



The COVID-19 Pandemic and Retooling Application Delivery

The Transformation from Physical to Cloud-Based Infrastructure

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ABSTRACT

As was the case with many sister institutions, the Office of Technology Services (OTS) at the Illinois Institute of Technology (Illinois Tech) needed to implement a robust solution for academic software access. The shift of primary university application delivery from locally-hosted Apache-based technology and physical computer labs to a cloud-based virtual computer lab during the global COVID-19 pandemic is presented. The method utilized had the following components: evaluation of different levels of conversion to cloud-based application delivery; evaluation of vendor capability; methodology for application deployment; methods of faculty engagement with software selection; methods of monitoring the user experience; quantitative assessment of total sessions, total usage hours, and maximum concurrent user usage; quantitative comparison of those fields to the previously used Apache iteration; quantitative and qualitative evaluation of support incidents generated; and qualitative assessment of the user experience. Overall sessions increased nearly threefold, and maximum concurrent users quadrupled, hours spent on the platform per capita decreased as a result of increased performance, engagement with faculty in the application delivery process increased, and improved overall user experience.

CCS CONCEPTS

• **CSS CONCEPTS: Human-centered computing; • Computer systems organization; • Social and professional topics;**

KEYWORDS

Application Delivery, Application Deployment, Application Virtualization, Classroom Technologies, Cloud Computing, COVID-19, User Experience, Virtual Computer Lab, Virtual Computing Lab

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1 INTRODUCTION

Prior to the COVID-19 pandemic, the Office of Technology Services (OTS) was already contemplating a new Virtual Computing Lab (VCL) solution to replace our locally-hosted aging Apache-based VCL. [1] The virtual servers hosting that solution were running Windows 7 machines with 4GB of RAM, insufficient for many high-throughput applications used in academic learning. Not only would the machines need to be rebuilt from scratch to accommodate Windows 10, but they would also require the resources of at least one full-time systems engineer dedicated to the creation of a replacement, and it was estimated that the individual would need at least one year to create, test, and implement the solution. [2] Additionally, the university had already been attempting to cut back on demands on physical infrastructure due to budgetary and personnel constraints. Among initial discussions within our division, a decision was made to pursue both hybrid and full-cloud solutions for deployment to replace our Apache-based VCL.

2 UNIVERSITY REQUIREMENTS

2.1 Needs

The initial assessment began with a discussion within OTS and key university deans and faculty. A host of qualifications were determined to be desirable in vendor candidates as initial candidates in the following categories: capabilities, services, demonstration, and cost. [3] For capabilities, the qualities initially sought were the ability to have a virtual desktop interface (VDI), application virtualization (AppV), Linux capabilities, cloud capabilities, and on-demand machines. Services, support hours, service-level agreements (SLAs), setup time, shared management of infrastructure, and local administrative access were also evaluated. For demonstration, it was determined that the vendors needed to show knowledge of their product(s), communicate with both the technically-minded and general user populations, and have a practical demonstration of their product(s). The cost was a critical factor, requiring up-front pricing with different service tiers presented in each. [4]

2.2 University Strategic Plan

The move to a cloud-based model was fortunately timed to coincide with the publication of a new five-year university strategic plan for 2020–2025. The four points given were as follows:

Appendix Grow and develop both our undergraduate and graduate student bodies with an emphasis on student success, both

during the students' time at Illinois Tech and after graduation in their professional careers

Appendix Fully realize our identity as the premier technology-focused university in Chicago and one of the five premier technology-focused universities in the nation

Appendix Strengthen our finances to enable strategic investments in our faculty, facilities, and educational and research programs

Appendix Become a leading university in the development and delivery of our educational and research programs [5]

The move to a cloud-based VCL infrastructure would directly correlate with each point as follows:

- This would assist in student success by equalizing the student experience with regard to software worldwide.
- As Illinois Tech pushes to become the premier technology-based university in Chicago and a leader in the nation, a cloud-based VCL would put the university on equal or better footing with our university counterparts.

A virtual environment would not only be more cost-effective but would free up limited labor pools to work on other improvements to technology on campus.

Cloud virtualization would also make Illinois Tech a leading university in the delivery of educational programs solely by availability and equal access. In addition, staging a software deployment in a cloud environment is much more agile than in physical labs.

3 PLANNING AND IMPLEMENTATION

This section will outline the process of selecting a vendor, initial discussions, setup, testing, launch, and tweaking.

