keywords
cloud computing, secondary education, basic education, digital divide, South Africa

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Introduction

The use of the Internet and Information and Communication Technologies (ICTs) to deliver educational resources is considered mainstream in the 21st century, yet in secondary education in developing countries it is often seen as a luxury. This has far reaching effects on teachers, learners and educational institutions in these countries, which often include a lack of basic ICT infrastructure and limited or no support for the training of teachers and learners in the use of digital online information sources. It is increasing accepted that in the future most information sources and desktop applications currently use will be mainly accessed through the Internet, now increasingly referred to as 'the cloud'. This means that at secondary school level ICTs should be adopted as a matter of urgency to enable teachers and learners to access this new direction in Internet technology and application delivery. Teachers and learners will no longer have to physically carry their documents and data around with them; instead they

will be able to access them in the ‘cloud’ anywhere, from any connected device. This blending of traditional teaching and learning with online applications and tools for collaborated learning via the Internet is thus a fundamental concept of cloud computing.

The term ‘cloud computing’, which has been described as an Internet computing model that offers unparalleled access to computing resources, began entering the public domain around 2006 when Amazon announced a limited public beta version of its Amazon Elastic Computing Cloud (EC2) system. By this time Google’s Gmail application (first released as Google Mail in Germany in 2004) was already more than 2 years old, but many did not at the time associate the application with the concept of cloud computing. It was only in 2006, when Google’s CEO, Eric Schmidt (quoted in Bogatin, 2006), described his company’s commitment to a new mode or model of computing called “cloud computing” that would be different from the “old client/server” computing business model largely invented by Oracle, that the term ‘cloud computing’ as a data service architecture on servers in a ‘cloud somewhere’ began to take off. This new type of ‘web’ service would allow anyone with a web browser and a connection to the Internet to access services in the cloud irrespective of the kind of digital device they use, such as a PC, a Mac, a mobile phone or new devices still to be developed (Bogatin, 2006).

Since cloud computing is Internet based, reliable Internet access over high-speed broadband connections constitutes the most significant element in its future development, marketing and delivery to secondary education. While some cloud services may not require users to have fast Internet connections or use large amounts of bandwidth to access web applications such as text messages through Facebook or Gmail, others, such as downloading a streaming video file through Youtube or uploading large quantities of data to Amazon for storage (S3) or processing (EC2) do. In the limited broadband/bandwidth environment of the ‘digital divide’ this presents a significant problem to overcome in order for cloud computing to substantially contribute in bridging the digital divide (Le Roux and Evans, 2010).

Cloud computing, like the Web, is the evolution of a variety of technologies that have come together over the last decade or more to alter an organisation’s approach to building its IT infrastructure and hosting its information systems to present its web services to the public as a business model (Reese, 2009). According to Reese (2009), there is nothing fundamentally new about any of the technologies that make up cloud computing. Just as Netscape (Netscape, 2008) came to harness the different web technologies into its suite of Internet tools in late 1999, so Amazon in 2003 began to harness existing web technologies, web services and protocols to deliver remote computing services collectively referred to as Amazon Web Services (AWS). The best known among these cloud computing platform services are the organization’s off-site Simple Storage Service (S3) and its Elastic Cloud (EC2), launched in 2006. (Reese, 2009)

While cloud computing services, especially Software-as-a-Service (SaaS), are rapidly becoming a reputable concept among businesses which have fast and reliable access to the Internet (which is perhaps the most crucial requirement for cloud computing), their uses and virtues in secondary education are poorly utilized in developing countries around the world.

Cloud computing service models

Cloud computing is current delivered in three main service models, namely, cloud-based applications known as Software-as-a-Service, or SaaS, development platforms known as Platform-as-a-Service or PaaS, and computing resources for storage and processing common referred to as Infrastructure-as-a-Service or IaaS.

SaaS applications are currently the most widely used cloud applications in secondary education. Popular applications include: Google's Gmail, Google Docs, Zoho Office Suite, Microsoft Office web apps (Office Live), Quicken Mint, Adobe Buzzword, WriteRoom, Facebook, eLearning, (Microsoft) Docs for FaceBook, Creatly.Com for online diagramming and collaboration and Yahoo Calendar.

