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Modernizing IT Infrastructure in Academia: A Case Study from AGH University of Krakow*

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Abstract

Modern universities increasingly depend on unified IT infrastructures that can support teaching, laboratory work, and remote access. Fragmented systems, inconsistent laboratory environments, and limited identity management, significantly reduce usability for students and create administrative overhead. To address these challenges, a modernization project was initated at the Department of Applied Computer Science at AGH University of Krakow. Although prior studies discuss identity management or digital transformation in higher education, there is limited documentation of fully integrated, department-level infrastructure reform carried out using only open-source technologies and limited resources. This paper fills that gap by presenting a practical case study, offering a replicable model for institutions seeking cost-effective modernization. The project unified identity and access management with FreeIPA, standardized laboratory environments using automated deployment via Ansible and Kickstart, and introduced a virtualization platform based on QEMU/KVM with customized image distribution and VM management tool. Department Panel was developed as the central user interface integrating public services. The evaluation method included a survey of 100 students actively using the new environment. Results demonstrate very high user satisfaction. Students strongly indicated that the availability of modern IT services positively influences their learning experience and could shape their choice of university.

Keywords: academic environment, open source, IT infrastructure, identity management, virtualization

Introduction

Efficient management of the IT infrastructure and related digital services has become a critical requirement in modern universities. Laboratory rooms and teaching environments increasingly depend on automated, secure, and unified systems that support daily classroom operations and provide essential computing services to students and teaching staff (Mindaña 2020, Antonopoulou et al. 2023).

Modern students expect universities to provide the same level of technological reliability and usability they experience in commercial digital services. Improving the IT infrastructure and user experience has become a strategic factor in attracting and retaining students in higher education. Institutions that fail to meet these standards risk lower engagement and competitiveness in recruitment. Furthermore, technical issues may contribute to increased stress levels among studentsts (EDUCAUSE 2022). Therefore, investments in modern, accessible, and well-integrated systems directly support both educational quality and institutional sustainability.

Many students prefer to bring their own laptops to classes when institutional labs provide only local, nonportable workspaces. If files and settings are still tied to a single workstation, students cannot seamlessly resume tasks

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across rooms or sessions, which discourages the use of laboratory machines. In contrast, personally owned devices offer continuity of tools and data, reducing setup time. Studies in higher education report student acceptance of using personal devices for learning due to the interactivity and accessibility of teaching resources (Cheng et al. 2016), and this could be potentially changed if students were provided with well-integrated and easily accessible institutional environments for their work.

This article presents a case study on infrastructure modernization conducted in the Department of Applied Computer Science at the AGH University of Krakow (Poland). The initiative aimed to unify user management, automate laboratory environments, and provide reliable remote access for teaching. Using open-source tools like FreeIPA, KVM/QEMU and Ansible, heterogeneous legacy systems were replaced with a cohesive platform.

Although other works in this area have addressed identity management in higher education institutions (Thota 2024), and the ongoing digitalization in this area, discussed in more abstract terms of data infrastructures and institutional dependencies on digital platforms (Komljenovic et al. 2024), fewer publications document a fully integrated departmental transformation executed with limited resources. The contribution of this paper lies in detailing such a transformation, providing a replicable model for other academic units seeking cost-effective infrastructure modernization.

The project started as a grassroots initiative by one of the department's staff members, Konrad Zaworski, a teacher at the Department of Applied Computer Science. Initially, a very simple panel was developed to manage laboratory services such as SSH accounts and databases. At that stage, most of the developed services were hosted on his personal workstation and made remotely accessible to his students during and outside of classes.

As its usefulness became clear, the department's leadership expressed interest in formalizing and expanding the initiative, since new funding had been secured for the physical server and laboratory infrastructure that could be adopted by the project. The prototype was further developed with additional services related to user identity management and the unification of future laboratory computers. Then it was gradually migrated to the institutional infrastructure and became a foundational element of a larger modernization effort.

This article focuses specifically on that early stage of the work: the prototype and its transition to the department's infrastructure, where it was initially deployed in two laboratory rooms.

The general architecture of the infrastructure

The modernization of the department's IT infrastructure was designed as an integrated environment that combines administrative, educational, and laboratory services. Its purpose was to replace fragmented local systems with a unified platform that ensures security, data mobility for students, and simplified management of physical resources (laboratory computers). The general structure of the solution is illustrated in Figure 1.