3.1 Vendor Selection

OTS began with seven possible vendors. The categories stated in Section 1.1 were used to vet these selections and pick the best three to proceed to a final evaluation. The criteria that differentiated the strong contenders from the weaker ones were in 24/7 support, how much setup time would be needed, how strong the presentation was, and if the vendors were transparent with pricing at different tiers.

The three vendors that were selected for a final review were scrutinized in more detail with the criteria in the table below:

The criteria in this table were evaluated on a five-point scale as follows: 4 - Exceeds Needs, 3 - Meets All Needs, 2 - Meets Most Needs, 1 - Partially Meets Needs, 0 - Does Not Meet Needs.

The full Application Delivery (AppDel) team then evaluated each vendor, with the strongest candidate selected: Apporto.

3.2 Initial Conversations on Implementation Design

The setup of the environment required the evaluation of several components. In establishing the structure of how Illinois Tech would interact with the vendor, one Illinois Tech systems engineer (Shadi Beidas) and one Apporto director of customer success (Max Lushchan) were selected to streamline communications, with an SLA of emergency issues being under two hours.

3.2.1 Structure. The service access page was given a domain name by Apporto, and linked to our central authentication service (CAS) single sign-on (SSO). Two environments, a GPU and non-GPU option, were determined to be sufficient to serve the needs of the university community. In addition, full desktop VDIs were designed and tested. VPN tunnels were established from our licensing servers to the servers on which Apporto hosted their solution.

3.2.2 Service. Apporto notified the AppDel team that every person that would contact the team regarding setup or troubleshooting would be an engineer. Furthermore, the team assigned from Apporto were specific individuals, build familiarity with the unique needs and ongoing issues present within Illinois Tech. Five to seven business days would be required from setup to deployment of a new application. [6]

3.3 Implementation

With the initial launch, it was communicated with the university community that we would be moving primarily to an app-as-a-service model. The university faculty were contacted to request applications to be deployed in Apporto via a Google Form. Deployment prioritization was made for applications that were paid university apps or particularly resource-intensive apps. Most freeware was initially restricted from deployment during the first year of service until user demand could be assessed.

Beginning in the second academic year of our collaboration with Apporto, both high user demand and a coincidental move to Microsoft Endpoint Configuration Manager (MECM) for physical computer lab deployments necessitated a change in the policy of restricting freeware from Apporto. A fair amount of freeware that professors were requiring for learning were restricted to Windows, and a number of students and faculty utilized Apple or Linux-based devices. In addition, freeware deployment in MECM is especially difficult in the packaging process, as the installers are rarely in MSI format, and many are not updated frequently. [7] Freeware application requests are accepted for deployment in Apporto when a review of the end-user license agreement (EULA) allows, and that the application(s) requested are deployable in a Microsoft Server 2019 environment.

In addition, a new model of professor engagement was adopted by selecting a delegate faculty member from every department to directly coordinate to one system engineer in AppDel. This was set up in the hope of increased engagement and streamlining services.

3.4 Testing

Each department requesting software was required to select delegate professors or graduate students to assist AppDel with deployment testing as a condition of the request process. In the second deployment year, the faculty delegates either assumed that responsibility themselves or delegated the task and reported back results.

3.5 Deployment

Apporto launched the Illinois Tech instance in early August 2020, though it was not released to the university community until August 15th.

Table 1: Final Vendor Qualifications

Evaluation Criteria	
Category	Financial Proposal
Description	50 separate applications 250 projected maximum concurrent users Cost per minute of on-demand options 8,000 users to have access to the environment AppV/VDI proposed infrastructure plans The vendor is able to provide a good balance of 24-hour and on-demand machines. Comprehensive of all aspects of cost (setup, maintenance, support, etc.). Competitiveness of the price. Comparative solutions to clients of a similar institutional size as Illinois Tech
Category	Customer Service
Description	What are the hours of service for the helpdesk? What is the maximum response SLA to a query? What is the average turnaround with issue resolution? What level of account management and support is provided?
Category	Administrative Compliance, Vendor Responsibility, and Partnership
Description	Very strong references of similar size and scope from other higher education institutions. Good known experience with vendor. Strong plan for program implementation and transition.
Category	Technical Proposal
Description	Vendor is able to provide a cloud-based portal for both VDI and app virtualization. Both local administrative access as well as technical support are provided. Vendor supports Windows, Linux, and macOS applications/desktops. Infrastructure outline and approaches to providing us with a comprehensive solution. Outlined the throughput of the infrastructure at all subscription levels. High data security options.
Category	Prepared Demonstration:
Description	Product experience Full demonstration of client-side experience Highlights of the administrative interface Showed administrative tools we can use to customize the user interface, experience, and usage time. How to adapt offerings with ones more relevant to student needs, and how to scale up or scale down our offerings quickly and efficiently. Showed machines of three different levels and one Linux-based device with the requested software and the provided demonstration files. This must be a live demonstration, and not a video demonstration of the software. High-end performance with robust GPU: AutoCAD 3DS Max 2020 Midrange performance with lower-end GPU: MATLAB 2020 Lower performance: Excel 2019 sheet with executable macros Linux distro: Ubuntu with Open Office

