Cloud Computing Opportunities for Post-Secondary Education

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EXECUTIVE SUMMARY

We are approaching a world where computing isn't an infrastructure you build and maintain, but a utility you consume. Post-secondary education can use this new environment to lower costs, improve institutional agility, and enrich education and research. The key to the transformation is cloud computing.

"The Cloud" and Cloud Computing

Today, "the cloud" refers loosely to technology tools and content you can call up over the Internet as needed, independent of the device you're using to access them. Increasingly these services are made possible by cloud computing, which makes pooled computing power available to remote users in flexible, easy-to-use ways. In its essentials, cloud computing is:

- On-demand: cloud services are just "there" and available for use, and billed on a usage basis rather than being owned or leased;
- Shared: many customers use the same resources via networks, feeding economies of scale;
- Configurable: individual customer services can be flexibly configured and managed with minimal or no expert intervention; and
- Elastic: capacity and service use can grow on demand, then shrink or disappear when demand drops or needs have been satisfied.

Cloud computing makes many sorts of technologies and capabilities available "as a service." Three basic categories are commonly offered: Infrastructure as a service provides basic hardware like servers and storage, accessed by customers who never see the physical machines they're using. Platform as a service provides, in addition to basic hardware and storage, technical components such as programming languages or other tools that make it easier for users to create and deploy their own applications. Software as a service delivers specific applications such as e-mail or payroll via a web browser or a device app.

The flexibility to obtain and deliver many kinds of computing as a service, off-the-shelf or built to order, with different models of ownership and governance, makes cloud computing a powerful addition to post-secondaryeducation's technology options.

Cloud Opportunities for Post-Secondary Education

Cloud computing has some advanced technology elements, but its ultimate purpose is to make computing power easier to consume. In many ways, it's merely the culmination of technology trends that higher education pioneered. By making services readily available while minimizing the complications of deploying and delivering them, cloud computing can improve focus on academic and business fundamentals and both reduce and clarify costs. What's more, cloud computing lends itself to sharing services and pooling demand among institutions, feeding an ecosystem of "above campus" resources that takes pressure off the local IT organization.

The cloud is becoming an important strategic resource because it affords post-secondary education opportunities to:

1. Reduce and Rationalize IT Capital Expenses.Cloud services are available on demand, can be used as much or as little as needed, and are billed according to use. By contrast, premises-based computing typically requires a lot of up-front investment and "just in case" capacity planning. The cloud model eliminates some up-front costs, permits others to be treated as operating rather than capital expenses, and allows costs to be allocated directly to those consuming the service without the

complications of accounting for shared infrastructure and services.

2. Aggregate Demand and Share Services.Creating post-secondaryeducation-specific community clouds and shared cloud services can help institutions aggregate demand, spread costs, and improve their leverage with vendors. Promising efforts to create a "post-secondary education cloud," largely being led by national and regional networking organizations (like ORION in Ontario and BCNet in British Columbia), now focus mainly on infrastructure services but are likely to move toward delivering complete business solutions.

3. Improve Institutional Agility by Distributing IT Choice. The cloud "consumerizes" IT capabilities, making it easier for departments and individuals to get what they need without an IT organization. By lowering the bar of entry and making exploratory computing efforts more feasible, cloud services can help feed an institutional culture of responsiveness and creative problem solving.

4. Support the Global Campus. Many institutions today pursue international teaching and research partnerships, but providing these initiatives with technical support is complex and costly. The cloud's characteristics of on-demand service, elastic capacity, and sharing of resources are tailor-made for delivering services unconstrained by time and place.

5. Make IT Greener. Cloud computing can be much more energy efficient than traditional premises-based computing, and cloud data centrescan be located where energy costs are low. Taking advantage of these differentials can substantially lower an institution's IT carbon footprint and energy expenses while reducing the demand for local data centers.

6. Deliver Education as a Service. The cloud is spawning a vast ecosystem of educational resources that will make it easier to deliver education itself "as a service." Educational content is increasingly digital in nature and consumed on cloud-ready devices, and emerginglearning platforms are delivered as, or make heavy use of, cloud-based services. Providing the characteristic on-demand convenience, self-service simplicity, and cost effectiveness of consumer cloud services will be a major goal of the next generation of technology-enhanced education.

Cloud services remain immature, and institutions adopting them will face risks and challenges. Among these are unproven economics, security and compliance issues, integration and performance limitations, vendor exposure, and cultural changes associated with doing business in new ways. These considerations are sufficiently serious that a companion paper, Meeting the Challenges of the Cloud in Post-secondary Education, is being developed to assess them.

But it is clear that the cloud is shifting the balance of computational power beyond campus bounds. The time is ripe for post-secondary education to begin thinking about the cloud as a strategic resource and to recognize that it presents new ways to make education financially and environmentally more sustainable, to improve institutional agility and focus, and to enhance learning and research. Institutional leaders need to learn about cloud computing's possibilities and consider how to seize the opportunities outlined in this paper.