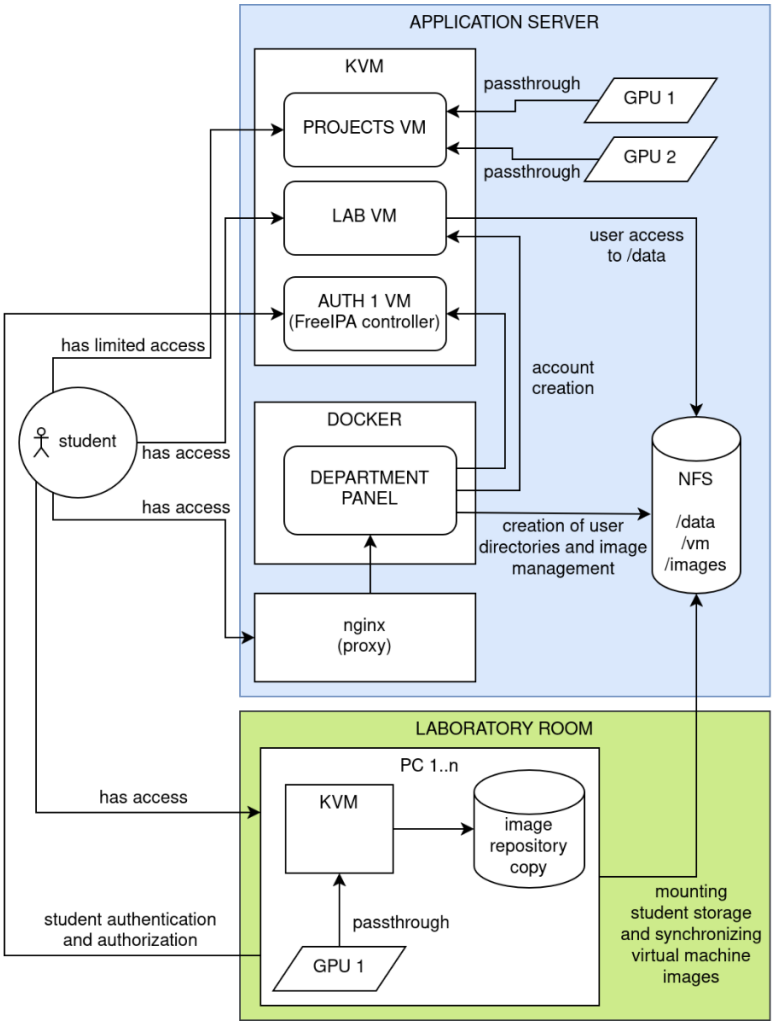

Figure 1 Architecture of the integrated IT infrastructure at the Department of Applied Computer

The **application server** acts as the central component and integration point of the entire infrastructure. It hosts several key subsystems:

- Department Panel,
- domain controller (*FreeIPA*),
- laboratory virtual machine (*QEMU/KVM*),
- projects virtual machine (*QEMU/KVM*),
- user storage area (*NFS*),
- virtual machine image repository (*NFS*).

The **Department Panel** serves as the main user interface to the infrastructure. It is a web-based application developed specifically for this modernization project, which integrates all the services offered.

The **domain controller**, based on *FreeIPA* software (free version of Red Hat Identity Management), provides centralized identity and access management. Each student can create an individual domain account through the Department Panel, which offers authentication on laboratory computers. *FreeIPA* integrates an LDAP directory with a Kerberos authentication server, ensuring secure credential management and fine-grained access control policies.

FreeIPA has been successfully adopted in several research institutions as a reliable open source system for centralized authentication and authorization. Among others, the Thomas Jefferson National Accelerator Facility (Jefferson Lab) migrated from NIS to Red Hat IdM to enhance the scalability and security of its scientific computing infrastructure (McGuckin & Slominski 2020), confirming the suitability of this solution for academic environments.

The application server runs **laboratory virtual machine**, which provides educational services such as SSH access to the Linux system, personal websites and database environments, useful during the course of study. These services are available remotely, allowing students to continue their work from home.

After the migration of the infrastructure to a new server, a **project virtual machine** was also introduced. Upon request, administrators can grant access to this environment to students and staff. It is equipped with two high-performance GPU cards directly attached to the virtual machine via *QEMU/KVM* GPU passthrough capability, enabling advanced scientific computations and experiments.

An essential component of the system is the user storage area, provided via the *NFS* protocol. It functions as a shared data repository accessible from all lab computers and virtual machines. User directories are automatically created when an account is registered through the Department Panel. Authentication in laboratories is handled by *FreeIPA*, which automatically mounts the user's *NFS* directory upon login. This ensures that students can work in any laboratory room while retaining access to the same files, configurations, and development environments.