4 RESULTS

From personalized discussion appointments with key university faculty involved in software selection, many accolades on the improvement of VCL were seen in the Fall 2020 semester when compared to the Spring 2020 semester. Any issues were readily attributed to expected issues moving to a new delivery system. A potential issue that is still being monitored is more than doubling our software library for the fall with the inclusion of freeware, as well as the anticipated wide-scale spin-up of offering both Linux and Windows VMs. To date, the university went from offering 53 applications

in Apporto in Fall 2020 to 107 in Fall 2021. The university is currently offering three virtual machines for academic use: an Ubuntu blockchain course, a SQL server, and a Trimble applications suite, though that number is expected to climb significantly.

The comparative utilization statistics between Apache and Apporto can be seen in the figures below:

As far as overall trendlines, a rough doubling of the total number of sessions students have used over the past year in Apporto VCL versus usage in the last year of Apache VCL was observed. The number of users roughly quintupled. The hours of usage each semester roughly doubled between F19 v. F20 and S21, but the S20 trendline

Total Sessions (Apache) and Total Sessions (Apporto)

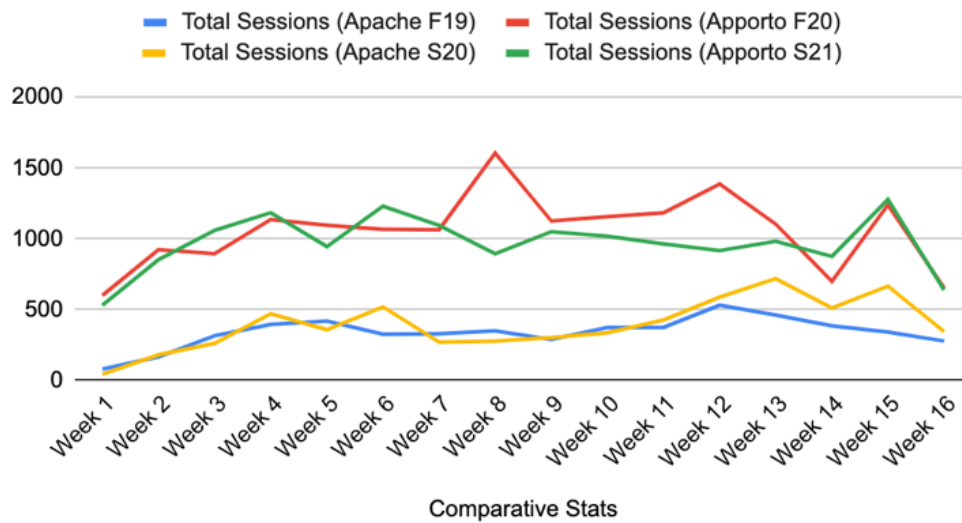


Figure 1: Total Session Comparison Between Apache and Apporto VCL Solutions

Total Hour Usage (Apache) and Total Hour Usage (Apporto)

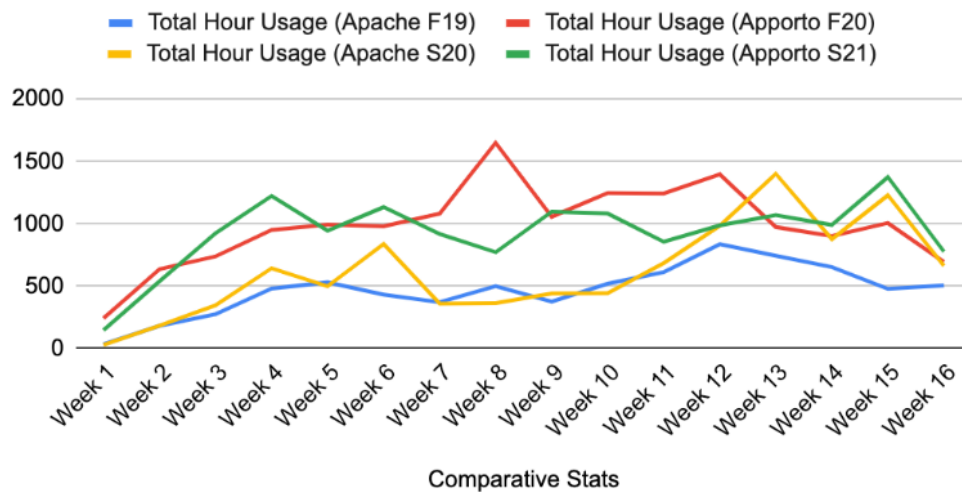


Figure 2: Total Hours of Usage Comparison Between Apache and Apporto VCL Solutions

