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IT Infrastructure Strategy in an Undergraduate Course

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Abstract

Cloud computing has grown immensely in the past decade and is becoming increasingly important to organizations. The Computer Information Systems (CIS) program at Cal Poly Pomona has gone through a re-visioning process that included the addition of a course on IT infrastructure. This paper reports on the newly created IT infrastructure course, which is in the beginning of two emphases (curriculum tracks) in the CIS department.

Keywords: Infrastructure, Cloud Computing, IS Curriculum, Kubernetes

1. INTRODUCTION

IT infrastructure has been viewed as a strategic asset in organizations for at least twenty years (Broadbent & Weill, 1998; Weill, Subramani, & Broadbent, 2002) and continues to grow increasingly relevant as changes in IT infrastructure offer organizations new avenues for differentiation with reduced cost and risk. Despite the importance of the integrated IT infrastructure, undergraduate Information Systems (IS) courses continue to offer distinct courses such as telecommunications and database that focus on the individual IT infrastructure components. This paper presents an overview of the IT Infrastructure course and the inclusion of IT strategy as a component.

Courses on main components of an IT infrastructure, such as database, provides insights into the strategic value of IT infrastructure. However, such coverage may not demonstrate the strategic synergies that underlie the integration of IT infrastructure components. This paper reports on a process to develop an IT Infrastructure course that will replace an introductory business telecommunications course in an undergraduate IS program. The IT Infrastructure course introduces the individual IT components while also highlighting the integrated nature of these technologies and synergistic relationships made possible because of integrated and automated IT infrastructure. The course highlights the strategic role of IT infrastructure and includes technical topics including hybrid-cloud infrastructure, telecommunications and systems administration.

This paper is broken into four major components including hybrid-cloud infrastructure, telecommunications, systems administration and coverage of the strategic role that IT infrastructure can play within organizations. The paper also addresses an IT Infrastructure course platform selected to offer the course. Key elements of the curriculum plan for the program

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are included to provide context for the IT Infrastructure course and to support arguments related to this course and the IS model curriculum.

While this course is considered to be a minor contribution in terms of originality, the focus of the paper is to motivate a conversation on the inclusion of IT infrastructure in undergraduate IS/IT education and perhaps the consideration of a review of the Model IS Curriculum in light of recent innovations in IT infrastructure and data science capabilities.

2. IT INFRASTRUCTURE & STRATEGY

The choice to present fundamentals of IT strategy as part of a course on IT infrastructure in an undergraduate program initially drew skepticism. An argument was made that this topic is beyond the preparation level of undergraduate students and is in the purview of a master's program. The conclusion; however, was that while IT Infrastructure strategy does belong in a master's program, an introduction to the topic is still appropriate in the undergraduate curriculum. The close integration and shared dependencies of IT infrastructure components in a cloud environment make IT infrastructure strategy more important than ever.

Not only was this course placed in the undergraduate curriculum, but also placed, along with an introduction to operating systems course, at the beginning of the information security and forensics emphasis in the CIS curriculum. The IT infrastructure course was placed at the beginning of the business intelligence emphasis as well Figure 1 shows the CIS core required of students in each of the three CIS emphases. Figure 2 shows the specific classes required of students in the Information Security and Forensics emphasis and Figure 3 shows the classes required of students in the Business Intelligence emphasis.

General education, college of business core requirements as well as mathematics preparation courses required of students in the CIS program are not presented as they are similar to course requirements for most information systems programs.

Computer Information Systems Core
CIS 3050 – Database Design and Development
CIS 3090 – Object-Oriented Programming for Business
CIS 3252 – Business Intelligence

Figure 1 Computer Information Systems Core

Information Security and Forensics Emphasis
Core
CIS 2650 – Contemporary Operating Systems
CIS 2670 – IT Infrastructure
Electives *(select 4)*
CIS 3470 – Telecommunications Networks
CIS 4333 – Information Systems Auditing
CIS 4670 – Network Security
CIS 4710 – Information Security
CIS 4810 – Computer Forensics

Figure 2 Information Security and Forensics Emphasis

Business Intelligence Emphasis
Core
CIS 2670 – IT Infrastructure
CIS 3150 – Systems Analysis and Design
Electives *(select 4)*
CIS 3454 – Data Warehousing
CIS 3650 – Digital Analytics
CIS 4321 – Data Mining
CIS 4567 – Big Data Analytics
CIS 4680 – Advanced Data Analytics

Figure 3 Business Intelligence Emphasis

Hybrid-Cloud Infrastructure

NIST Special Publication (SP) 800-145 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). Cloud computing offers benefits such as faster time-to-market and improved scalability due to on-demand provisioning of pooled and shared computing resources.

