Information Systems Education: The Case for the Academic Cloud

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Abstract

This paper discusses how cloud computing can be leveraged to add value to academic programs in information systems and other fields by improving financial sustainment models for institutional technology and academic departments, relieving the strain on overworked technology support resources, while adding richness and improving pedagogical delivery of course content. A literature review on cloud definitions and how cloud paradigms are being implemented in academia is conducted. The author suggests that for smaller programs and institutions, cloud hosting of applications, services and platforms in support of information systems programs may be the only financially viable solution to course technology requirements. The impact of transitioning core information systems courses to a cloud paradigm is discussed, and examples of how the transition can improve course content and delivery are provided. Finally, details are presented on how a transition to the cloud is being accomplished in the information systems program of the school of continuing studies at the author's small liberal arts university.

Keywords: Cloud Computing, Academic Computing, Information Systems Education, Emerging Technologies, Cloud Virtual Machine

1. INTRODUCTION

The field of information systems is undergoing a paradigm shift, with cloud computing significantly changing enterprise business processes. This paradigm shift also affects university technology department and information systems program financial sustainment models and pedagogical delivery of course materiel.

The ramifications of cloud computing for higher education institution technology departments are significant. Decreasing levels of financial support from government and increased competition from for-profit institutions, coupled with falling enrollments, have a deleterious effect on the ability of college and university information technology (IT) departments to provide support and services. Even as IT requirements are increasing due to the impact of technology and collaboration on daily life, institutional IT budgets are decreasing. Smaller schools or departments are impacted to an even greater extent, since they do not have the size to garner sufficient support in the face of decreasing institutional resources.

A bright spot in this scenario is the emerging cloud computing technology. This allows smaller programs to develop models with increased capability over legacy hosted servers, at lower cost. If a university lacks resources to host dedicated servers for small departments, cloud computing provides these technologies at the application, platform and infrastructure levels. The cloud provider is able to deliver Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). These services allow departments to reap the benefits of hosted servers, applications and infrastructure, without the cost of local maintenance. The cost is no greater than, and often less than legacy tuition and course fee based school financial models.

This paper reviews literature on how emerging cloud computing technology is being implemented in the academic environment. It discusses how cloud computing may be the only viable option for providing necessary academic support to smaller information systems programs. The work argues the case that regardless of size, a switch to the cloud is likely to enhance delivery of content in information systems core courses. It discusses how cloud computing could potentially enhance courses in other fields. Finally, it details how the author's information systems program in the school of continuing studies at a small liberal arts university is transitioning from locally hosted to cloud virtualized resources.

2. LITERATURE REVIEW

Cloud Computing

There are many differing definitions of cloud computing. For example, Gartner, Inc. defines cloud computing as "a style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service to external customers using Internet technologies." However, the National Institute of Standards and Technology (NIST) definition is most cited, and is arguably the most widely accepted definition.

NIST defines cloud computing as "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." (Mell & Grance, 2011, p.3)

NIST further defines cloud computing in terms of characteristics, and service and deployment models. Service models include Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Deployment models include private, hybrid, community and public models. Private clouds are owned by a single organization. Public clouds provide services to multiple clients using shared infrastructure. Hybrid clouds are often used to leverage the security of the private cloud with the scalability and other advantages provided by the public cloud. Community clouds are those used by a group of users with similar interests, and are thus advantageous to the community.

Cloud Computing in Higher education

Early uses of the cloud in higher education included collaboration, data storage, library science repositories, messaging, flexibility, and computing power.

Mircea and Andreescu (2011) note that the service oriented architecture (SOA) of cloud computing makes it a viable option for academia when financial conditions are poor. They propose a strategy for academic cloud adoption using a stepped migration model. Sultan (2010) suggests that cloud computing may be effective in reducing costs in difficult economic times. Hignite, Katz & Yanosky (2010) discuss opportunities and challenges facing implementation, and suggest that cloud computing leads to a sustainable business model. González-Martínez, Bote-Lorenzo, Gómez-Sánchez, & Cano-Parra (2015) survey 112 articles on cloud computing in education, and note advantages in cost and functionality, tempered by limitations and risks in security, performance and licensing.