approached F20 and S21. Far more students used Apporto VCL because of necessity in F20, and Apache VCL in S20. As physical labs reopened, Apporto VCL maintained strong usage in S21 comparable to F20 levels. As stated in previous analyses, the reason Apporto hours of usage did not increase proportionately to higher adoption rates was due to an increased quality of service. [8] Apache VCL

was limited to 4GB of RAM, running Windows. A disproportionate increase in use hours in S20 v. the number of student users needing more time on the service to complete tasks was observed. From initial analyses available to the Illinois Tech systems engineering team at this time, the lengthy time of spinning up each VM, launching applications, and the fact that no virtualized GPU was available

Max Concurrent Users (Apache) and Max Concurrent Users (Apporto)

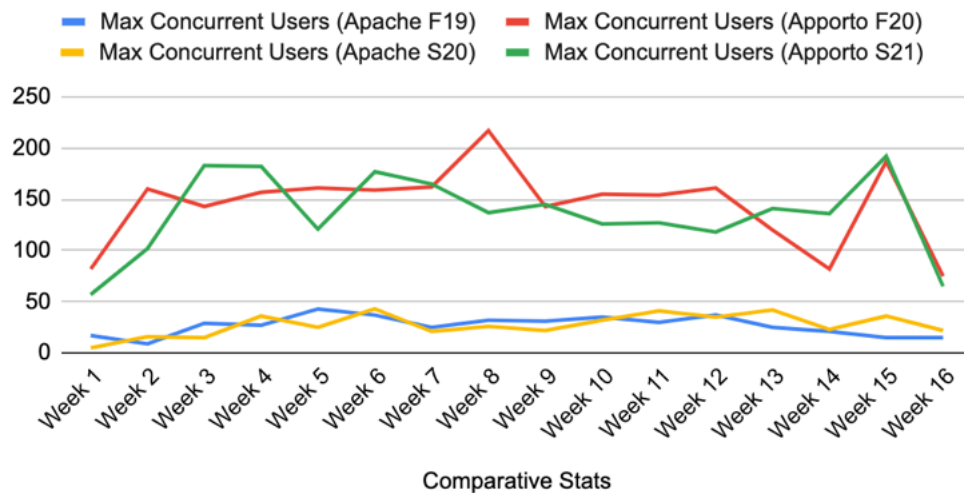


Figure 3: Total Concurrent Users Comparison Between Apache and Apporto VCL Solutions

Fall Total Session Comparisons

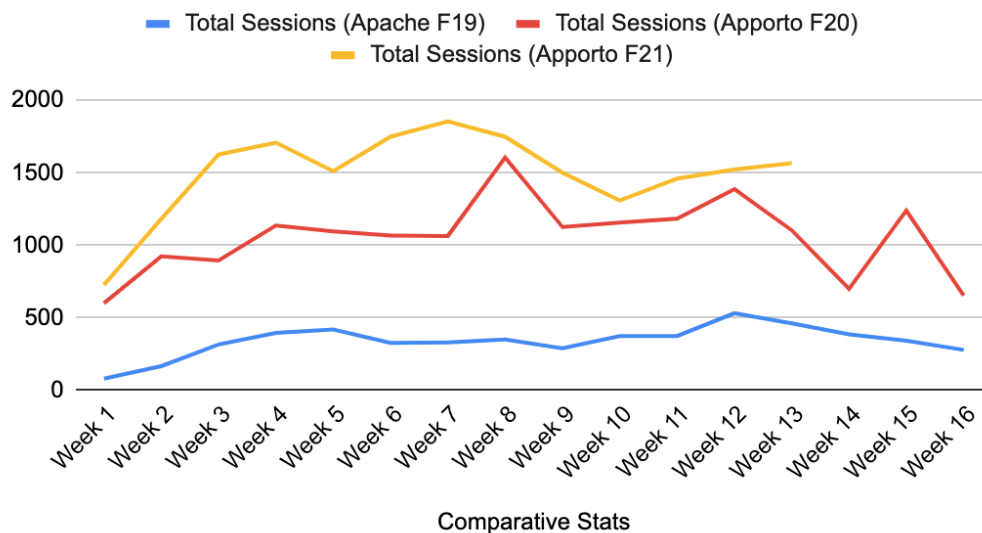


Figure 4: Preliminary Session Comparison Among Fall Semesters, 2019-2021.

