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Utilizing a Virtual Internet Testbed and Private Cloud to Teach Organizational Cloud Integration

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ABSTRACT

Cloud based technologies have steadily diffused into corporations, and even while educational institutions have adopted such resources to improve student experiences, little has been done to educate students on how such services are integrated into an organization. We posit that it is vital to enhance the ability of IS professionals in training to perform successfully in post academic environments that utilize cloud technologies. Unfortunately, the very nature of cloud technology requires public IP's, DNS servers to route to external cloud resources, organizational credentials, and more. To minimize organizational overhead, we use a private cloud, existing within an Internet-Scale Event and Attack Generation Environment (ISEAGE) testbed, to mimic real-world processes required for deployment of these services. This, compared via post and pretest surveys, will be directly compared to more traditional deployment methods to view any statistical differences in the pedagogical efficacy of such an environment.

Keywords

cloud, education, private cloud, lab

INTRODUCTION

Cloud computing is an ever-increasing resource utilized by corporations. Statistics show that 94% of all enterprises use cloud services with the cloud computing market totaling 371.4 billion dollars in 2020 (Sumina 2022). Cloud computing technologies have also shown increased usage in education for the past decade (Baldassarre et al. 2018). This usage includes utilizing cloud software for collaboration (Dmitriev et al. 2012), platforms for programming integration (Bhattacharya et al. 2011), and virtual labs for understanding infrastructure deployment (Luse and Rursch 2021). Overall, cloud has been highly utilized by information systems programs and higher education as a whole for providing better instruction for students in many different areas.

While cloud computing has been utilized within higher education, instruction in the organizational integration of cloud itself is lacking. Specifically**,** within information systems, while cloud technologies are utilized for setting up a database for a class or deploying a web development project, education in the actual integration of these systems within the larger organization has not been explored. For example, while many use online storage provided by their employers (e.g., docs.corp.com), the knowledge of how this environment was setup and linked to the organizational namespace including organization-specific credentials is lacking. Furthermore, the ability to provide education in these concepts is difficult given the need for public IP addresses, domain name system names, and corporate-level infrastructure integration mechanisms are not available to faculty or students.

This research aims to bridge the gap between cloud integration and use through education in this infrastructure setup. Through the use of a private Internet testbed and private cloud implementation, students are provided with the infrastructure tools needed to fully implement these concepts that are unavailable in the real world. By providing students with knowledge in these concepts, we hope to provide the missing link between the cloud systems they use, and the corporate integration needed to provide this use.

BACKGROUND

The use of cloud technologies in education has become an important topic over the past decade. Cloud technologies have been found to facilitate student learning in several ways. These methods fall in line with the three models of cloud service including software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS) (González-Martínez et al. 2015).

Software as a service is the most visible usage of cloud services by educational institutions and has been that way for several years (Baldassarre et al. 2018). Broadly this consists of using the cloud to host collaboration tools and storage for students (Sclater 2010). This includes online applications used for classes such as google apps or office365 (Bennett and Pence 2011; Bhattacharya et al. 2011; Bonham 2011; Dmitriev et al. 2012). Storage applications such as SkyDrive or Dropbox are also popular for use as repositories by students and instructors (Lennon 2012; Siegle 2010). This software can also include more specialized software for specific classes such as an online R lab for analytics and stats (Chine 2010). Additionally, with the recent move to online education, many instructors stream lectures utilizing software such as YouTube (Dmitriev et al. 2012).

Platform as a service has also been highly utilized within educational institutions. Learning management systems such as Blackboard, Canvas, or D2L have been utilized within universities for both traditional and online education (Bradley 2021; Watson and Watson 2007). In information systems this includes programming environments and app engines (Bhattacharya et al. 2011; Hollingsworth and Powell 2010). For example, Azure provides the necessary platform for integrating database or web services in programming courses, without the need to understand or control the underlying virtual machines and infrastructure. This can also include virtual desktop environments with preconfigured software preinstalled (Chine 2010; Yang et al. 2011).

Infrastructure as a service has also been utilized in education to help educate students on the infrastructure technologies within an organization and how they are integrated. For example, virtual labs provide a method for understanding systems integration including network and service setup (Luse and Rursch 2021). These virtual labs have also been used to help better understand the integration of wireless technologies (Luse et al. 2021) as well as the setup of network services and how to properly secure these systems (Rursch et al. 2010).

One area that has been absent in the literature, is the training of individuals in the integration of cloud technologies within the organization. All the above examples use cloud technologies, but either expect them to already be integrated into the workplace or use them separately as a standalone object away from the workplace. In the organization, these technologies need to first be setup and deployed so that users are able to effectively utilize them. For example, many individuals may utilize a SkyDrive account, but expect to be able to access this resource at a given URL (e.g., docs.org1.com) using their organizational credentials (e.g., user1@org1.com) seamlessly as if it were always there. Information systems professionals need to be educated as to how to integrate services in this way.

