The Use of Virtual Desktop Pools to Meet Course Outcomes during the COVID-19 Pandemic

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***Abstract*—The outbreak of COVID-19 has changed all our lives. In academia, we have had to take another look at how we teach and deliver courses. Learning was not put on hold as a result of the pandemic. We had to look at innovative ways of teaching and providing content to students. At Illinois State University, we have technology labs that play an essential role in fulfilling the lab requirements for technology-based courses. Students were not able to come to the physical labs as a result of the pandemic. This article outlines some of the strategies used to meet the lab requirements in ways that did not compromise the quality of education delivered. Virtualization technology made it possible for students to complete their lab requirements from anywhere in the world. All they needed was access to a computer and a reliable Internet connection. In the virtual environment, resources are provided virtually instead of in a physical way. Furthermore, system virtualization uses an encapsulation software layer surrounding an operating system. It provides computing functions such as input, output, storage, and processing in the same way as physical hardware. While virtualization has been around for decades, it has gained popularity in the last decade. The benefits of virtualization were leveraged during the pandemic to provide students with labs in a virtual way. Virtual desktop pools were created, and students were given access to the pools. Virtual desktop pools, which are a group of virtual desktops hosted on identically configured virtual machines, were deployed for students. The virtual desktop pools were loaded with software that students use in physical labs. The software included Visual Studio, NetBeans, Packet Tracer, and Scene Builder. Because of the implementation of virtual desktop pools, students could complete required labs and meet all the course outcomes.**

***Keywords*—virtual desktop pools, virtualization, virtual learning, e-learning**

I. Introduction

The COVID-19 pandemic affected every aspect of our lives. Bork-Hüffer *et al.* [1] pointed out that most societies worldwide were not prepared for the pandemic outbreak. As a result of this global pandemic, most businesses were shut down. The shutdown affected the academic world as colleges had to shut down and send students home. What started as an early spring break for some colleges and universities in 2020 extended for several months. Most institutions resorted to virtual learning for most of the 2020–2021 academic year. For some institutions, virtual learning continued into the 2021–2022 academic year. College students and grade school students had to continue their educational journey from the comfort of their homes. Learning from home presented some challenges for both students and educators.

Educators had to scramble to finish the academic year in 2020. Some of the challenges were in delivering high-quality classes online. This required the use of various digital tools to provide content to students. While digital tools and technologies that can be used virtually have existed for many years, many educators did not use them. Many were content with how they delivered their classes using the face-to-face modality and did not see the need to learn new technologies. The pandemic forced educators to quickly learn what they were reluctant to learn during normal times. The challenges for some began with putting their content on the Learning Management Systems (LMS). Affouneh *et al.* [2] noted that some professors lacked instructional skills and technical skills to use the LMSs. In a study conducted by Bork-Hüffer *et al.* [1], most students indicated that they had to study independently during the earlier days of the pandemic as faculty were learning and getting used to virtual teaching methods. After placing the material on the LMS, the next challenge was to conduct lectures and labs in ways that could keep the students engaged.

In this article, some of the solutions and tools that can be leveraged in delivering content to students in the online environment are reviewed. The tools include virtual software that can be used in creating and delivering virtual laboratories. The specific tools used to deliver high-quality courses with lab requirements are listed and discussed.

II. Literature Review

Hu [3] pointed out that the innovation of virtual machine technology has reduced the limitation of practical computer teaching to a great extent. Virtual machine systems and VMware workstations are the applications of virtual machine technology. Hu [3] defined a virtual machine system as a virtual computing platform installed on a real computer operating system known as the host machine. Several virtual hardware

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environments, known as virtual hosts, can be simulated on the host machine. The virtual host, or the base computer, enables sharing physical hardware, including an optical disk drive, floppy disk drive, and a USB interface. Another form of virtualization is desktop virtualization. Hodgman [4] mentioned that desktop virtualization allows multiple computers to share a single piece of hardware, like a server, without realizing that they are sharing any hardware. To that end, desktop virtualization allows end-users to access the desktop environment remotely through thin clients, which are stripped PCs connected to function in a virtualized system. There are several desktop virtual computer software, including VMware Workstation. VMware Workstation has outperformed other virtual computers because of its superior technology and versatility. Consequently, VMware workstation allows users to run multiple operating systems simultaneously on the same computer. Additionally, Hu [3] pointed out that VMware Workstation can replicate an actual network environment on a physical machine. Her [5] submitted that educational institutions utilize desktop virtualization to expand their technology utilization.