INTRODUCTION: A NEW WORLD OF SERVICES

Not that long ago, to use a computer, you had to go to one. Now the computer comes to you. In fact, networks put millions of computers at our disposal, delivering services so useful and varied that there hardly seems to be

any task they can't help us with.

Increasingly, this world of services is known as the cloud. Most of the time, the cloud relies on the same familiar Internet that we've been using for nearly two decades. But in recent years, advances in technology have transformed what we can do via the Internet. Networks are so speedy, and distant data centres so powerful,

that more and more work that originates at your fingertips can be done by faraway servers. Thanks to mobile devicesand wireless networks, the cloud surrounds us all the time, wherever we go. We are approaching a world where computing isn't an infrastructure you build, but a utility you consume.

It is as important for post-secondary education to understand this transformation as it was to comprehend the last comparable development, the emergence of the World Wide Web in the 1990s. More and more, knowledge that was once concentrated in physical places like university and college campuses and libraries—or their data centres—can simply be pulled from the sky. Just as colleges and universities shaped older technologies like publishing and broadcasting to meet academic needs, they will have to master the cloud's new breed of smart information services.

There are also immediate and practical reasons for post-secondary education leaders to put their heads in the clouds. Responding to cost pressures, reaching new student markets, extending research frontiers, and operating effectively in a world of cross-institutional collaboration all are critical challenges that the cloud can help post-secondary education meet.

How well or how soon we might realize such benefits is still uncertain. Like all new technologies, the cloud is subject to exaggeration, marketing hype and unknown risks. But cloud computing is almost universally recognized as the next major stage in the evolution of our digital lives. It will be increasinglynecessary for our institutions to have not just technology plans for the cloud, but genuine institutional strategies and road maps for realizing the opportunities it presents.

Cloud Computing: What It Is and What It Does

Clouds—the real kind, in the sky—can be hazy or they can have crisp, sharp forms. Definitions for the new kind of technology cloud come both ways too, and there are some advantages to each kind.

"The Cloud"

For some people, "the cloud" is just a new metaphor for the Internet. That's too broad, but still it's probably best to definethe cloudin a hazy way, without getting too specific. Today itrefers loosely to the technology capabilities that are available as services over the Internet—that is, tools and content you can call upas needed, independent of any particular machine and its configuration. Work that you might be accustomed to doing on your PC or institutional server is done by cloud infrastructure at the far end of a network connection, allowing your local devices to be simple and limited in function.

From a user's standpoint, the great thing about the cloud is that it frees you from managing software and from relying onspecific machines and physical media.As long as you have an Internet connection, you can edit a document on any computer, rather than just the one your word processing software is installed on. You can access a huge library of movies without owning a single DVD. If you close a digital book on your e-book reader and then later open it on your smartphone, it will not only be there, but it will start at the right page.As networked mobile devices get more sophisticated, this ability to access your own virtual information environment in the cloud will get ever more powerful.

Cloud Computing

More and more, the services we access from the cloud are made possible bycloud computing, which calls for a sharper, more specific definition. A commonly cited definitioncomes from the U.S. National Institute of Standards and Technology: "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction."Reduced to essentials, cloud computing has several distinct characteristics:

- On-demand: from the user's standpoint, cloud services are just "there" and available for use, and billed on a usage basis rather than being owned or leased;
- Shared: many customers use the same resources via networks, permitting economies of scale;
- Configurable: individual customer services can be flexibly configured and managed with minimal or no expert intervention; and
- Elastic: capacity and service use can grow on demand, then shrink or disappear when demand drops or needs have been satisfied. This is a marked departure from the current practice of building "just-in-case" IT resources to accommodate growing institutional demands.

When we summon up servicesfrom the cloud, we really don't care how they're deployed; we just want them to work. Cloud computing helps hide complexities from end users,giving them just the services they want without extraneous effort. This is made possible by technologies that pool computing power (often at very large scale) and allow it to be used very flexibly by many remote users.Among these technologies are ways to create "virtual" computers with different characteristics than the physical computers they run on, techniques for easily increasing or decreasing the amount of computing power a customer uses, and computing methods that split workloads between local and distant machines, connecting them with fast networks.