PRIVATE CLOUD IMPLEMENTATION

While better understanding of the underlying integration of cloud technologies within the organizational infrastructure is important for information systems professionals, the ability to effectively teach these concepts is problematic. To integrate these systems, organizations utilize corporate DNS servers, public IP addresses, organizational credentials, etc. to connect all the pieces. For example, to offload a simple webpage for the organization to the cloud, the organization needs to setup public IP addresses to receive DNS queries that redirect requests to their webpage (e.g., www.corp1.com) to be rerouted to an external resource hosting their webpage. Educational institutions do not have the capacity to purchase separate public IP ranges for each student, separate DNS domain names, as well as cloud computing to enable this type of educational integration.

INTERNET-SCALE EVENT AND ATTACK GENERATION ENVIRONMENT

ISEAGE is a virtualized Internet testbed developed for cybersecurity research (Luse et al. 2021) that has been used for education in infrastructure development (Luse and Rursch 2021). The environment mimics the Internet by providing routable public IP networks and routing between these networks. ISEAGE accomplishes this by providing an air gap proxy so these public IPs do not escape into the actual Internet. Students are able to traceroute to other addresses within ISEAGE and are presented with the same types of hops that they would see on the actual Internet. Furthermore, ISEAGE provides DNS functionality found on the Internet by supplying its own root DNS server. Students are able to setup their own corporate DNS systems to enable other students to access their resources utilizing user-friendly DNS names such as corp1.com that are routed correctly through system.

ISEAGE provides the ability to setup complex network arrangements that are not possible in the real world without large amounts of money and hardware. Students are given several virtual machines where they install Windows and Linux servers as well as client machines such as Windows 10 as well as virtual switches and routers. This allows the students to have access to several virtual hardware devices in a completely online lab environment for the course. Figure 1 provides a logical overview of the ISEAGE environment.

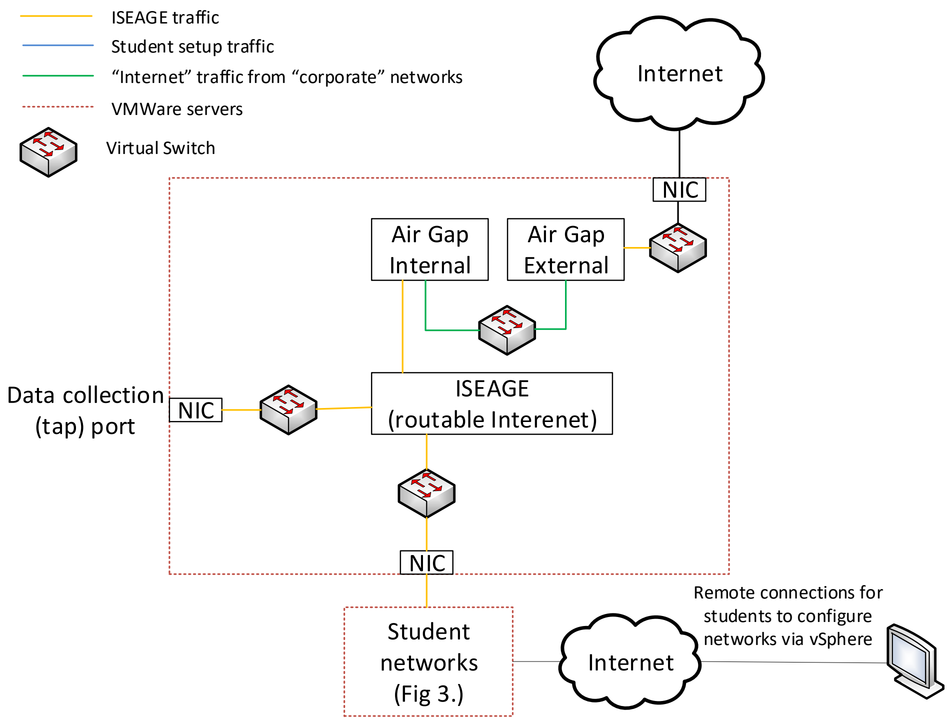

Figure 1. ISEAGE environment

PRIVATE CLOUD

One advantage of ISEAGE is its ability to mimic the true Internet by preventing traffic from entering the actual Internet; however, this advantage leads to issues when it comes to cloud computing. Given that cloud is inherently Internet-based, the closed nature of ISEAGE does not allow it to access Internet cloud systems. In order for students to effectively integrate their corporate network environments in ISEAGE with external cloud resources, cloud resources need to be accessible from within ISEAGE.