Virtualization, simulating a computer in software, allows users to run multiple systems and share resources, in a flexible, scalable environment. Murphy, & McClelland (2008) discuss their experience in developing a high performance virtualized lab, extolling the benefits of virtualization, and demonstrating a scalable solution. Erkoç, & Kert (2010) suggest an infrastructure prototype for a complete cloud distributed campus.

Mohktar, Ali, Al-Serafi and Aborujilah discuss cloud computing in academia, noting the ability to create virtual environments providing the capability to have concurrently managed parallel environments, with an instance for each student. O'Donnell & O'Donnell (2014) provide a detailed discourse on how virtualization enables students to use remotely stored resources transparently.

The literature suggests that cloud paradigms provide improved flexibility, scalability and reliability over local systems, with virtualization making changes in resources transparent to users. These benefits come with significant cost savings.

3. CLOUD AS THE ONLY OPTION

For a small institution or program, moving to the cloud may be the only choice. At the authors' small liberal arts university, the information systems program is part of the school of continuing studies. Bachelor's degrees and postbachelor's certificates are offered in information systems and information security. Students are local, and most tend to stay in the area. Course enrollments are capped at 15 students, with courses offered annually, and some biennially. As a boutique school, with courses consisting of 15-20 students per course per year, there is no sustainment model which works. Fifteen students in a specific course each year is too few to amortize hardware or software investment.

The Continuing Studies Example
As a school within the university, continuing studies is required to purchase hardware and software specific to school needs. To support project management courses, the school paid to have a public lab outfitted with Microsoft Project, and pays for new version upgrades. The support infrastructure does not support school specific hardware acquisition. The school has access to university wide software licenses, using Oracle running on a university server, as well as Adobe Dreamweaver for web design. The information systems program has a Microsoft DreamSpark subscription allowing students and faculty free licenses to Microsoft software products.

The current level of support is not sufficient to provide students with experience with emerging technologies that will help them on the job market. Developing courses using cloud resources enables instructors to raise the level of training and realism, while lowering cost and providing scalability.

Piloting a Private Cloud
An information systems professor at a local community college designed and implemented a private cloud using a Microsoft grant. The cost to establish the solution was over $100K, not including his time and that of IT support personnel helping to facilitate the project. The project successfully implemented a virtualized private cloud, which was tremendously successful in proving the value of cloud computing. However, even with the grant, this private cloud was not financially sustainable. Although the community college has a larger student population than the authors' institution, it is still small, and several factors contribute to making the system impracticable. First, the annual cost of software licensing is over $10K, which cannot be supported by students taking cloud courses. Second, the IT department is not resourced to support the system. Finally, there is no budget for recapitalization. Still, this pilot project demonstrated how cloud computing can add value to information systems courses.

Hybrid Cloud not the Answer
While a hybrid cloud makes sense for some applications in academia, it does not offer any advantages for delivering information systems courses. Hybrid clouds are appealing to enterprises that want the cost savings, flexibility and scalability that are strong points of public clouds, but are forced by regulatory constraints to protect data by hosting it on a private cloud. Therefore, academic departments dealing with student information, and subject to the Family Educational Rights and Privacy Act (FERPA), may consider use of a hybrid cloud, with data protected under FERPA hosted locally, and other data and applications on the cloud.

FERPA concerns have been a barrier towards full acceptance of cloud computing in meeting all use cases in academia. However, even these concerns are being recognized by cloud and third party services providers. As the cloud paradigm continues to emerge, provisions to accommodate FERPA requirements and other regulatory and business compliance issues continue to evolve.

