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Enhancing Cybersecurity Education through Cloud Computing

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ABSTRACT

CONTEXT

Cybersecurity education faces the challenge of providing hands-on practical experiences to students while ensuring the security and integrity of educational environments. Traditional lab setups often lack scalability, accessibility, and cost-effectiveness. Cloud-based solutions, such as Azure Lab Services (ALS), offer a promising alternative by providing virtualised lab environments that can be easily accessed and managed remotely.

PURPOSE OR GOAL

This paper explores the implementation of a Virtual Lab Platform (VLP) based on cloud-computing for cybersecurity education to address the challenges of providing practical, hands-on learning experiences to students. The study aims to investigate the effectiveness of the VLP in improving student engagement and experience, enhancing accessibility, and reducing the administrative burden on educators in delivering practical learning activities.

APPROACH OR METHODOLOGY/METHODS

The study employs a mixed-methods approach to investigate the effectiveness of using the VLP for delivering practical cybersecurity learning activities. This includes quantitative analysis of data from end-of-semester survey on the VLP's use for practical activities and qualitative examination of student feedback. The analysis also compares student engagement in lab activities before and after implementation of the VLP for teaching computer lab classes in Introduction to Cyber Security unit at the University of Canberra.

ACTUAL OR ANTICIPATED OUTCOMES

Survey results show that using the VLP for practical cybersecurity activities significantly enhances learning experiences and increases accessibility to lab resources. Analysis of student engagement data in practical activities confirms the VLP's effectiveness as a scalable and accessible solution for cybersecurity education. Positive student feedback further underscores the platform's convenience, flexibility, and reliability for teaching computer lab activities.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The findings of this study contribute to the growing body of literature on cloud-based solutions for cybersecurity education. The implementation of a VLP significantly enhances the quality and accessibility of practical learning experiences for cybersecurity students, paving the way for future advancements in cloud-based education environments.

KEYWORDS

Cybersecurity Education, Cloud Computing, Hands-on Learning.

Introduction

As the higher education landscape shifts into online learning, cybersecurity education faces the challenge of providing hands-on practical experiences to students while ensuring the security and integrity of educational environments. Traditional lab setups often lack scalability, accessibility, and cost-effectiveness (Xu et al., 2013). Cloud-based solutions, such as ALS, offer a promising alternative by providing virtualised lab environments that can be easily accessed and managed remotely. This paper explores the implementation of a VLP for cybersecurity education to address these challenges and improve student learning outcomes.

Cloud computing's potential to revolutionise education has been well-documented. Researchers have highlighted its ability to transform traditional educational models by enhancing resource sharing, collaboration, and accessibility (Masud & Huang, 2012; Pardeshi, 2014). Specifically, cloud-based virtual laboratories, such as those described by Xu et al. (2013), provide scalable and accessible environments for network security education, which are essential for comprehensive learning in cybersecurity.

Implementing cloud-based solutions in cybersecurity education addresses several critical challenges. Traditional labs necessitate significant investment in hardware, software, and ongoing maintenance (Alharthi et al., 2015). In contrast, cloud-based labs offer cost-effective, on-demand access to resources, enabling institutions to provide cutting-edge educational tools without the associated infrastructure acquisition and maintenance costs (Kabiri & Wannous, 2017). Furthermore, cloud solutions can mitigate security risks by isolating practical cybersecurity exercises from the university's corporate network, thereby protecting institutional data and systems (Ali, 2022).

Studies have shown that cloud computing significantly enhances collaborative learning and resource sharing, leading to improved educational outcomes (Hu et al., 2018; Gercek & Saleem, 2014). For instance, Hu et al. (2018) demonstrated that collaborative learning in cloud-based virtual computer labs significantly improved student engagement and performance. Similarly, Gercek and Saleem (2014) found that applying cloud computing technology in academic computing labs increased resource availability and flexibility.