PaaS services, on the other hand, provide the infrastructure on which SaaS applications are built and run, which can be Windows, Unix or open source systems such as Linux or Ubuntu. Examples here include: Google's App Engine; Heroku (a Ruby on Rails platform) and Joyent's cloud software for service providers, which can host applications developed in various computer languages, and include SmartDataCentres, SmartMarchines and SmartPlatform. The latter is an open source JavaScript cloud platform that provide users with a single, unified web application development platform with infinite scale. According to the Joyent website, its SmartPlatform "abstracts away all the complexity of a modern data center" by using a "SmartDataCenter to manage specific hardware and network topology behind the scenes" and allow for "maximum productivity, efficient resource utilization and best-in-class application performance"(Joyent, n.d.).

IaaS, the third group of cloud services, offers virtual computing resources as a service. This means that instead of buying servers, software, data center space or network equipment, consumers can buy these resources as a fully outsourced cloud service (Infrastructure-as-a-Service). This type of cloud service, which is similar to buying electricity, is generally referred to as utility computing. Popular examples are Amazon's Elastic Compute Cloud (EC2), GoGrid, and Windows Azure. Although one popular use of IaaS is to develop websites, IaaS resources are normally used for more challenging and extensive computing and research efforts not normally performed at secondary school level (Le Roux and Evans, 2010).

To better understand the impact that cloud computing may have on the development and delivery of secondary education in developing countries, we need to turn our

attention to the development and current use of cloud computing service in the developed world.

Cloud computing in secondary education. The developed world.

Perhaps one of the most informative sources on the use of cloud computing applications by pre-college education institutions in the developed world is the K-12 edition of the *Horizon Report,* published annually since 2009 by The New Media Consortium in collaboration with the Consortium for School Networking (COSN) in the United States (*Horizon Report 2010. K-12 edition*:1-35).[1]

The reports provide a valuable insight into cloud computing resources currently being used by schools in the developed world. Each edition of the report introduces six emerging technologies or practices, their potential use and impact on teaching and learning, and their estimated adoption time over the next 5 years (*Horizon Report 2010. K-12 edition*:1-35). The six technologies identified are:

1. cloud computing (one year or less)
2. collaborative environments (one year or less)
3. game-based learning (2–3 years)
4. mobiles (2–3years)
5. augmented reality (4–5 years) and finally
6. flexible displays (4–5 years).

For the purposes of this paper the authors have decided to concentrate mainly on cloud computing as it has the best possible chance of implementation in developing countries over the next 5 years as compared to its implementation in the developed world. Although the adoption time for collaborative environments, also referred to as Learning Management Systems (LMS), in the developed world is seen as similar to that for cloud applications, the authors believe that given the current status of Internet connectivity and infrastructure in the developing world in general, and South Africa in particular, its adoption time in secondary education will be slower than general cloud applications for educational purposes.

This belief is partially borne out by the fact that even in the developed world the use of cloud applications by schools only began to take off by the beginning of 2010 as compared to 2009, when, according to the 2010 K-12 edition of the *Horizon Report*, few examples of cloud computing could be found in schools. Most of the cloud based applications adopted by secondary schools in 2010 were mainly for administrative purposes and productivity such as curriculum development, scheduling and collaboration (*Horizon Report 2010. K-12 edition*:1-35). The response of different secondary educational institutions around the world to the 2010 K-12 Report can be found on the COSN website (*Horizon Report 2010. K-12 edition*:1-35).

One of the most compelling reasons for adopting cloud services, especially Software-as-a-Service (SaaS) is the substantial savings in cost in terms of IT support, software and hardware expenses. This is largely due to the fact that because most of the required processing power needed for cloud computing is shouldered by large data centres, electronic devices with minimal processing power and memory can be used to access cloud applications, especially SaaS applications.

A significant finding of the K-12 Report was that while schools were increasingly beginning to adopt cloud-based applications in 2010 to manage calendars, rosters and grade books, and to facilitate communication between school and home, the actual use of cloud applications by students was still slow, suggesting that either teachers were slow to adopt cloud applications applicable for use in classrooms or that the infrastructure, namely fast high-speed broad connectivity, was not available, or a combination of both factors.