Due to the limited ability of academic IT departments to control and monitor cloud security, institutions are reliant on controls and compliance by cloud providers. Many institutions lack the resources to evaluate or audit cloud provider resources. Third party providers may have the lead in addressing these issues. One third party provider suggests that they can comply based on their provision of a dedicated disk controller and storage media owned by the institution, and serviced by the third party provider. Emerging paradigms may result in third party providers addressing compliance issues by adopting substantially equivalent alternative standards, implementing alternative compliance schema, or by demonstrating compliance themselves, thus transferring compliance responsibility from institution to provider. The final solution remains unclear, as cloud technology and business cases for academia continue to emerge.

In the case of course delivery, there is no FERPA protected data present, so a hybrid cloud has all the disadvantages of a private cloud, with none of the advantages of a public cloud.

The Public Cloud Paradigm
Using the resources of a public cloud for course delivery offers advantages over locally hosted systems. All of the required resources for software, platform and infrastructure are hosted on the cloud, with cost savings, flexibility, scalability and reliability. For information

systems courses, a complete environment can be provided to students, with little consequence for mistakes – individual images can easily be reset by the instructor.

As currently implemented, use of the cloud for course delivery is free for instructors, and grants for student course use are easy to obtain. Even without grants, the cost for the level of service required is trivial. Costs do not mount significantly until systems are deployed.

As cloud computing is still an emerging technology, cloud paradigms continue to change. A risk associated with a switch to a cloud paradigm is the lack of technical support for academic cloud users. As cloud paradigms mature, these risks continue to be mitigated. For example, Microsoft Azure now supports Oracle databases. Using such a database involves provisioning the database in Azure – users are not required to configure a virtual server for the database. Making this portion of the task transparent to users mitigates the need for tech support in server administrator tasks.

In summary, use of the public cloud is efficient from a preparation/user standpoint, is easy for students to use, provides required functionality, and has potential to improve the pedagogical delivery.

4. CLOUD IMPROVES DELIVERY

Cloud hosting makes it economically feasible to attain the required functionality, but also better facilitates course content delivery. Cloud infrastructure, services and applications enable courses to provide unparalleled real-world experiences. This is especially true for information systems courses, where cloud technology capitalizes on the core competencies of leveraging technology to solve business problems.

Security Courses

The cloud's ability to improve course realism is especially true for security courses. For example, target and attack servers may be independently and completely configured within an encapsulated environment, and students are provided with a unique opportunity to use current applications and methods when studying offensive tactics. This experience gives them immediate credibility when seeking employment as penetration testers or enterprise security architects.

Common applications in the penetration tester's toolkit may be used with relative abandon in a contained environment. Penetration testers use an application called John the Ripper to attack local passwords. Similarly, the Cain & Abel tool is commonly used for password recovery. To use either John the Ripper or Cain & Abel proficiently, it is essential that practitioners practice by actually using the application.

The use of cloud computing enables students to obtain first-hand knowledge and experience in use of the penetration tester's tools. This gives students an advantage as they enter the workforce. If they have a job interview, and are asked about their experience in penetration testing, they can reply that they have actually used these and other tools in a real world environment.

If students were to attempt to use these tools outside of the encapsulated cloud environment, the university's IT department would likely be up in arms. Practicing and learning to use these tools on the institutional network may not only be non-compliant with acceptable use policies, but may also be illegal. One option would be to use a closed network for this work, but it would not be feasible to build a lab environment due to the aforementioned financial and support issues.

If dedicated lab resources were somehow made available, the cloud computing paradigm would still be preferable to the physical hardware environment. Envision the confusion and damage which could be caused by a section of students independently attacking intricately configured target computers in the lab. At best, the target computers would have to be reset and re-imaged following an attack event. Using a virtual cloud environment, target servers could be reset anytime, merely by clicking a mouse. This encapsulated environment can be replicated for each student.

The only remote requirement for students to access the virtual environment is internet connectivity. Another advantage of the cloud solution is that students are able to access virtual environments from off-campus home or work computers. In the legacy university hosted paradigm, anyone accessing the server would have had to use a Virtual Private Network (VPN).