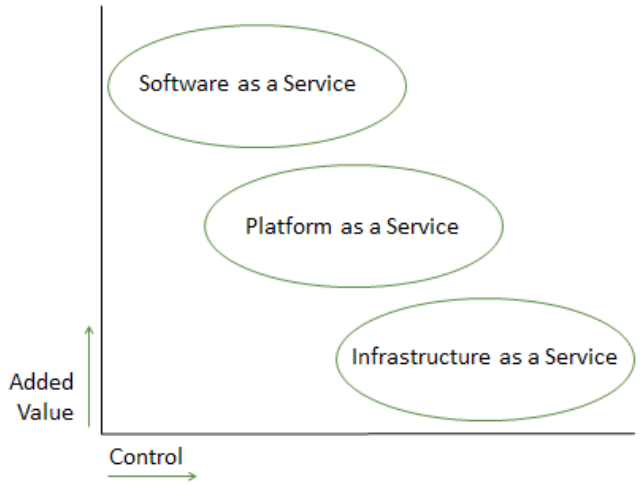
While on-demand, shared, configurable, elastic services typify cloud computing, exactly what any given service provides can vary.

- Infrastructure as a serviceprovides basic hardware like servers and storage, accessed by customers who never see the physical machines they're using.
- Platformas a serviceadds technical components that simplify the creation and deployment of custom applications. provides, in addition to basic hardware and storage, technical components such as programming languages or other tools that make it easier for users to create and deploy applications.
- Software as a service delivers specific applicationssuch as e-mail or payroll via a web browser or a device app.

These different types of services can be built on top of one another. For example, an institution or consortium could obtain a basic infrastructure service, add its own platform components in order to run a certain application, and offer the finished package to constituents in the form of software as a service.

Cloud services, then, range all the way up the IT "stack", from raw computing chiefly consumed by technical users to refined applications directly useable by students, faculty members, and staff. Generally speaking, cloud services lower in the value chain offer more control but leave more for the user to manage, while those farther up are more constricted but easier to use (see Figure 1).

Figure 1. Cloud Services Models



Public, Private, and Community Clouds

While "the cloud" refers broadly to all the services available over the Internet, it is possible to configure individual clouds—service-offering infrastructures that have the characteristics of cloud computing—with various ownership and access models. Public clouds offer cloud services on the open market for anyone to use.A classic example is Amazon's Elastic Compute Cloud (EC2), an infrastructure service thatlets you set up a virtual server environment and pay for it with a credit card. Technology companies like IBM, Microsoft, Apple, Oracle, and SAP are investing heavily to create consumer- and business-oriented public clouds that deliver a wide range of services.

Private or community clouds are made available only to a specific organization or group. Clouds like these may not spread costs over as many users as public clouds do, but they can be better tailored to suit particular needs, such as special technical requirements, non-standard contract terms, or compliance with a regulatory regime. Users know more about the other "tenants" sharing the cloud infrastructure, and have more say over who can join. Access might be over the Internet or through private networks.

None of these categories is totally standardized, and all can take hybrid or customized forms. The boundaries between, say, infrastructure as a service and platform as a service, are fuzzy. "Virtual" private or community clouds can be carved out of public clouds. This flexibility to obtain and deliver many kinds of computing as a service, off-the-shelf or built to order, with different models of ownership and governance, is what makes cloud computing such a powerful addition to post-secondary education's technology options.

SIX CLOUD OPPORTUNITIES FOR POST-SECONDARY EDUCATION

The cloud may be the most over-hyped concept since pundits declared a "New Economy" in the 1990s. Post-secondary education leaders are and should be cautious. That said, cloud computing is the most important IT development in years and will in many ways define post-secondary education's technology and processes for the foreseeable future.

The cloud is in fact the natural culmination of ubiquitous network access, the proliferation of networked resources and services, and the virtualization of computer hardware and software. As these forces become more and more

widespread, mature, and secure, we need no longer think about where any given resource comes from, and can even begin to stop thinking about how that resource works. Our focus can shift to integrating and tailoring such resources in ways that support our institutional missions and ambitions. Not so long ago, many of our institutions operated steam generators to provide power and heat for our classrooms, labs, and dormitories. Today, most of us worry about managing the cost of power, about the security and reliability of our power supply, and about ensuring that the right amount of power is available to the right stakeholders at the right time. And of course, we think about business interruptions and how to minimize them.

Now, and for the foreseeable future, our reach for the clouds will be viewed as a set of choices about how to organize IT, how to balance the mix of IT costs, how to provide for growth in digital services, and how to balance scale economies with security, privacy and other critical institutional concerns.

Moving to the cloud creates at least six opportunities for post-secondary education.

Opportunity 1: Reduce and Rationalize IT Capital Expenses

Today, most college and university enterprise software systems are hosted on campus. Their lifecycle goes something like this:

- Phase 1: Capital expenditures. If a commercial purchase, buy a software license; if open source, download. Purchase or lease hardware, possibly also upgrading network and data centre capacity.Because of the need to meet peak loads and provide some room for growth, these up-front hardware investments nearly always (by design) exceed near-term and average needs.

- Phase 2: Development and deployment. Software is installed, configured, and often customized to meet special needs. Integration with other systems—often technically challenging but necessary, and the source of a lot of IT value—is carried out. System hardware is tested to ensure that it can handle estimated peak loads.