While some schools, like the Columbia Secondary School (CSS) in New York, and the Minnesota Online High School have adopted cloud solutions to facilitate student work in engineering, English and debate, others have not yet utilised available cloud applications for teaching and learning.

In the Minnesota Online High School the use of cloud applications has actively freed the school from having to press, ship, and inventory software CDs. It also made it simpler for their IT support staff to assist students, who use a wide range of computer platforms.

An even more advanced example of the use of cloud computing is the iLabCentral virtual science lab run by Northwestern University and the Massachusetts Institute of Technology (MIT). The project is an cooperative effort run by the two higher education institutions to share their high-end scientific instruments with high-school science teachers over the Internet to support virtual science labs. Kemi Jona, the Director of the iLabCentral project, argues that virtual labs are just as good, if not better than actual or physical labs, in preparing students for modern laboratory research (Young, 2009).

Northwestern University is not the only institution to follow this partnering route. North Carolina State University, for example, is working with IBM to provide cloud applications, computing power, and storage space to every public school in the state. Towards the end of 2009 IBM in the United States announced the release of its Cloud Academy which it describes as, a global forum for educators, researchers and IT personnel at higher educational institutions to pursue cloud computing initiatives, develop skills and share best practices for reducing operating costs while improving quality and access to education (IBM Advances Cloud Computing in Education (2009).

According to IBM Cloud computing makes it easier for those in the education industry, including students, faculty and administrators, to gain immediate access to a wide range of the latest educational resources and research applications and tools (IBM Advances Cloud Computing in Education (2009).

Cloud computing therefore represents good value for money by providing access to services and tools that would otherwise require substantial infrastructural investment. Add to this the fact that cloud applications can be accessed from a variety of devices, ranging from desktop to laptop computers and notebooks as well as many mobile devices, and the reason for shifting to cloud computing for secondary education starts to make a great deal of sense (*Horizon Report 2010. K-12 edition*:10).

In October 2009 it was reported online that Australian primary and secondary schools have started publishing educational content on iTunes U, which is a section 25 of the Apple Store, allowing educators to share materials. The Western Australia Department of Education (DET), the Catholic Education Network (CEnet), the Presbyterian Ladies' College WA (PLC), and the Scotch College WA are the major drivers of this program initiative. While the DET's content is designed mainly for the professional development of teachers, the CEnet's contributions are mainly classroom-oriented. Although iTunes U was originally designed for universities and other tertiary institutions it now actively caters for secondary schools (Withers, 2009).

The future of cloud computing in secondary education. The developing world.

Although cloud computing is a relatively new concept and many of the current SaaS applications, especially the cloud based office suites, offered by Google, Zoho and Microsoft, have some way to go before they will be as functional, features rich, and compatible as existing desktop-based office applications, there can be little doubt that the future of office suites is cloud rather than desktop based.

As pointed out the onset of this paper, cloud computing is primarily dependent on high speed broadband connectivity which is critical to its successful adoption. According to statistics released by the International Telecommunications Union for 2009 (ITU, 2010), the estimated number of Internet users for the developing world was given as 18 percent as compared to 66.6 percent for the developed world (see Table 1).

Similarly the number of fixed line internet connection for the developing world was 12.3 percent as compared to 42.7 percent for the developed world.

Cellular subscriptions by 2009 stood at 57.9 percent compared to 115.3 percent for the developed world while mobile broadband subscriptions in 2009 stood at 3.1 percent for the developing world compared to 39.9 percent for the developed world. Fixed-line broadband subscriptions were 3.6 percent for the developing world compared to 22.6 percent for the developed world.

As far as Africa is concerned, 37.5 percent of the continent’s population of more than a billion people had access to cellular devices. Only 2.2 percent of the entire population however had mobile broadband subscriptions. Although mobile broadband subscription was still relatively low it was expected to accelerate in the future as more and more

people on the continent make use of mobile devices to access the Internet. Total Internet users was estimated at 8.8 percent for the entire continent by the end of 2009 (ITU, 2010)(see Table 2).

Table 1. World telecommunication stats as a percentage of total population, 2009.