Shevchuk *et al.* [6] performed a research study to build and test the effectiveness of using universal training workstations based on cloud applications and virtualization technologies in the student learning system. They also pointed out that cloud computing technology is an internet-based platform in which resources are transmitted from server to client over network channels, replacing physical hardware and software. The study also noted that several cloud platforms could be used to create virtual machines in the cloud, including VMware vSphere, Amazon Web Services, Microsoft Azure, Google Cloud Platform, and Yandex. Using the platforms mentioned above, a complete workstation can be obtained, which developers can use. Shevchuk *et al.* [6] further noted that cloud computing is built on virtualization, and it is currently classified into four types:

(1) Desktop virtualization allows multiple desktops to be managed on a single server.
(2) Network virtualization divides network bandwidth into multiple channels and then assigns them to servers.
(3) Software virtualization – which separates programs from operating systems and technical equipment.
(4) Storage virtualization allows multiple users to use a storage device that integrates several networks attached to storage.

The study concluded that cloud services are extremely efficient in the educational system because of their ability to deploy applications and websites, data synchronization, recovery, and backup. Douglis and Krieger [7] concurred that the virtualization types listed above significantly impact Internet Computing.

Virtualization offers many operational benefits, including minimizing the total number of physical servers, reducing power consumption, and reducing software licensing [4]. Yao, Wu, and Gao [8] carried out a study to look into the shortcomings of traditional desktop deployment and the benefits of virtualized cloud desktops based on university computer room construction. The study listed the following as benefits of virtualized cloud desktops:

- Rapid deployment reduces the cost of operation and maintenance significantly.
- Multiple layers of security, ensuring excellent data security.
- Adaptable access to guarantee efficient use of resources.
- Satisfying personalized instructional demands, fostering teaching and research innovation.

However, virtualized cloud desktop also has the following disadvantages:

- It is overly dependent on the network environment.
- The virtualized cloud desktop technology is complex, which means the administrator has more requirements.
- Cloud desktop technology will generally work without a hitch, but a broken server failure may result in major educational mishaps.

TABLE I. FREE VIRTUAL LABORATORIES

Name of Laboratory	Features
LabVIEW-based model	Web-based lab used across all testing needs of the electrical machine
Modelica-based model	Used in electronic and electrical machine laboratories as an internet-based laboratory
Java Ejs Model (Easy Java Simulations)	It can be used as a desktop and web-based lab. It Includes three window visuals showing current density, torque-speed curve, and on or off status of electric machine
Shakshat Virtual Lab	Characteristics include magnetic field behaviors in single-coil, DC twist for stator resistance, no-load test, Stator resistance starter, Star-delta beginning, and Auto Transformer
MHRD Indian Government virtual lab	The virtual lab provides a unique platform for conducting experiments on electrical machines that perform tasks including load testing separately excited DC motors, load testing three-phase alternators, short circuit testing three-phase alternators, synchronous motor V and inverted V curves, and blocked rotor testing three-phase induction motors

Ramirez, Tellez, and Rivera [9] highlighted implementing a virtual laboratory for teaching electrical machine lab work. It is worth pointing out that electrical machine experiments in physical laboratories are usually expensive. Furthermore, they are risky as they need hardware equipment, which is costly to upgrade and maintain, sometimes they can lead to accidents. This has led to the development of various virtual laboratories in remote teaching of electric machines. Using these virtual labs, students can experiment and get familiar with circuit

parameters, losses in the machines, and the performance of the machines at various loading points, all achieved by working remotely. In their study, Ramirez, Tellez, and Rivera [9] evaluated different types of virtual laboratories. Free virtual laboratories are listed in Table I, and paid virtual laboratories are listed in Table II.

TABLE II. PAID VIRTUAL LABORATORIES

Name of Laboratory	Features
MATLAB/Simulink Model	Offers a wide range of engineering packages available for electronic engineering, mechanical engineering, chemical engineering, machine learning, and deep learning
Electromechanical Systems Simulation Software (LVSIM-EMS), from FESTO:	It gives students the ability to operate various electromechanical systems on a computer screen.