Database Courses

There are many other scenarios and courses where cloud computing contributes value beyond that of a remote host for provision of content. During a recent database course, it took some students until the fourth week of class to establish a remote connection to the database on a university server. Students were expected to connect using a thin client on their laptop computers. Other students, particularly those working in the information systems field, were able to immediately connect. There were several obstacles keeping students from connecting. First, the university firewall prevented students from using client software. Second, the connection methodology was technically demanding. Finally, students experiencing difficulty were typically weaker or inexperienced and were technically challenged and daunted by the process. An academically weak student is at a tremendous disadvantage when they are unable to complete the first weeks of coursework. Those who need help the most are a quarter of the semester behind, without accessing the database. Additionally, the process of connecting to the database is not one of the course goals or objectives.

For the same course using the virtualized cloud environment, a database and application to connect to it (SaaS) would be delivered on a virtualized cloud server (PaaS) in a virtual environment without physical hardware (IaaS). The instructor could then develop an image with a server, database and application for each student to interface with the database remotely. The connection between database and application would already be configured, and the image copied into a virtual environment for each student. Students would only have to log into the cloud provider site to access their virtual environments, negating the requirement to use a VPN and other facilitating software. The students are able to use the application to run SQL commands on their virtual database. The ability to access the database via the application is immediate upon logging into the provider system. Therefore, the cloud environment actually improves course delivery by reengineering the process to allow students to focus on activities reinforcing course goals from the outset.

Networking Courses

Cloud Computing is an outstanding vehicle to host networking courses. In the legacy environment, networking was offered using physical hardware. Now, the cloud based networking course uses a virtual environment based on a private cloud, and features a project with students working to develop a notional network architecture. The course begins with the first half of the course concentrating on traditional (Open Systems Interconnection model, architecture and topology, etc.) networking theory.

Following the midterm, students are introduced to network configuration in a virtual cloud environment on Microsoft Azure. Students are quickly able to register, configure their accounts, then define specifications for and implement a Server 2012 R2 server in their virtual environments. Students then further refine their networks, designing architecture, and specifying routers, switches, etc. The ability to configure networks virtually is a huge advantage in convenience and time.

Development and Web Design Courses

Similar to the database courses, instructors for application development and web design courses are able to create virtual images with development tools, connected databases and web servers to publish pages and deploy applications. The outcome of a potential switch to the cloud for Web design courses is still emerging. In the case of the author's institution, the course is taught using Adobe Dreamweaver, for which there is an institutional license. Although Dreamweaver developed sites can be deployed to Azure, Adobe is marketing its software as a service on its proprietary Adobe Creative Cloud platform, which runs on Amazon Web Services. The ability to run Adobe projects on Azure in the future is unknown. The significance to the program is that if other core courses are standardized on Azure, how will the deviant conditions of the web design course be handled? Will the Adobe product continue to be used as it is still considered the industry standard? Will Microsoft Expression Web (currently being integrated into MS Visual Studio) be adopted for standardization purposes? As Visual Studio is currently the standard for database application development courses, it may be easier if Visual Studio was used for both web and application development courses. These issues have not yet resolved themselves, particularly with continued evolution and emergence of cloud provider offerings.

Courses in Other Fields

Although the focus of this paper is on the information systems field, the philosophy, advantages and justifications for using a cloud paradigm apply to other fields as well. The usages range from simple to complex. A professor for a Chaucer class may have a distributed application which takes a Middle English passage and converts it into modern English. Making this application available on the cloud negates the need for local hosting. Students will be able to access the application from off-campus without using a VPN. Any maintenance or troubleshooting can be done by the cloud provider, rather than the overtaxed university technical support staff.