Category	Year	%
Fixed telephone lines		
Developed	2009	42.7
Developing	2009	12.3
Mobile cellular subscription		
Developed	2009	115.3
Developing	2009	57.9
Mobile broadband subscriptions		
Developed	2009	39.9
Developing	2009	3.1
Fixed broadband subscriptions		
Developed	2009	22.6
Developing	2009	3.6
Estimated Internet users	Year	%
Developed	2009	66.6
Developing	2009	18.0

Table 2. Telecommunication stats as a percentage of total population for Africa, 2009.

Fixed telephone lines	Mobile cellular subscriptions	Mobile broadband subscriptions	Fixed broadband subscriptions	Estimated Internet users
1.5	37.5	2.2	0.1	8.8

While the above figures are still relatively low for the use of modern Internet based technologies such as cloud application in secondary education in the developing world, especially Africa, progress is slowly been made despite questions being asked about the cost and sustainability of the process in the face of the many complex infrastructural and other challenges facing the continent (African ministers pass ICT directive, 2010).

On the positive side, according to a report on the 5th International Conference on ICT Development for Education and Training held in Lusaka, Zambia in May 2010, "more and more African nations are embracing full-scale regulatory reforms and market liberalisation in a bid to attract more investment in the Information and Communication Technology (ICT) sector and exploit the potential of low-cost technologies [and] their efforts to improve access to the Internet are slowly paying off "(Ng'andwe,2010).

The conference acknowledged that while 17 African countries already have an Information and Communication Technology (ICT) policy for education, only 10 have developed an implementation plan or have actually started implementation. While a number of best e-learning practices were proposed at the conference, no mention was made of the utilisation of cloud computing as a solution to bridging the digital divide in African education(African ministers pass ICT directive, 2010).

Cloud computing in secondary education. The South African picture.

At the beginning 2010 it was reported by World Wide Wrox that the number of South African Internet users had researched the 5.3 million out of a total population of almost 50 million people (South African Population Stats, 2010). This was an increase of some 15 percent from 2009 when the figure stood at 4.6 million users. Most of this growth was in the urban areas of the country and was expected to increase by about the same percentage in 2010 (Broadband Speeding Ahead, 2010).

The Wrox study also found that most of the growth in fixed-line broadband came from small and medium enterprises (SMEs) upgrading to ADSL, thereby providing Internet access to more than half a million South Africans working in small offices, who did not previously have access to the Internet.

Although wireless broadband, on the other hand, was found to have grown by some 88 percent during 2009, this was from an almost non-existing base and was mainly the result of large companies supplying 3G cards to employees who need to be connected whilst out of the office (Broadband Speeding Ahead, 2010).

According to the same source's 'Mobile Internet in South Africa 2010' study, almost all urban cellular users have WAP-capable phones, and a high proportion have used that WAP capability to access a variety of Internet based content on a regular basis. Mobile web browsing, which is measured directly in the new study, accounted for almost 3.5 million users by the end of 2009.

The Mobile Application Internet, which is measured across several applications, such as instant messaging, downloadable applications, Gmail, etc., is estimated to have about 9 million user (The Mobile Internet pinned down, 2010).

While this steady growth in internet connectively and usage amongst South Africans represents an encouraging picture the reality is that it currently has a very small footprint in the South African public schools landscape where most still have no library facilities or any formal access to the Internet. Although attempts are being made to address the inequalities of the apartheid past with regards to school infrastructure and facilities such as libraries, the backlog is huge and it remains to be seen to what extent the revised curriculum announced at the end of 2010 will make a difference in providing broadband capacity to South African public schools **(**Statement By The Minister Of Basic Education, 2010**).**

In a 2004 paper entitled 'Realities Versus Ideals With Regard To E-Learning In South Africa', Conradie and Roodt argued while there have been optimistic statements from official quarters, such as the hope that was expressed in the 2003 Draft White Paper on E-learning that South Africa could leapfrog into the future, there are many serious challenges to be overcome, such as a marked urban-rural digital divide in the country (Conradie andRoodt, 2004). The 2003 Draft White Paper on e-Education is now not only completely dated but the ideals set out by it to 'transform teaching and learning through ICT" was never implemented in policy or practice. A new policy on e-education that accommodates the new directions in technology, especially cloud based technology, is thus urgently needed.