III. APPLICATION OF THE VIRTUALIZED DESKTOPS AT ILLINOIS STATE UNIVERSITY

Similar to many other institutions, classes had to be delivered online during the pandemic at Illinois State University. The delivery of three courses within the Department of Technology will be used as the focus of this study. The courses focused on networking fundamentals, Java, and C# programming. All these classes have lecture and lab requirements. The lecture part was carried out using the Zoom platform. The lab part used both the Zoom platform and the virtualized environment. Before the pandemic, students completed the lab requirements in our physical labs. During the pandemic, they were able to complete the same labs in the virtualized environment. The labs include connecting computers in Local Area Networks (LAN) and Wide-Area Networks (WAN). The devices used in the LAN and WAN include routers, switches, servers, desktops, and cables. After connecting the devices, students then configure the devices with different settings. The routers, servers, switches, and desktops take various configurations. Students complete different labs using the NetBeans and Visual Studio Integrated Development Environment (IDE) for the programming classes.

The pandemic presented some challenges for the students as they could not all complete the labs successfully at home. They lacked the necessary networking devices like routers and switches. Some students struggled with installing the Microsoft-based IDE on their Mac computers. Running simulation software on their computers was also a challenge as they did not have enough resources on their personal computers.

Working with the Information Technology department, we were able to provide our students with two solutions. The first solution was to create virtual pools that could be accessed by the students. Each student would have a desktop on the Virtual Pool. The desktop on the Virtual Pool came with all the software they needed to complete the labs. The second option included using Citrix to virtually provide students access to our physical labs. Once access to the physical lab was established, students would have access to all the software as if they were physically sitting on the machine. Accessing the virtual pools and physical labs using Citrix requires a browser and an Internet device. These solutions meant that students did not have to install any software on their computers. Some of the software they would have access to virtually include:

- Cisco's Packet Tracer – simulation software for creating LANs and WANs
- Oracle VM VirtualBox – hypervisor for creating virtual desktops and servers
- NetBeans – IDE used for developing Java applications
- Scene Builder – a visual layout tool for Java applications
- Visual Studio – Microsoft-based IDE used to develop C# applications

The instructor also had access to the same virtual machines. The instructor had the ability to teach and demonstrate using the same virtual solutions that students would use to complete their labs. Fig. 1 shows the interface that students use to join the Virtual Pool using a browser.

Fig. 1. Interface to join the Virtual Pool using a browser.

Fig. 2 shows some of the labs that students can join virtually using Citrix.

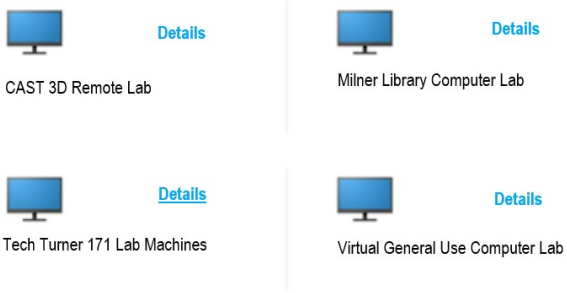

Fig. 2. Interface to join a lab using Citrix.

Fig. 3 shows the Desktop view and applications students have access to while inside the Virtual Pool.

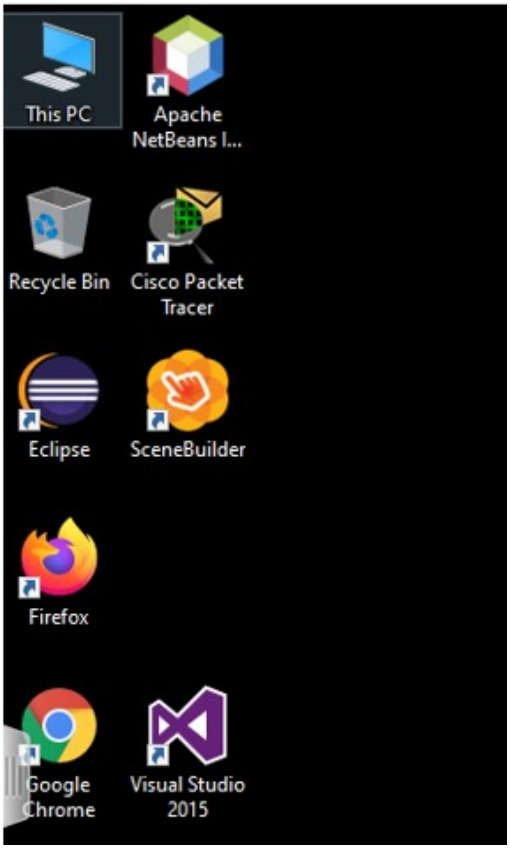

Fig. 3. Desktop view inside the Virtual Pool.