- Phase 3. Operations. Once live, periodically update as new versions come out. Major releases may demand substantial programming work and hardware upgrades, and integration work is ongoing. Arrange data backup, provide for business continuity in the event of disaster, and manage security, privacy, and regulatory compliance.

The premises-based approach offers a lot of control, but it also means up-front capital expenditures in the form of software licenses and a dedicated infrastructure. If new IT growth exceeds data centre capacity, even larger investments will be needed. Operationally, in a premises-based model,the institution commits to the perpetual care and feeding of its system. Furthermore, some project development and operational costs are spread across general infrastructure and shared technical services, which makes it difficult to say exactly what the institution is spending to provide a particular service--and who should pay for it.

Consider how cloud computing options can simplify this process and reduce or avoid these capital expenses so that they can be put to better use elsewhere. Instead of buying hardware capacity based on peak loads that only happen occasionally, the institution can deploy the software on "elastic" cloud infrastructure and ratchet it up at busy times—when thousands of students are simultaneously registering for classes, or studying online for upcoming exams—and then takeit back down again for normal or low-load periods. Data centre capacity is the service provider's concern, and the hardware costs become operating costs based on actual usage.

If the institution chooses the more complete option of software as a service, it avoids the up-front software license fee as well. Upgrades are performed centrally, as are security, backup, business continuity, privacy compliance and other administrative chores. Some management and integration duties remain on the institutional side, and the networks that deliver the service may have to be beefed up. But again, a lot of capital expense has

been avoided or translated into operational expense, and the bill arrives in the form of a discrete, line-item cost.

Cloud computing's ability to measure usage and charge "by the sip" can not only avoid capital expenses, but help make the sponsors of an activity responsible for the cost of their technology consumption. In a premises-based environment, for example, a researcher's use of IT may adddemand tocentral infrastructure that is hard to measure accurately or charge back directly. In a cloud environment, those services are metered and billed by the use, and can become a direct expense of a research project allocable to a government grant or research contract.

The most familiar examples of institutional cloud-based services in higher education are the email and office productivity suites offered by Google, Microsoft, and others. In the USA, over 40% of institutions have adopted one of these systems for student email. In Australia and New Zealand, three quarters of universities have done the same. While adoption has been slower in Canada, owing to a greater regulatory sensitivity to IT security, privacy, and international data management practices, some institutions, including large ones like the University of Albertaand the University of Toronto, have made the switch.

At the University of Alberta, the Google suite has been rolled out to the entire university—students, faculty, and staff, totaling over 120,000 accounts. Jon Schaeffer, vice provost for information technology at theUniversity of Alberta, wanted to improve service and consolidate the university's 82 separate email systems in a cost effective way. "We looked at the costs to unify all those systems if we hosted it locally," Schaeffer says, "and they were very high." Google was the much cheaper option, and though it took over a year to negotiate contract terms that satisfied federal, provincial, and university privacy and security concerns, Schaeffer feels the contract now provides a good model for most other post-secondary institutions in Canada. Since rollout began, tools like university-wide calendaring and collaborative cloud-based document editinghave begun to change work culture in ways that are hard to measure financially, but seem to be both popular and positive. "We did zero marketing of the online collaboration tools," Schaeffer says. "That just spread by word of mouth. Once people see it and understand what they can do, it's huge."

Cloud-based services are also making inroads in other areas of campus technology. More recent product categories, and especially products designed from the ground up for Internet delivery, tend to have higher cloud adoption rates.About 28% of US institutions report using cloud-based delivery of learning management systems, which is well above the 4% using cloud delivery for major administrative (ERP) systems. This is partly because systems that support learning are usually newer and less tightly integrated with other campus systems, and in some cases, are being written for the consumer market, not the institutional market. Administrative systems typically have a longer technology heritage rooted in software designs that are harder to move to the cloud. They also have deep roots in institutions' staffing. While institutionsmay be less likely or even unlikely to replace longstanding premises-based systems and the staff who support them, theyare very likely to look to the cloud to supply important newer solutions, where demand is high, but investment capital is scarce. At the same time, taking into account "proto-cloud" strategies, like multi-institutional sharing and vendor hosting of administrative systems, would add substantially to the pool of institutions that have opted for the basic concepts of cloud delivery.

Furthermore, the range of options is getting broader. Heavyweight business software vendors like Oracle and SAP have made big commitments to software as a service, particularly in their latest-generation software suites. SAP's purchase of the cloud HR service vendor SuccessFactors was seen as a watershed endorsement of the cloud concept from a company whose name is synonymous with large-scale premises-based enterprise systems. A new breed of "born in the cloud" vendors is leapfrogging incumbents with products that have no premises-based legacy to overcome. One of these, Workday, has signed upfive large US universities for its human resources software-as-a-service product, and is pursuing post-secondaryeducation as one of its key target markets.