There is also NFS-based storage for virtual machine images. Each laboratory workstation maintains a local mirror of this repository, synchronized nightly to reduce network load and enable fast cloning and launching of preconfigured virtual machines prepared by instructors. Virtual machines running on laboratory hosts have direct access to GPU devices through GPU passthrough capability.

It is worth noting that all components of the project are based on open source software. The adoption of OSS in academic institutions benefits both students and faculty by reducing costs, supporting professional certification pathways, and fostering practical learning through direct access to source code (Satyarajan & Akre 2011).

Details of the structure of certain system components

The following subsections present a more detailed description of some of the infrastructure components mentioned above. Particular emphasis is placed on original solutions. It should be noted that most of them are published under the GPL v3 license.

Department Panel

AGH University of Krakow offers a range of services that students can manage through the institutional panel. However, these functionalities are not specifically designed to support learning in computer science-related programs, but provide general utilities such as access to Wi-Fi, VPN, and email. Both students and instructors continued to require additional services dedicated to coursework and laboratory activities. Consequently, a need for a local system was arising that would complement the existing university panel. One of the key initiatives, and the primary point of contact between students and the new departmental infrastructure, is the Department Panel, developed entirely from scratch by Konrad Zaworski, a faculty member. Fragment of this system is illustrated in the Figure 2.

This platform provides access to all services offered by the Department, including student accounts for laboratory workstations (FreeIPA), SSH accounts on the laboratory server, a web-based VS Code IDE for programming tasks, personal website hosting, database services, and the generation of WireGuard VPN keys, which enable modern and secure access to internal network.

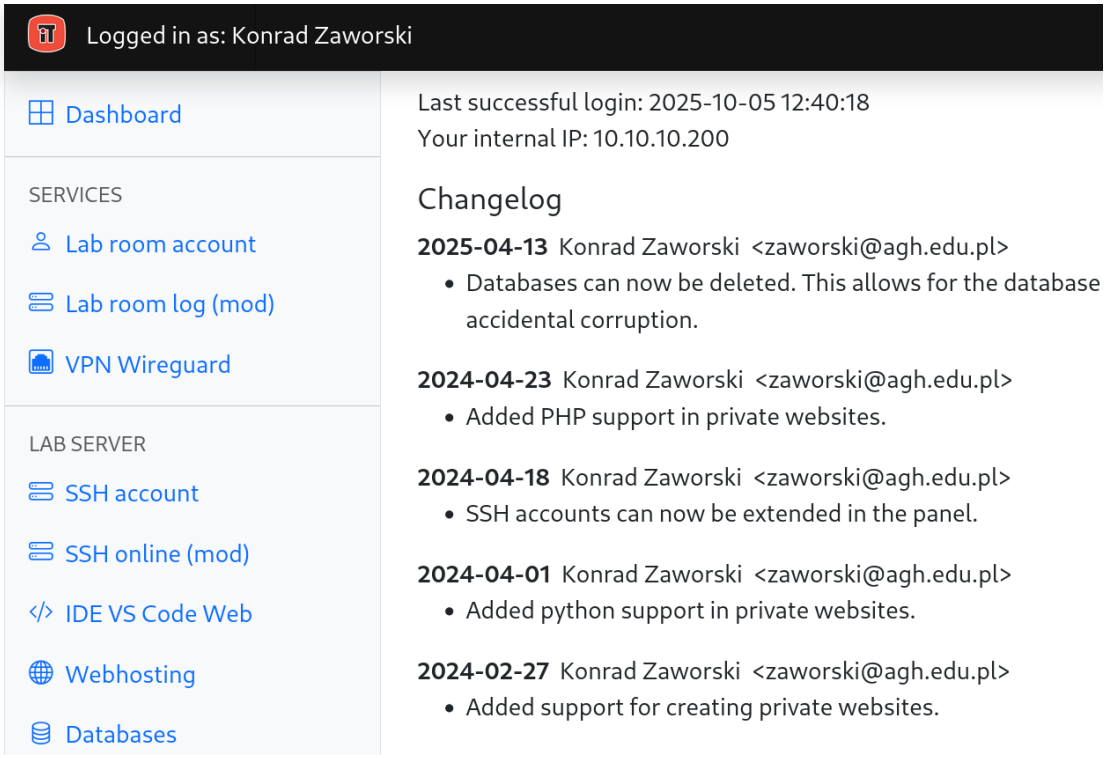

Figure 2 Fragment of the Department Panel

In coordination with the higher-level university administration, the panel was integrated with the institutional Single Sign-On (SSO) system, eliminating the need to create separate accounts for students and staff. Authentication is performed securely using the same credentials used for other university-wide systems.