Perhaps a more compelling case would be that of a recent graduate music student, at another institution, working on building her dissertation with a project collecting and indexing instrumental harp music. Her intent is to create a searchable database where instructors can run queries on search terms including such topics as difficulty, category, length, composer, etc., and provide a listing of music. The music instructor could then select and purchase the appropriate music. If this project was developed using a cloud paradigm, it could easily be operationalized into an online database, and monetized with linked e-commerce site to enable a complete cloud solution.

Institutional Issues

In any business process paradigm shift, there are barriers to change. This is no different in implementation of cloud computing. Institutional leaders are often concerned that new implementations will negatively affect regulatory compliance or information security. Administrators and IT staff worry that cloud computing cannot be accommodated by current information security infrastructures. Sometimes these concerns are through ignorance of cloud computing details, but many of them have solid foundations. However, cloud and service providers generally recognize deficiencies and are devising ways to overcome these difficulties as cloud computing continues to emerge.

In any case, interaction with and support from institutional IT departments is critical to successful adoption of cloud resources. As an example, accessing the cloud environment on wireless or wired institution networks requires use of the Remote Desktop port (RDP). The problem is that RDP is typically constrained by the institutional firewall. Most conscientious IT departments prohibit outgoing TCP connections on port 3389, the default RDP port. Most professionals know that this port is the default port, and scans of this port are becoming more common. There are several ways around this. If a static IP address can be obtained for the cloud environment, the IT department may consent to whitelist it. Alternatively, the IT department may make an exception and open port 3389 during class time. Yet another option would be to collaborate with the IT Department to expose port 3389 to port 443, which is typically configured to allow outgoing TCP connections to access secured websites. Due to encryption required to access secured sites, firewall scrutiny is reduced, and RDP may be possible, depending on other variables. The point of this discussion is not to address the details of RDP resolution, but to suggest that there are many ways to provide an environment where cloud computing can work. This example also illustrates that cloud implementation requires close collaboration with the institution IT department.

5. TRANSITION TO THE CLOUD

As discussed in a previous section, the information systems program at the author's institution is currently in the midst of transitioning technology resources for core information systems courses to the cloud. Based on decreasing resources and increasing costs, but faced with the need to ensure that graduates receive sufficient experience to make them viable in the workforce, the program developed a plan to transition to a public cloud model. The benefits of this transition would be twofold; the program would have a cloud-based solution, and students would gain hands-on experience in cloud technologies.

The plan to transition to the cloud paradigm did not arise from a strategic vision for cloud computing from program leaders. When a professor teaching a networking course received a Microsoft grant to allow his students access to the Microsoft Azure cloud for the semester, the grant approval process at the university proved to be so cumbersome that not only was the grant not approved in time to give students access to Azure that semester, it was never approved. That non-event forced information systems program leaders to take a hard look at cloud computing from a holistic view. It was determined that a transition to a cloud based solution for the program would yield tremendous benefits. It was also seen that several continuing students working in the field had effectively doubled their salaries when they acquired cloud competencies. Since information systems is a practitioner's field, it was determined that providing students with competencies in this emerging technology was essential.

The plan to transition from the legacy courses to those supported by the cloud began with a group of three students enrolled in an independent study course during the spring of 2015. This group reviewed literature regarding cloud basics, determined requirements for offering a summer course supported by cloud resources, examined institutional policies and procedures affecting cloud implementation, and recommended a cloud provider for the summer course.

It was decided that the summer networking course would be offered with public cloud support. Although the students in the spring independent study course made a recommendation regarding cloud providers, cost and functionality provided by each provider changed dramatically during semester break, rendering the recommendation invalid. The instructor selected Amazon Web Services for the functionality it provided, along with low cost to students. The week before the hands-on portion of the course was to start, the instructor switched to Microsoft Azure for two reasons. First, it was available on DreamSpark, and second, he was able to secure the grant funding student use.