Taking advantage of cloud opportunities to get institutions out of the IT infrastructure-building business will require some new skills and a fuller understanding of how these rapidly developing services work in practice. Institutions will want to be sure that their data and operations can be trusted to cloud providers, and they will have to become adept at choosing the optimal combination of cloud and premises-based options. But the day is coming when much of what post-secondary education does to provide itselfwith IT services will feel as outdated as running a farm to supply the campus cafeteria or a generating plant to keep the lights on. Post-secondary

education will benefit, not just from redirecting capital funds elsewhere and allocating costs more rationally, but from better strategic focus on the core work of education and research.

Opportunity 2: Aggregate Demand and Share Services

The economics of the cloud are all about aggregation. In big public cloud data centres, lots of computing power gets pooled and allocated to meet lots of aggregated customer demand. The greater the scale, the lower the unit cost of providing service. Cloud vendors use many techniques to take advantage of aggregation, from serving many customers with the same application and database ("multi-tenancy") to keeping contract terms standardized over as broad a customer base as possible.

Post-secondary education institutions are keenly aware that there are both advantages and disadvantages to this sort of sharing. They want to realize the cloud's economies of scale and the other benefits of shared services. But they don't want their unique needs to be lost in a homogenized technical or contractual environment, or worse, their data to be somehow exposed to other tenants in a shared infrastructure. What's more, they want to move beyond the divide-and-conquer vendor tactics that typify the premises-based IT environment.

Fortunately, post-secondaryeducation has a culture of cooperation and collaboration that can be channeled toward providing IT services. There are many recent precedents for doing so, from multi-institutional collaborations to build and operate scientific apparatus to educational consortia that help aggregate learning materials and distribute courses and academic programs. As two university CIOs point out, cloud computing can help createa whole new range of "above campus services" that are better and cheaper than any one campus can provide on its own.

A key goal of demand aggregation is to achieve a better balance of knowledge and market power between vendors and institutions. Most of the time today, buyers are isolated because they shop individually and are bound by non-disclosure clauses that keep them from openly sharing terms and prices. Furthermore, in important areas such as enterprise administrative and learning management systems, vendor acquisitions and mergers have reduced the range of market choice. Cloud computing provides pathways for institutions to combine their power as buyers and to create consortial services able to compete with vendor hosting and cloud solutions. In addition, entrepreneurship inspired by the cloud's possibilities has introduced hungry new players into a dwindling field of "usual suspects" catering to post-secondary education's technology needs.

Instances of effective demand aggregation in post-secondary education are growing in number and importance.

Some of the most promising initiatives in post-secondary education IT today are efforts to provide the benefits of a "post-secondary education cloud" aggregated at the right level and providing the right services. Such initiatives have been launched by organizations in the UK, the Netherlands, Australia, the United States, Canada, and other countries. National and regional education/research networking organizations have been notable leaders in this work, which makes sense: educational network providers already are experienced at something similar to cloud demand aggregation. They compete with commercial networks by pooling network demand across a range of institutions, fine-tuning services to meet educational needs, and providing appropriate forms of member governance. They also control one of the key inputs to cloud computing: the networks that connect customer to cloud provider.Since transport costs—charges for sending data back and forth—can be a significant factor in the cost of cloud services, access to consortial and high-performance networks is a major advantage for post-

secondary education.

In Canada, regional research and education networking organizations like ORION (Ontario) and BCNet have introduced cloud-basedservices includinge-mail and calendaring, backup/storage, video teleconferencing, and educational content delivery. In the USA, Internet2 has announced agreements to broker cloud computing and storage services from HP and the cloud storage provider Box on behalf of its members. Most of these services are new and still in the experimental stage."We needed some mechanism whereby university CIOs had some impact on where the cloud is headed," says Internet2 project director Khalil Yazdi. Like some of ORION's services,

Internet2's initiative makes use of public cloud services, but with special pricing, terms and conditions, and agreements to leverage their network. In turn, vendors gain access to a valuable customer base and avoid the costs and delay that would come from negotiating with institutions one at a time.

Instances of effective demand aggregation in post-secondaryeducation IT are growing in number and importance. In Texas, seven universities that are part of the University of Texas system have pooled their needs and are working to build a shared service for their core enterprise systems and for data reporting and analytics. One education and research network is exploring pooling the concurrent demand of its members for a voice-over-IP solution, to create or contract for a shared service that would meet the collective demands, at far lower costs than if acquired separately. The cloud means that we longer have to think about "one campus, one (telecommunications) switch!"

We can expect the pace of collaborative cloud-related efforts to accelerate and their focus to broaden as aggregated cloud services move "up the stack" from infrastructure toward complete business solutions. To createpost-secondaryeducation-friendly cloud services, institutions will also cooperate on contract templates, integration and security services, and regulatory compliance. Efforts like these will make it possible for institutions not only to benefit from, but to shape the way cloud services develop.