The panel incorporates advanced security measures. To minimize potential risks, its interaction with associated services is strictly restricted to necessary operations (e.g., account creation, password reset, or VPN key generation). Each service exposes a securely protected access point to ensure that the panel does not become a single point of failure. Given the public availability of the panel, multiple layers of protection have been implemented at both the physical and operating system levels (e.g. RAID array, secured room, use of physical YubiKey authenticators, backups, SELinux, firewall). This presented a significant challenge that was approached with full commitment and careful attention to detail.

FreeIPA platform

In the past, before the start of each semester, the departmental system administrator was required to obtain student lists from the Dean's office and manually create individual accounts for them in each laboratory room. Some rooms operated with a single shared student account, which offered no privacy and prevented users from storing their personal work. As a result, students were forced to transfer their files between workstations using USB drives.

To address this issue, FreeIPA software was introduced, a system to streamline identity management, access control, and policy settings. This solution integrates an LDAP directory, a Kerberos authentication server, certificate management, and access policy enforcement within a single platform. Initially, two laboratory rooms were managed through the new system and further deployments were implemented later as part of the broader modernization efforts.

Furthermore, any data saved by a student on one workstation is automatically available in all other laboratories. Each user is provided with private storage space on an application server, which is automatically mounted upon login. This applies not only to personal files but also to user configurations for applications such as web browsers or various development IDEs.

This solution has significantly reduced the number of work hours required from technical staff, who previously had to create accounts multiple times per year and reset forgotten passwords on a regular basis. However, the

greatest benefit has been for the students, who can now seamlessly access and continue their work across different workstations and laboratory rooms.

Unification of environments in laboratory rooms

The Department maintains numerous laboratory rooms that until recently were equipped with a variety of operating systems and software configurations. This diversity led to a number of challenges related to the management of such complex environments and required instructors to assess the setup of each room before reserving it for their classes. In many cases, certain rooms were unable to support specific types of coursework due to system limitations.

In laboratories integrated with the previously mentioned IdM system, we have implemented standardized environments to ensure consistency across all teaching spaces. Figure 3 shows a photo taken in one of the laboratory rooms. As a result, every instructor can now reserve any laboratory room with the confidence that it will provide the same configuration and be fully ready to conduct classes, without concerns about missing software or unavailable student accounts.

Figure 3 Photo taken in one of the laboratory rooms showing the unified software on the computers

A set of custom Ansible scripts, a professional open source automation framework, and Kickstart (operating system installer) configurations have been developed to enable not only the centralized management of existing laboratory rooms but also the rapid deployment of entirely new ones. As a result, there is no longer a time-consuming manual installation of the operating system on each individual machine. A fully functional laboratory, with IdM integration, can now be deployed in a single working day, assuming the physical infrastructure is already in place.

Virtualization platform and application for managing virtual machines

Rocky Linux is an operating system installed on every laboratory workstation. It allows the installation of numerous software packages required for conducting classes; however, no operating system is perfect or capable of supporting all possible use cases. For this reason, it became necessary to enable the use of additional operating systems within laboratories.

Previous studies have shown that virtualization has proven to be a practical and reliable solution for academic laboratories (Miseviciene et al. 2012). This allows students to launch alternative operating systems directly on their workstations, running in separate application windows within the already installed Rocky Linux environment. Multiple virtual systems can be executed simultaneously, effectively simulating the operation of several distinct computers, which is particularly useful for courses in operating system administration and related subjects.

Images of these additional operating systems are prepared in advance, usually by course instructors, and then distributed to all laboratories overnight from the application server. The synchronization tool is based on the customized *uftp* software, which uses multicast transmission to send data only once, while simultaneously delivering it to all computers. This approach significantly reduces the network load within the AGH infrastructure. The original *uftp* client and server code has been modified to include version control for the distributed system images.

The virtualization platform and the image synchronization system have been complemented by the application developed to manage virtual machines, shown in Figure 4. It is an overlay for the QEMU/KVM platform. Students can launch the application directly from their workstations and conveniently select, from a user-friendly menu, which system images they wish to run.