in Apache-based VCL for more model-intensive applications, and was further complicated in that the VMs in Apache VCL had more than a dozen apps apiece on the weak machine configurations on locally hosted physical devices. Further investigation is planned via both quantitative and qualitative means.

Preliminary comparisons of Fall 2019, Fall 2020, and Fall 2021 data can be seen as follows:

5 ANALYSIS / CONCLUSION

Replacing the aged Apache VCL was a primary goal of this endeavor. The AppDel team successfully vetted, deployed, and maintained

Fall Total Hour Usage Comparisons

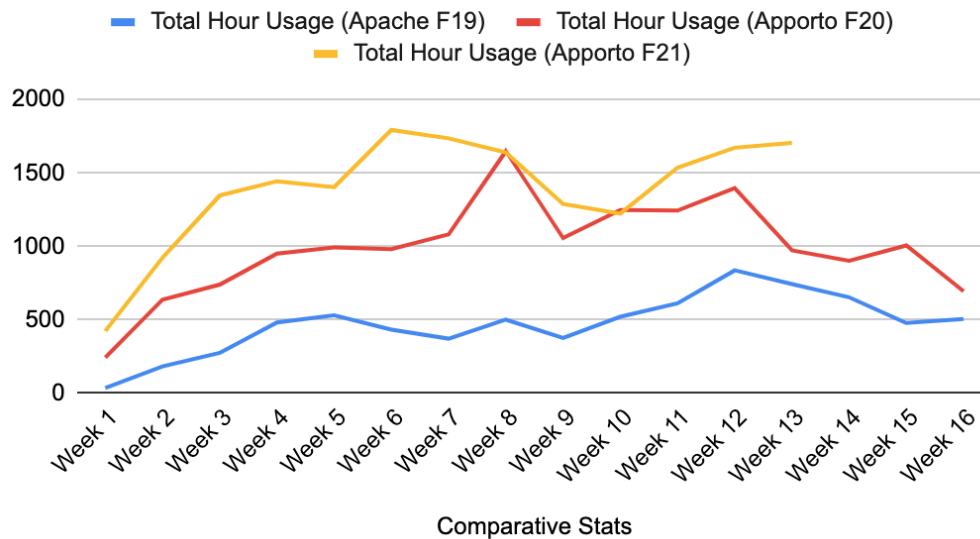


Figure 5: Preliminary Hours of Usage Comparison Among Fall Semesters, 2019-2021.

Fall Max Concurrent User Comparisons

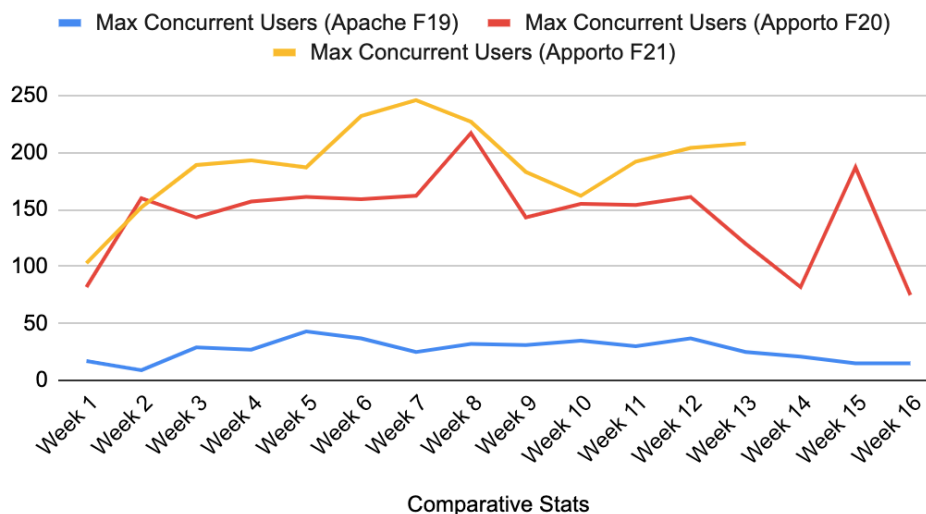


Figure 6: Preliminary Concurrent Users Comparison Among Fall Semesters, 2019-2021.

an appropriate vendor who offered a completely virtualized option, negating the need for on-premise servers.