Opportunity 3: Improve Institutional Agility by Distributing IT Choice

A computer science professor wants her students to explore a certain programming problem in several different technology environments that they might encounter professionally. But setting these environments up on campus servers is expensive and a lot of work, and this part of the course only takes up a week of the academic year. The solution? Use platform-as-a-service products that can be summoned up, quickly configured, and let go until the next time the course is offered.

This example reminds us that the cloud opens opportunities all the way up and down the institution, not just at the level of enterprise IT. The cloud "consumerizes" IT capabilities. Many of the preliminaries to getting technology-enabled academic or business work done in a premises-based setting aren't needed in a cloud environment. Cloud services lower the bar of entry and make short-term, exploratory, or speculative computing efforts more feasible. People who might have had to go hat in hand to an IT organization to answer their computing needs will increasingly be able to find cloud services that get the job done. The people we're accustomed to calling "users" of IT will become "choosers" of services.

The ability to choose cloud services directly will have many advantages for institutions. Just as some services might go "above campus" to exploit aggregated demand across institutions, some will fall "below campus"—taken over by consumer cloud services that are good enough to replace institutional ones altogether. Faculty members who are able to find collaboration or content creation tools in the cloud will be less likely to demand that their institutional IT unitsdeliver them. Departments with some special application need will be able to fulfill it without waiting for an unpredictable campus IT governance process to prioritize a jumble of competing requests.There will be less temptation to set up amateurish departmental "shadow systems" that don't meet sound system administration standards—a common circumstance that CIOs dread because such systems often bristle with security, privacy, and compliance risks.

Reducing the skills and infrastructure overhead needed to obtain IT services means that projects can focus more on academic or business needs and less on technical ones. The power to get things done will shift down the IT

hierarchy and involve fewer people, simpler workflows, and less bureaucracy. Budget resources now dedicated to shared central IT efforts will likely moveto academic and business units that are directly accountable for fulfilling institutional mission goals.

Many post-secondaryeducation leaders put a high priority on developing an institutional culture of responsiveness and creative problem-solving. The cloud can be a tool in that effort. Undoubtedly there are risks as well as opportunities in a cloud-empowered institution—duplicated efforts, security and regulatory vulnerabilities, invisible dependencies—that will demand new kinds of IT support and active efforts to teach staff how to use the cloud wisely. But if these challenges are met, the cloud can help change institutional culture for the better.

Opportunity 4: Support the Global Campus

Post-secondary education has always had cosmopolitan interests, but its operations have traditionally been surprisingly local. That, however, is changing,and higher education is going global. Factors including economic growth in formerly "third world" economies, liberalized borders, and the globalization of business and research are driving more students to look for education--and more institutions to look for students--across national boundaries. Today about 3 million students seek highereducation outside their home countries, an increase of 57 percent in the last decade.

Even more important than the rising number of globally mobile students is the growth of new centres of higher education, which is unfolding even as nations with established higher education systems realize that they must adapt to a globalizing economy. Just as North America imported practices from Germany and other parts of Europe to create its own world-class research universities, institutions in Asia, the Middle East, and Latin America are embarking on ambitious development programs that borrow from, and partner with, established institutions in the West.Their work is bearing fruit. China, though still a major source of international students training at institutions around the world, is a net exporter of post-secondaryeducation, mostly to other parts of Asia. Competition for research talent is going global too, as aggressive emerging institutions become increasingly attractive to expatriate researchers and to other scholars hungry for the resources and green field opportunities they see there.

The need to stay competitive and to realize the benefits of globalization has stimulated a remarkable wave of global entrepreneurialism among North American institutions and their partners. Program-level partnerships between institutions half a world apart are now commonplace, and initiatives to create whole new campuses and institutions like the Yale-National University of Singapore College, NYU Abu Dhabi, and Duke University Kunshan (China) have proliferated as well.

All such ventures rely on technology and many would be unthinkable without it. Yet providing technology support to a global enterprise is a complex business that can require substantial rethinking and rebuilding of classic campus-based IT operations. Business process requirements must change to meet local circumstances; new computing demands swamp existing data centres that weren't built with them in mind; support hours lengthen and maintenance downtime becomes harder to schedule. Giving globally distributed units their own local infrastructure is not only expensive but frustrates the fast-movingentrepreneurial ethic that often governs the new ventures.

The cloud provides a powerful new tool to help those institutions for whom globalization is a priority. Its characteristics of on-demand service, elastic capacity, and sharing of resources are tailor-made for delivering services unconstrained by time and place. Georgetown University'sneed to roll out administrative support easily to its Doha campus, for example, was one reason why the university decided to use the software-as-a-service provider Workday for its next-generation HR and payroll systems. As the cloud services marketplace grows, it will help globalizing institutions both by increasing the value obtainable from core systems and by increasing the supply of targeted, locally-appropriate services needed to manage far-flung educational enterprises.