NIST SP 800-145 goes on to define four cloud computing deployment models including hybrid-cloud. Hybrid-cloud is defined as "a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds)."

The newly revised CIS curriculum focuses on public/private hybrid-cloud infrastructure given the benefits this deployment methodology offers organizations. Private-cloud infrastructure offers organizations the ability to run secure applications within their own control and with lower operational costs for applications with steady demand. Public-cloud infrastructure offers the ability to outsource common applications (i.e. email) as well as applications requiring significant resource scalability. Hybrid cloud creates a bond between the two environments offering the ability to transfer loads between the public and private clouds to meet organizational needs. The hybrid-cloud deployment models offers organizations the ability to take advantage of both public and private cloud computing environments and by binding the two environments together organizations can enjoy nearly unlimited scalability, reduced costs and can also optimize cost benefits with the ability to transfer workloads back and forth between public and private clouds (Mazhelis & Tyrväinen, 2012).

Telecommunications

Telecommunications is an important component in our IT infrastructure course in part because the introductory telecom course was sacrificed to make room for the IT infrastructure course. In addition, telecommunications is increasingly integral and embedded within the IT infrastructure given the emergence of Software Defined Networks (SDN) and Network Function Virtualization (NFV). In fact, network functionality is increasingly embedded into applications within the cloud infrastructure and less reliant on stand-alone hardware devices.

SDN separates the network control and forwarding planes allowing network operators an enhanced level of managerial control of the entire network (Shahzad, Mujtaba, & Elahi, 2015). NFV seeks to move network functions from hardware devices such as routers and firewalls to software applications. These two innovations offer significant promise when coupled together to provide unprecedented control and automation to computer networks (Duan, Ansari, & Toy, 2016). Automation and holistic managerial control of networks, coupled with machine learning, are required for networks to integrate with a dynamic hybrid-cloud environment and build needed operational network services in real time.

Systems Administration

Systems administration has not typically been a part of information systems programs. However, the integration of IT systems and services evident in the virtualization of computing resources, and now the virtualization of networks and network services, require IT/IS professionals to wield substantial systems administration skills to manage IT infrastructure components. Campbell and Cohen (2005) suggest the most critical tools to teach in a systems administration course are:

- Introduction to scripting
- A scripting language (such as Python)
- Text manipulation and regular expression pattern matching
- Interfacing with operating systems shells
- Operating systems namespaces (like DNS and NIS) and file systems (like NFS)
- Network concepts

While the list of needed skills for systems administration may change some in a cloud computing context, the list above from Campbell and Cohen remains relevant and will allow students to interact and provide operational control over the myriad applications distributed across the hybrid-cloud system. This is further reinforced by (Appiahene, Kesse, & Ninfaakang, 2016) who emphasized the importance of system administrators to reducing time barriers to market for businesses. A potential addition to the critical tools for system administration is an introduction to machine learning. Scripting languages such as Python offer significant power and flexibility for IS professionals in configuring and managing IT infrastructure. However, recent developments in AI and machine learning, coupled with the programmability features of modern IT infrastructure, offers new opportunities in automation but require fundamental knowledge and skills with machine learning.

IT Infrastructure Strategy

IT infrastructure has evolved from hardware to software and IT infrastructure strategy must adapt to leverage this powerful new platform. The importance of IT strategy has been well documented even before the advent of cloud computing (Byrd & Turner, 2001; Weill, Subramani, & Broadbent, 2003). Over the past

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20 years, IT infrastructure components were virtualized with recent changes including Software Defined Networks (SDN) and Network Function Virtualization (NFV) completing the transition. The ability to control and manage IT infrastructure via software, means that perhaps IT strategy is best expressed in software via algorithms. The software platform selected to teach and provide "hands-on" learning in IT infrastructure and strategy is Kubernetes running in Red Hat OpenShift.