5.1 Strategic Plan Alignment

Moving to a cloud-based service has aligned us with the following four main goals of the 2020-25 University Strategic Plan [5] as such:

Goal 1: This assists in student success by equalizing the student experience with regard to software worldwide. [9] Students can use any piece of software that they would in the physical labs on any device, meaning someone with a \$100 Acer Chromebook will have the same software experience as a \$2,800 M1 MacBook Pro. This software is accessible anywhere in the world, 24/7 with a modest broadband connection.

Goal 2: Apporto has put the university far ahead of the curve in pushing to become the premiere technology-based university in Chicago and a leader in the nation. During the several conferences that we attended last year, the universities that are usually at the forefront of software content delivery were reported still to be in the initial stages of transitioning to cloud-based application delivery. Illinois Tech currently has 107 active applications in Apporto VCL. In discussion, it was showcased what Illinois Tech accomplished so far, with many universities looking to this model for future development. It has significantly raised the image of Illinois Tech among our peers, and opened the door to more connections with peer institutions via educational technology discussion forums, discussions with peers at other institutions, and via virtual and in-person conferences.

Goal 3: This change in software delivery strengthens university finances by enabling migration from costly physical labs to a virtual environment. By increasing the number of seats in the university subscription, it is now possible to proceed with a proposal dramatically decrease the university's physical computer lab footprint. [10] A replacement of the majority of the remaining physical lab assets with inexpensive small form-factor devices, containing a barebones MECM image, is projected to occur within the next three to five years. All software use in those labs would go through Apporto. Furthermore, this change significantly reduces the high energy cost of keeping machines on and maintained 24/7.

Goal 4: For many of the reasons already stated, this transition to cloud-based software deployment will assist Illinois Tech in becoming a leading university in the delivery of our educational programs just by making the applications available. [11] In addition, staging a software deployment in Apporto is much more agile than in the physical labs. With Apporto, AppDel only needs to submit the licensing information, ports required, and the installer to the Apporto team. With physical labs, an MECM deployment has to be created and implemented in a change window.

The solution developed not only fulfilled educational content delivery during the restrictions necessitated by the pandemic, it may led to an entirely new standard set for higher education application delivery.

5.2 The New Normal

With the preliminary data from Fall 2021, two important assessments can be made: normal usage surge patterns are returning, and a marked increase in virtual application delivery as an educational tool is apparent. Prior to the pandemic, it was observed that many faculty in the university preferred a two-midterm or midterm-project learning evaluation strategy. This is supported by legacy data and by the Fall 2019 data with regards to total sessions, total users, and total hours of usage. In the 2020-2021 year, the Fall semester saw a move to application usage peaking in the middle of the semester, which aligned with many professors moving towards a one-midterm or one-project teaching model. The Spring 2021 semester saw a less defined pattern, and the Fall 2021 semester saw a return to the dual-surge model. This indicates that overall, educators at Illinois Tech have returned to a two-midterm or midterm-project model.

While the usage patterns have largely returned to pre-pandemic model shapes, preliminary data indicates that Illinois Tech has not returned to pre-pandemic usage patterns. In fact, virtual lab usage is projected to exceed physical lab usage, which was not at all the case pre-pandemic.

6 FUTURE WORK

An assessment is being planned to send out to select university community members regarding their experiences with VCL to analyze better from a qualitative perspective. The selected users will be community members who utilized both the Apache-based and Apporto-based VCL environments.

Educational sessions on the usage of Apporto as a viable alternative to in-person computer labs are being planned and implemented. These sessions will be made available to the student, faculty, and staff bodies to highlight the advantages of a cloud-based application delivery system from the perspectives of accessibility, availability, and cost-savings.

The success of Apporto has enabled AppDel to plan for both the phasing out of higher-performance physical devices in favor of thin-client devices and reduction in the number of endpoints. The cost savings will finance the following planned service expansions:

References Virtual Cyber Range: Allowing for the full functionality of this learning resource without any risk to onsite physical systems.

References VM Expansion: Building out more class-specific VMs for different educational purposes, especially useful for students with lower-end devices that would not run a VM manager well.

References Apple VMs: With a combination of departmental funding and cost-savings from other Apporto services, upgrading the current license to include Mac VMs.

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