Following the networking course, a special topics course on virtualization was offered in the fall, 2015 semester. In this course, students worked on projects virtualizing lab environments to support core information systems courses. This initial offering of the course resulted in completion of a cloud database environment to support the traditional database course, complete with Oracle database schema. Teams of students developed solutions based on both Microsoft Azure and Amazon AWS environments. These prototype solutions were developed in collaboration with the instructor and students enrolled in the current database course. The success of this course resulted in the course being changed from a special topics course to a standard offering, listed in the school catalog with permanent course number. A similar course was then adopted by a local community college, and it is expected that the community college course will be accepted in transfer.

Finally, during the spring of 2016, a capstone course is offered which has changed from the traditional applied systems analysis capstone to one designed to enhance cloud competencies from a holistic, managerial view. Consisting of four parts, this course first has students conduct directed reading designed to provide them with basic knowledge on the cloud, followed by a quantitative assessment. Second, students conduct library research on current developments on cloud technology, and write a short paper on the state of the technology. Third, students collaborate on a team project to conduct an analysis of alternatives recommending a cloud solution to support information systems courses. Finally, after presenting their findings, students develop a prototype cloud based system to meet the requirements of a use case examined during the analysis of alternatives.

This sequence of courses provides students with a cloud competency which will stand them in good stead as they enter the workforce. As the cloud paradigm continues to evolve, program managers must continue to evaluate and make changes to ensure that the course sequence remains relevant to industry and student needs.

6. FUTURE RESEARCH

Following completion of the cloud computing course sequence implementing cloud paradigm, program leaders must assess the results from a holistic view, and decide how next to proceed to improve the program, experience and outcomes.

One means of determining how well the project has succeeded is to apply technology acceptance models, which have been well documented and validated in previous research. A recent model is the Unified Theory of Acceptance and Use of Technology (UTAUT), where dependent variables are usage intention and behavior. It is planned that a quantitative study using a survey instrument be used to validate relationships suggested by the UTAUT model.

Another measure of how well the implementation process has succeeded is what students take away from the course sequence. When exposed to the cloud paradigm in the classroom, a quantitative analysis of student self-efficacy in cloud competencies would yield insight into the relationships between implementation and competency assimilation. In addition to a multi-variate regression analysis, Structural Equation Modeling could be used to identify latent variables accounting for some portion of the variance.

A third opportunity to gauge the effects of cloud implementation would be a qualitative analysis of the process. This could be from inductive analysis, ethnographic approach or a case study methodology.

7. SUMMARY AND CONCLUSIONS

Cloud computing is an attractive alternative to traditional, locally hosted technologies for supporting information systems courses. This work suggests that public cloud computing presents a viable model to provide resources necessary for information systems core courses well within the financial sustainment models of smaller institutions or programs.

The literature supports the assertion that cloud computing is financially viable for support of information systems courses, and also yields value due to the flexibility, scalability and reliability of the cloud paradigm. It is suggested that for smaller institutions and programs, the cloud model is currently the only financially viable option.

Despite the lower costs, examples of how cloud computing pedagogical delivery improves content provision in the information systems program areas of information security, database, networking and application/web development depict a case of added value at reduced cost. Examples of courses in other fields are also provided, and demonstrate the value that cloud computing is anticipated to add across the board.

This work discussed a transition to a cloud paradigm at the author's institution that is currently in progress. Although not complete, efforts to date have been successful and on-time, and the expectation is that continued implementation will go smoothly.

In summary:

1. Cloud paradigms are particularly attractive where the student population is too small to support amortization costs of technology on locally hosted systems

2. The cost of private clouds is not sustainable for small institutions and programs where lifecycle costs must be amortized over a small student population.

3. Public cloud paradigms are currently the only sustainable options for smaller institutions and programs.

4. Cloud paradigms improve pedagogical delivery of course content for information systems and other courses.

5. Emerging technologies and provider strategies must be constantly monitored for change.

6. Offering cloud courses at smaller institutions or small programs is contingent on cloud provider support and keeping costs to students affordable.

7. With current levels of provider support, switching a small information systems program to a cloud-based paradigm is achievable and yields many benefits.

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