Given ISEAGE provides an Internet testbed, the ability to provide this same type of cloud testbed within the system would be useful. By integrating a cloud within this testbed, students would be able to integrate their systems in the cloud within the same test environment. Apache CloudStack provides a private cloud environment for organizations. For this research, a machine running CloudStack was configured within the ISEAGE environment. Students were able to access this resource within the ISEAGE environment by going to cloud.com. The students are presented with the same type of cloud page as on the actual Internet where they can procure cloud-based resources.

STUDY

Subjects for this study consisted of students in an upper-level undergraduate course on infrastructure development. All students for the course received the same instruction from the same instructor and completed the activities at the same time during the semester. The study consisted of a quasi-experimental within-subjects design where all students completed each of the two activities in the same order but at different timepoints during the semester. Due to the non-random nature of the treatments, several weeks elapsed between treatments to minimize carryover effects (Heppner et al. 2007). Furthermore, a pretest-posttest design was utilized for each treatment in order to covary out any learning effects from the first treatment. The design implemented is as follows, where T is a treatment and O an observation.

$$O_1T_1O_2 \quad O_3T_2O_4$$

The first treatment consisted of the subjects installing and configuring a web server using a traditional on-premises deployment. For this, students installed a Microsoft IIS webserver on a Windows Server machine they had already installed. The students then configured a simple webpage displaying their corporation and name. The students then configured access to their webserver to allow external users to access their webpage using a web browser.

The second treatment consisted of the subjects deploying a web server using a cloud provider external to their corporate network. The students utilized an account on the CloudStack portal to deploy a web server. The virtual machine deployed by the students consisted of the same Microsoft Windows server and IIS webserver versions to remove any differences due to software. The students then configured their corporate environment to redirect web traffic to this external resource to provide a transparent experience for external users.

Several measures were used to assess the activity. Subjects were asked the same questions both before and after each treatment. These measures included task-specific self-efficacy for deploying a webserver (Davazdahemami et al. 2018), interest in configuring webservers (Luse et al. 2014), outcome expectations (Changchit 2014), and intent to build their own website in the future.

RESULTS

In total, 35 students partook in the study. Reliability analysis for both pre and posttest items for each of the measures found satisfactory reliability for self-efficacy (α=0.89, 0.92), interest (α=0.77, 0.73), and outcome expectations (α=0.95, 0.97). Initial results from the first treatment show promise. Paired-samples t-tests show that subject self-efficacy significantly increased during the exercise (Δmean=0.85, $p < 0.001$), interest significantly increased (Δmean=0.29, $p = 0.015$), and their intent to build their own website significantly increased (Δmean=0.23, $p = 0.019$), but outcome expectations did not significantly increase (Δmean=0.09, $p = 0.18$). Table 1 shows the sample statistics.

	Pretest	Posttest	t-value
TSE	3.07	3.92	-6.10***
Interest	3.40	3.69	-2.58*
Outcome expectations	4.16	4.24	-1.34
Intent	3.46	3.69	-2.47*

Table 1. Sample statistics

These results will be compared to those using the cloud deployment treatment later in the semester.

CONCLUSION

Educational institutions routinely use cloud technologies as a means of improving the lives of their students and improving their educational experience. Unfortunately, even as educational institutions are actively participating in the application of such services, little has been done to elucidate their inner mechanisms. We posit that students need to understand these underlying mechanisms of cloud technologies as there still exists this belief that the "cloud" is some ephemeral thing without shape. This becomes an even greater weakness in academia as the application of cloud resources becomes more pervasive in corporations, and certainly where integration is necessitated.

An early experiment using traditional website deployment methods was conducted. Results from the posttest survey show that subjects experienced increased levels of self-efficacy, interest, and intent to deploy websites in the future as a result of the experiment. Most students were able to effectively install a Microsoft IIS webserver, customize a unique website based on their corp# (e.g., corp#.com), and make it routable to external entities trying to reach said website. This provides baseline statistics which will be compared to results gathered in Study 2.

Study 2, using ISEAGE as a testbed, will allow students to effectively deploy cloud technologies where infrastructural limitations would normally inundate their ability to do so. They will have a chance to perform all necessary actions to deploy, customize, and reach the website, not routed within their network itself, but routed to an external cloud resource where it will be accessible to external entities. This will provide students with a unique opportunity to experience the necessary processes required to integrate cloud technologies in an environment that is not dissimilar to real-world integration in corporate settings, thereby providing them a unique experience to learn this technology in a practical setting.

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