Opportunity 5: Make IT Greener

Computing is a power-hungry business, with serious implications for cost and environmental sustainability. Thanks mainly to the electricity it consumes, information technology accounts for about 2% of all global carbon emissions. Data centre operations are the fastest-growing component of this IT emissions footprint, growing at about 7% per year. While post-secondary education has made conspicuous commitments to environmental sustainability, a recent study of North American institutions concluded that progress toward greener IT was modest and uneven. Only about half of institutions thought that their data centre operations had become more energy efficient in the previous 12 months. One in six thought efficiency had decreased, while the rest thought it had stayed the same.

In fact, there are real limits to what institutions can do to make premises-based operations more energy efficient. Data centres are often found in legacy buildings not designed for the purpose, which can be hard to optimize for efficiency. The need to have enough horsepower at hand for occasional peak demand means that hardware runs needlessly when demand is low. Campus IT units don't have much choice about where to shop for electricity, and lack of department-specific metering and billing often makes it hard even to measure energy use and coordinate any effort to limit it. Meanwhile, demand for computing power increases relentlessly. An institution hitting its data centre's limits faces the huge capital expense of building a new one—which will probably be overbuilt in anticipation of future demand. In some cases, it may simply not be possible to bring enough electricity to a campus site to meet computing needs.

Cloud computing offers many opportunities to reduce energy use through economies of scale and intensive use of hardware. A lot of this comes from getting more work out of each server and storage device. Clouds can offset one customer's less-active periods with another's peak times, smoothing out variability while using the same servers and databases to serve many customers. One vendor study estimates that cloud delivery can reduce the carbon footprint of running a common enterprise application by over 90% for a typical small enterprise and over 30% for a large one.

Differentials in energy costs can effectively be exported from cloud providers to their customers.

In addition to efficiencies in the use of hardware, cloud operations can also exploit advantages of location. About half of the energy cost of data centre operations comes from cooling down hot-running hardware. Not constrained to a particular location, cloud data centres can be put in places where electricity is cheap and emissions-free—hydroelectric power can be half the cost of that produced by coal-fired plants—and where cool outside temperatures can be used to advantage. Because the optical networks that provide long-distance connections are very energy efficient, differentials in energy costs can effectively be "exported" from cloud providers to their customers.Cloud-scale data centres can also use sophisticated cooling techniques that aren't economical at smaller scale, and they can afford more redundancy in the cooling infrastructure. This is a key point. Strange as it may seem, air conditioning is high on campus CIOs' worry lists. Often there is little or no excess capacity and a failure would soon force operations to shut down.

Simply relocating traditional institutional data centres to exploit such advantages is oftennot cost effective, because energy savings at traditional scale are not great enough to justify the capital expense of new data centre construction. However, a recent report conducted on behalf of the Canadian networking organization CANARIE concluded that, compared to single-institution initiatives, "a green community data center [operated by CANARIE] has numerous other benefits and is more likely to be economically beneficial."

For many post-secondary institutions, sustainability is about much more than containing costs. It's a part of the institution's mission of service and of being an example to the community. Cloud computing provides a new avenue for fulfilling that mission in IT operations.

Opportunity 6: Deliver Education as a Service

Cloud computing's benefits extend to instructional technology just as they do elsewhere.Besides software-as-a-service and vendor-hosted options, institutions can manage their own LMS installations on cloud-based infrastructure. It's not hard to envision post-secondaryeducation clouds delivering such services as lecture capture or videoconferencing, particularly where they can make use of high performance networks.

But the cloud's impact goes well beyond just making today's instructional technologysimpler to provide or less expensive. The cloudis spawning a vast ecosystem of educational resources that will make it easier to deliver education itself "as a service."

In fact, the cloud already offers a lot of educational services. Consumer resources like Facebook, YouTube, and Twitter are awash in educational content, and are routinely incorporated into both classroom and online instruction. "Edupreneurial" ventures providing academic instruction over the Internet are plentiful and are beginning to operate at scale. One of them, the Gates Foundation-funded Khan Academy,has delivered over 135 million lessons from its cloud-based library of 3,000videos, and its systems are compiling an enormous database of how students interact with those lessons. Instructors lacking access to an institutional learning management system can use cloud-based tools like Coursekit and Blackboard CourseSites. On the learning content front, the cloud gives consumers direct access to vast book collections (Google Books), lectures captured in university classrooms around the world (Apple iTunes University), course syllabi and lecture notes (MIT OpenCourseware and others),and large libraries of open learning materials (MERLOT, Connexions, the OpenCoursewareConsortium).