Fig. 4 shows one the classes that students can join to complete the labs using Citrix.

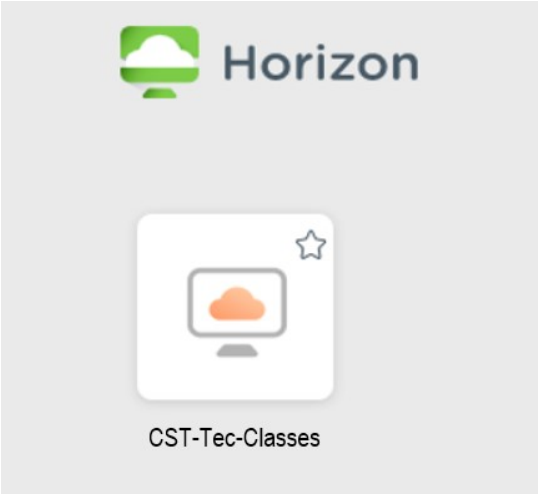

Fig. 4. Desktop view inside one of the labs using Citrix.

Fig. 5 shows some of the local area networks and wide area networks that students can create using applications available in Virtual Pool.

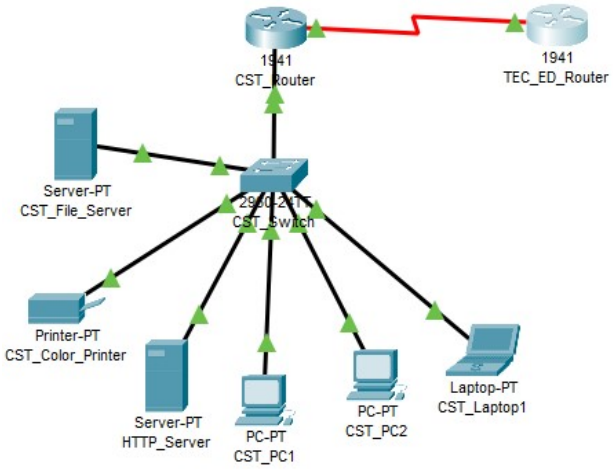

Fig. 5. LAN and WAN lab using Virtual Pool.

Fig. 6 shows the results of using the Visual Studio IDE to develop applications using the C# language in the Virtual Pool.

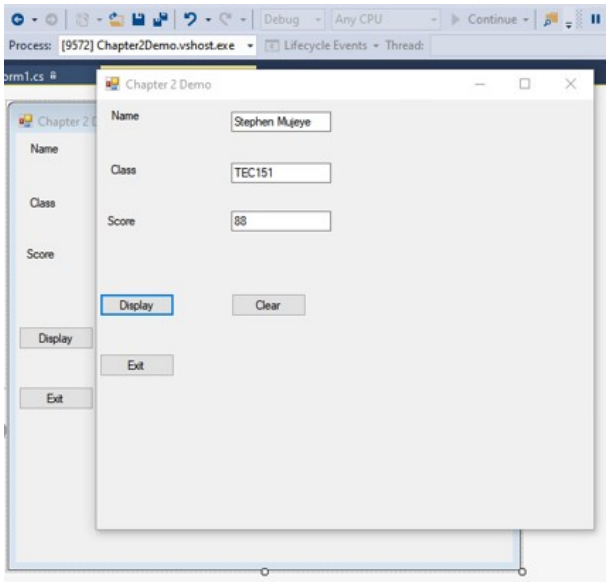

Fig. 6. Visual Studio IDE – C# programming in the Virtual Pool.

Fig. 7 shows the results form the SceneBuilder and NetBeans IDE used to develop Java applications in a Virtual Pool.