The reality is that 7 years after the release of the Draft White Paper on Education, only 8 percent of the more than 27,000 government schools have libraries and only 10 percent have some form of Internet connection. (Bloch and Ndebele, 2010). Equal Education (EE), a non-government group based in the Western Cape, has estimated that ZAR 2.2 billion is needed to equip every public school with a functional library and qualified school librarian. KwaZulu-Natal and the Eastern Cape are the worst affected (OBE wrong from the start, 2010).

On the positive side, South Africa has both the technology and the skills to bridge the digital divide that currently exists in secondary education. In 2010 the country delivered the most hi-tech World Cup event in history. Telkom, the semi-state telecommunications giant, played a key role in providing state-of the art telecommunication infrastructure for the games. For instance, all the stadiums were supplied with 20Gbps bandwidth networks that had capacity for High Definition TV broadcasting. A total of 1900 km of fibre optic cable alone was laid for the World Cup venues (The most hi-tech World Cup yet, 2010). Clearly, South Africa has the skills and the capacity to bridge the digital divide in the country's secondary education system. In 2010 it was announced that it would receive ZAR 165 billion or 20% of the country's total budget for the 201/2011 financial year. This represented an increase of ZAR 17-billion over the 2009/2010 financial year (R17bn Budget hike for education, 2010).

ZAR 5.5 billion of the ZAR 165 billion education budget was allocated for infrastructural development. This figure was expected to rise to ZAR 9.4 billion by the 2012/2013 financial year (R140bn is needed to fix school facilities, 2010). In March 2010 the Minister of Basic Education told parliament that South Africa needed ZAR 140 billion – slightly less than the total 2010 education budget – to build new schools, fix up old ones and provide libraries and other facilities, and that government was seeking outside assistance to foot the bill.

In July 2010 the Department of Education announced its Teacher Laptop Initiative (TLI) to "facilitate ICT integration in public schools across the country"(Media: Teacher Laptop Initiative Rollout Launch, 2010). According to the Departments website the initiative was an attempt to address "South Africa's need for a quality education system and forms part of the cohesive plan by the Department of Basic Education (DBE) and other stakeholders in education to improve the overall quality of education by making resources available to learners and teachers in the public education sector."

The ICT packages[1] for teachers would consist of a laptop with prescribed minimum specifications, school administration, national curriculum and other software, as well as Internet connectivity, insurance and financed (Media: Teacher Laptop Initiative Rollout Launch, 2010). While this development represents a step in the right direction it is not clear how the learners would benefit from this initiative which is primarily aimed at teachers and teaching administration. For instance, no provision is made for data projectors or how teachers will share the learning/lesson content on the laptop with their learners. Only time will tell how successful the initiative will be and to what its impact will be on quality teaching and learning in public schools in South Africa.

[1] Qualifying teachers will receive a monthly allowance of R130.00 (taxable) and are required to fund the difference between the allowance (R130.00) and the monthly repayments of the package.

Conclusion

In the introduction to this paper we asked to what extent cloud computing applications and services, currently used by secondary education systems around the world, can be used to help bridge the digital divide in secondary education in South Africa. The answer is that while many schools in the developed world are starting to make use of cloud applications especially suitable SaaS application for teaching and learning, South Africa despite its generous education budget and initiatives such as the TLI has not caught up with this new development despite the promise of saving on infrastructure and software cost. While the TLI represents a positive step in the right direction the next major step must be to provide reliable, fast and affordable internet access to public schools to enable teachers to start exploring cloud base application in their teaching and curriculum activities.

Finally, teachers need to be trained in the effective use of online information and cloud applications for teaching and learning purposes. Technology, as the TLI initiative suggest, can no longer be seen as a luxury available to only a select few. It should forms an essential part of the world of education today and this should especially be so in a developing country like South Africa. The success of the 1010 World Cup and the ability of semi-state entities such as Telkom to provide the necessary telecommunications infrastructure shows that South Africa has both the technical knowhow and the capacity to bridge the digital divide in its public education system and as such set the pace for the rest of the African continent.

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