3. IT INFRASTRUCTURE CLOUD COURSE

The IT Infrastructure course is based on Kubernetes and specifically on the Red Hat OpenShift platform. Kubernetes is a portable, extensible open-source platform for managing containerized workloads and services ("What is Kubernetes?," n.d.). Kubernetes is based on a series of technology enhancements for hosting IT systems at scale including LXC and Docker Containers. David Bernstein stated "Containers, Docker, and Kubernetes seem to have sparked the hope of a universal cloud application and deployment technology" (Bernstein, 2014, p. 84). This hope of a universal cloud application and deployment technology underlies the reason for moving our program in this direction.

Red Hat OpenShift is an enterprise-grade application platform that hosts containers with Kubernetes. Kubernetes running on Red Hat OpenShift was determined to be a reasonable platform for our program given its use in industry and the prescribed computing infrastructure requirements in the IS 2010 Curriculum Guidelines for Undergraduate Programs in Information Systems. The IS 2010 Curriculum Guidelines state "Information Systems students and faculty must have access to computing facilities at least equivalent to those used in a typical organization operating within a program's domain" (Topi et al., 2010, p. 2). The IS 2010 Curriculum Guideline document points out that access to computing facilities at least equivalent to those used in organizations is needed to prepare students for their profession and for faculty to contribute to the creation of new knowledge in the field.

The Red Hat Openshift infrastructure was placed in the Mitchell C. Hill Student-run Data Center (SDC) at Cal Poly Pomona. As such, senior students in the program worked with engineers from Red Hat and other partner organizations to design, and now build and operate the infrastructure for this course.

4. THEORETICAL IMPLICATIONS

If Kubernetes becomes a universal cloud application and deployment technology as suggested by Bernstein (Bernstein, 2014, p. 84), then a new operating environment is made possible in which IS professionals will exercise direct control of IT infrastructure. Infrastructure designers and operators will operate the cloud environment in much the same way that power companies control their infrastructures. IS professionals will consume services in a manner that best serves organizational needs from a set of cloud services run internally or through external providers.

In this scenario, IS professionals have the ability to exercise much greater control over their environments automating tasks via scripts and even using artificial intelligence where appropriate to manage variation in tasks designed to meet predefined criteria. In this case, a new class of IS/IT theories become possible. Mid-range theories with a limited scope leading to testable hypotheses are needed in any discipline (Merton, 1968). The IS/IT field is in greater need of such theories than most given the relatively scant theoretical foundation for much of the work in the field. A universal cloud application and deployment technology, such as Kubernetes, may also open the door to a more general (grand) theory of IS/IT which has so far eluded the discipline (Weber, 1997).

The need for the IS/IT community to integrate IT infrastructure more closely with business systems and processes is made clear in a recent paper on big data analytics in healthcare (Wang, Kung, & Byrd, 2018). This paper mentions IT infrastructure ten times with calls for aligning business value of information with appropriate IT infrastructure (p. 6), capturing benefits from big data analytics (p. 6) and creating shareable and reuseable IT resources that provide a foundation for business applications (p. 7). There is a significant, and growing, need to align IT infrastructure with business processes and IS researchers and practitioners must be at the forefront of this effort.

5. CONCLUSION

The newly revised curriculum is designed around the notion that hybrid (public/private) cloud technology is an important and growing platform for business computing. The success of such a platform relies upon a general computing platform that permits workloads to transition

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easily between private and public cloud infrastructures. Such an infrastructure provides significant advantages in creating robust, cost effective, scalable and secure compute platforms. A new course titled IT Infrastructure is at the beginning of the CIS emphases in Information Security and Forensics as well as Business Intelligence, which offers students an introduction to IT infrastructure and the increasingly importance of customization and integration of IT infrastructure with business processes.

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