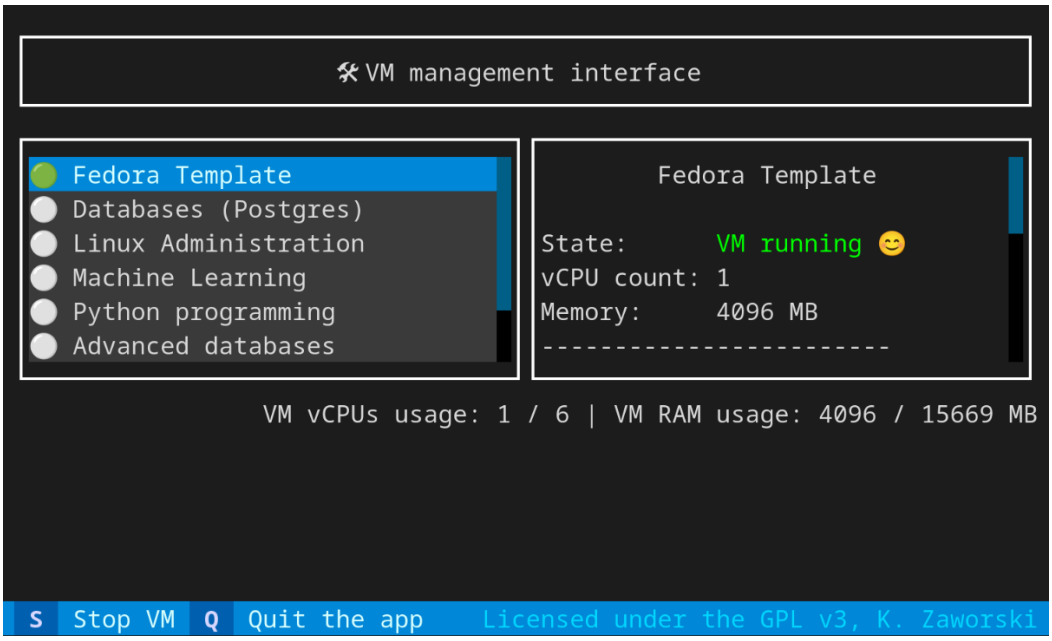

Figure 4 Preview of the application for managing virtual machines by students

We have also introduced a number of enhancements to the virtualization layer itself, enabling students to access their private directories directly from within the virtual machines. Additionally, virtual machines are capable of taking control of the graphics card, allowing the deployment of dedicated pre-configured operating systems optimized for high-performance computing tasks.

Survey conducted among students

A survey concerning the implemented solutions was conducted among **100** students of the Computer Science and Intelligent Systems program, taught by the staff of the Department of Applied Computer Science. The questions were addressed only to students who had used the new infrastructure. The set of questions and responses is presented in Table 1.

Table 1 Responses to the survey conducted among students

Question	Yes (%)	No (%)	No opinion (%)
Is logging into the Department Panel convenient and intuitive?	95	4	1
Is the Department Panel interface (after logging in) sufficiently intuitive?	85	9	6
Have the services offered in the Department Panel improved your work or study experience?	92	2	6
Do you think making our Department's solutions available as open source is a good idea?	63	4	33
In your opinion, do the solutions implemented in our Department (services available in the Department Panel, upgraded laboratory rooms) have the potential for wider use across the university?	93	0	7

Would you recommend our Department's IT services to other students who have not used them yet?	83	4	13
Would the availability of modern IT services at a university encourage you to apply for admission there?	86	4	10

The survey results show a very high level of user satisfaction with the IT infrastructure implemented. Students found the Department Panel convenient, intuitive, and helpful in their coursework. They also confirmed that the new services improved their learning experience and have the potential for wider use within the university. The results may indicate a low awareness of the importance of Open Source Software among students. It should be noted that the availability of modern IT services in a university would be an important factor in encouraging respondents to do their studies there. This finding is consistent with previous studies that emphasize the role of institutional IT quality in student satisfaction (Keane et al. 2022).

Summary and conclusions

The modernization of the IT infrastructure at the Department of Applied Computer Science, AGH University of Krakow, successfully unified identity management, laboratory systems, and virtualization capabilities into a single environment based entirely on open-source and free software. The new platform improved accessibility, security, and administrative efficiency while enhancing the overall quality of the student learning experience.

Survey results confirmed that the implemented solutions were considered intuitive and valuable by the vast majority of users. The project demonstrates that comprehensive infrastructure reform in academia can be effectively achieved using freely available technologies and limited resources, providing a practical and replicable model for other institutions.

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