This is only the beginning. Not only are many physical study and learning materials being digitized—film and music libraries, archival collections, museum specimens—but increasingly educational resources are born digital. Though printed books still dominate textbook sales today, electronic textbook sales are growing fast. One vendor estimates that digital textbooks, accounting for only 3% of US textbook sales in 2011, will reach 25% by 2015.

One reason for this anticipated growth is thatnew mobile devices are reshaping when, where, and how we read. Standards for packaging learning content so that it can be used on different systems and devices are maturing as well. Emerging electronic textbooks incorporate richer media than print can—a video clip embedded in a historical text, a physics problem with its own interactive graphing tool—and they are modular, permitting instructors to mix, match, and reorder modules.Most of these resources will be distributed and/or consumed through the cloud. This will get odder still. As learning content becomes "smarter", elements of that intelligence will be cloud services--the physics program triggering quizzes to assess student mastery. Quizzes may be routed to professors, or to quizzing engines built as cloud services.

To support instruction in this environment,campus technology will have to permit fluid interactions between many different resources, both inside and outside the institution. The enterprise learning management systemwill become only one part of a much bigger and more loosely-linkedworld of digital services, and new standards-based platforms for discovering, manipulating, and delivering electronic content will evolve.

Because students and faculty will be able to access many of these services directly, institutions will have to rethink the way they deliver educational content. The "official" enterprise learning management system will be less authoritative, and users may want to pull content into personalized environmentslike their Facebook pages, Google Apps accounts, or Kindle and iTunes libraries. The effort to create more personalized learning environments that work more seamlessly with other cloud-based tools can be seen in a number of interesting recent initiatives, including:

- The Open University's Distributed Open University Learning Systems project, which is exploring ways to incorporate cloud resources into the OU's learning environment and to allow content to be pushed out to student Facebook or Google Apps accounts;

A partnership between Google and educational publisher Pearson to launch a new cloud-based learning management system that works within institutional Google Apps environments;

- Cloud-based publisher content delivery platforms (Cengage MindTap, McGraw-Hill Connect) that mix interactive digital learning content with assessment and analytics tools; and
- Cloud-based "social learning platforms" (xplana) that allow students to pull together learning material they're interested in, and interact with other learners, from inside or outside an institutional setting.

For colleges and universities, the emerging educational cloud environment is a great opportunity to enrich classes with digital resources, and especially to improve the online learning experience. Online study will become more interactive, pedagogically adaptive and assessment-driven, and personalizable. Instead of being restricted to a PC, instruction will be available from many devices, permitting students to take course material into the field, to read it in more natural settings, to use different interfaces (like touch or voice recognition), and to share their work and their opinions. Harnessingthe wealth of the cloud to deliver online education with the same on-demand convenience, self-service simplicity, and cost effectiveness that consumer cloud services offer will be a major goal of the next generation of technology-enhanced learning.

SEIZING THE CLOUD OPPORTUNITY

We've noted that cloud computing can be seen asa culmination of post-secondaryeducation's technology journey. Once computers stood isolated and were found only in university laboratories. Higher education took the lead in connectingthem together, eventually blanketing campuses and the world at large with networks. With the arrival of cloud computing, the balance of computational power is shifting decisively beyond campus bounds, and the universe of external services will no longer merely supplement our institutional IT resources, but will be the default source of them.Post-secondary education isconfronting the results of itsown revolution—and they will surely lead toward more revolution in the future.

To take advantage of the cloud's opportunities,post-secondaryeducation must become as cosmopolitan in its IT endeavorsas in its intellectual ones, learning how to operate in an unbounded and permeable IT universe. This won't be easy. Cloud services, especially those specifically addressed toward education, remain immature. Their real costs are only imperfectly known and their potential is in many cases unproved. Technical and performance limitations mean that not every IT problem has a cloud-based solution. Institutions using cloud services will have to address security and regulatory issues, adapt to the more standardized environments that cloud computing requires, and learn how to integrate resources that operate below, on, and above campus. In addition, doing business in new ways will require cultural changes. These challenges are serious enough that a companion paper, Meeting the Challenges of the Cloud in Post-SecondaryEducation, is devoted to them.

But it's abundantly clear that the cloud is here to stay, and that the time is ripe for post-secondaryeducation to begin thinking of it as a strategic resource. Leaders need to recognize that the cloud presents new ways to make education financially and environmentally more sustainable, to improve institutional agility and focus, and to enhance learning and research.

It's also essential to understand that the cloud often reaches its greatest potential when it disrupts established practices and empowers interlopers. Its impact on millions of consumers is evident every time someone updates a Facebook page, watches a streamed Netflix movie, asks an Apple iPhone for directions to the nearest pharmacy, or opens a book on an AmazonKindle reader. These products, like many leveraging cloud power, are immature and imperfect—but they are revolutionizing old and established industries just the same. To realize the next generation of technology-enhanced education and administration, colleges and universities need to put their heads—and their resources—in the clouds.