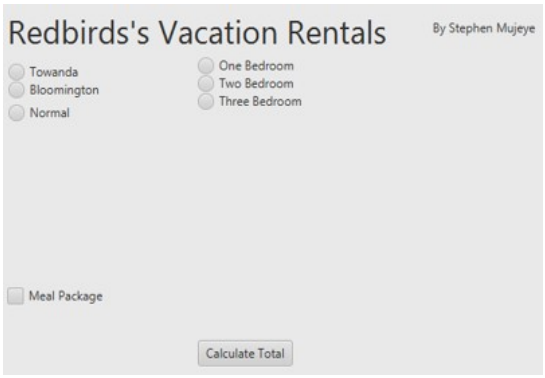

Fig. 7. SceneBuilder and NetBeans IDE – Java Programming in a Virtual Pool.

Fig. 8 shows the results of running three different virtual machines in the Virtual Pool.

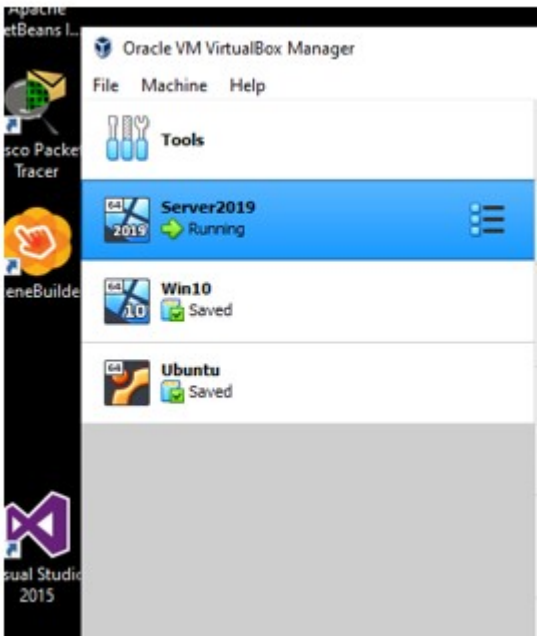

Fig. 8. Running three different virtual machines in the Virtual Pool.

Because of virtualization solutions, we were able to give our students the same experience they would have if they were in the physical labs. Utilizing virtualization solutions, our students could apply, practice, and apply networking and programming concepts in real contexts [10]. The virtual machines were a bit slower when students accessed them using Citrix; however, there was no significant delay when accessed using the Virtual Pool. The preferred method was to access the virtual machines using the Virtual Pool.

IV. Discussion

As the pandemic continued, educators became more and more comfortable with teaching classes online. More faculty were able to find innovative ways of delivering content to students. Some of the technologies made it more accessible and better to deliver high-quality content to students.

Online learning comes with some benefits. Some of the benefits include flexible time and schedules, fewer problems with overlapping courses, studying from home comfort, and elimination of commuting and transportation costs. As the pandemic continued, more and more students longed to return to campus for face-to-face learning.

There is no doubt that the lessons learned during the pandemic will be helpful and valuable in the future. At Illinois State University, Technology students are now more familiar with accessing labs virtually. In situations where they may not be able to make it to campus, they can complete labs from anywhere as long as they have a computer and Internet. This becomes possible as virtual pools and computer labs using Citrix are accessible anytime. The virtual pool and Citrix provide the same functionality students get when they are physically accessing the labs.

The use of Zoom makes it possible for faculty to have virtual office hours. As such, students can now get live assistance at any agreeable time. Assisting students is no longer restricted during the traditional 9-5 hours. Faculty are now only a zoom call away.

V. Conclusion

The pandemic also helped educators and students to realize they can mix learning modalities in ways that are beneficial to students. There are some aspects of learning that can be better delivered using Zoom. Zoom or similar technologies can be used in inclement weather. Classes do not need to be canceled because of snowstorms; the courses can be delivered online during those times.

Future studies can focus on how the implementation of 5G can advance smart classes and smart learning. As 5G becomes widely used, new opportunities in e-Learning become available. Augmented Reality (AR) and Virtual Reality (VR) can be used to enrich the learning process. There is a need to explore the integration and implementation of AR and VR in the classroom.

Conflict of Interest

The author declares no conflict of interest.

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