The VLP, a cloud-based solution, offers a practical approach to address the limitations of traditional cybersecurity labs. By providing a consistent, reliable and uniform lab environment that can be accessed from anywhere, the platform ensures a uniform learning experience for students in online, mixed, and on-campus deliveries. This paper explores the implementation of a VLP for cybersecurity education in Introduction to Cyber Security unit at University of Canberra, aiming to enhance student experience, improve accessibility, reduce administrative burdens on educators, and mitigate security risks on corporate network.

The study employs a mixed-methods approach to investigate the effectiveness of the VLP for delivering practical cybersecurity learning activities. This includes quantitative analysis of end-of-semester survey data on the VLP’s use for practical activities and qualitative examination of student feedback. The analysis focuses on comparing student engagement and experiences before and after the VLP’s implementation for teaching computer lab classes.

Virtual Lab Platform using Cloud Computing

Overview of Azure Lab Services

Microsoft’s ALS is a cloud-based platform that enables the rapid setup and management of virtual lab environments, making it an ideal solution for educational institutions and training programs. It automates the provisioning, scaling, and management of lab infrastructure, providing a user-friendly experience that significantly reduces the need for technical expertise and resource allocation. This fully managed service allows educators to create and manage virtual labs efficiently, leveraging cloud computing's scalability and flexibility.

ALS architecture, as shown in Figure 1 below, offers a versatile range of use cases, including the creation of virtual classrooms, research labs, and high-performance computing environments. By utilising preconfigured or custom virtual machine images from the Azure Marketplace, lab environments can be tailored to specific academic or professional requirements, ensuring that the infrastructure aligns with the unit objectives. This flexibility extends to the setup and modification of virtual networks, which can be customised to optimise performance and security as well as providing a uniform learning environment for instructors, tutors, and students.

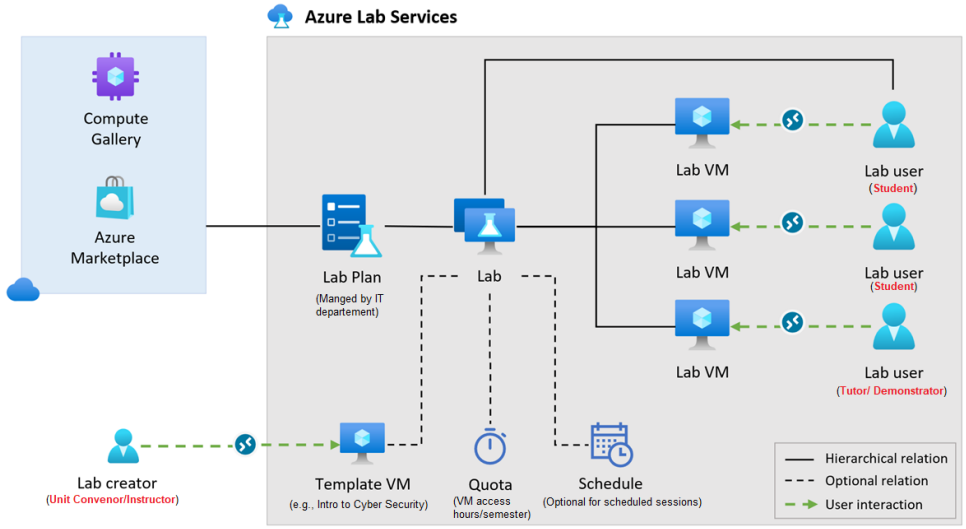

Figure 1: Conceptual diagram of ALS (Adapted from Microsoft Learn)

Teaching Cybersecurity using the VLP

The use of a cloud-based solution for teaching cybersecurity activities is particularly compelling due to its advanced networking capabilities provided in isolated environment suitable for performing “risky” practical activities. These features allow educators to create realistic, hands-on learning environments that mirror real-world cybersecurity challenges for effective cybersecurity education (Chisholm, 2015). For example, in a practical learning activity focused on vulnerability assessment in the Introduction to Cyber Security unit, we were able to deploy a deliberately broken machine with known vulnerabilities as a server within the lab environment. Students can perform vulnerability assessment on this server, as demonstrated in Figure 2, using their dedicated Azure virtual machines, which are preconfigured with multiple Windows and Linux based nested VMs with tools like Nessus and Nmap, respectively.

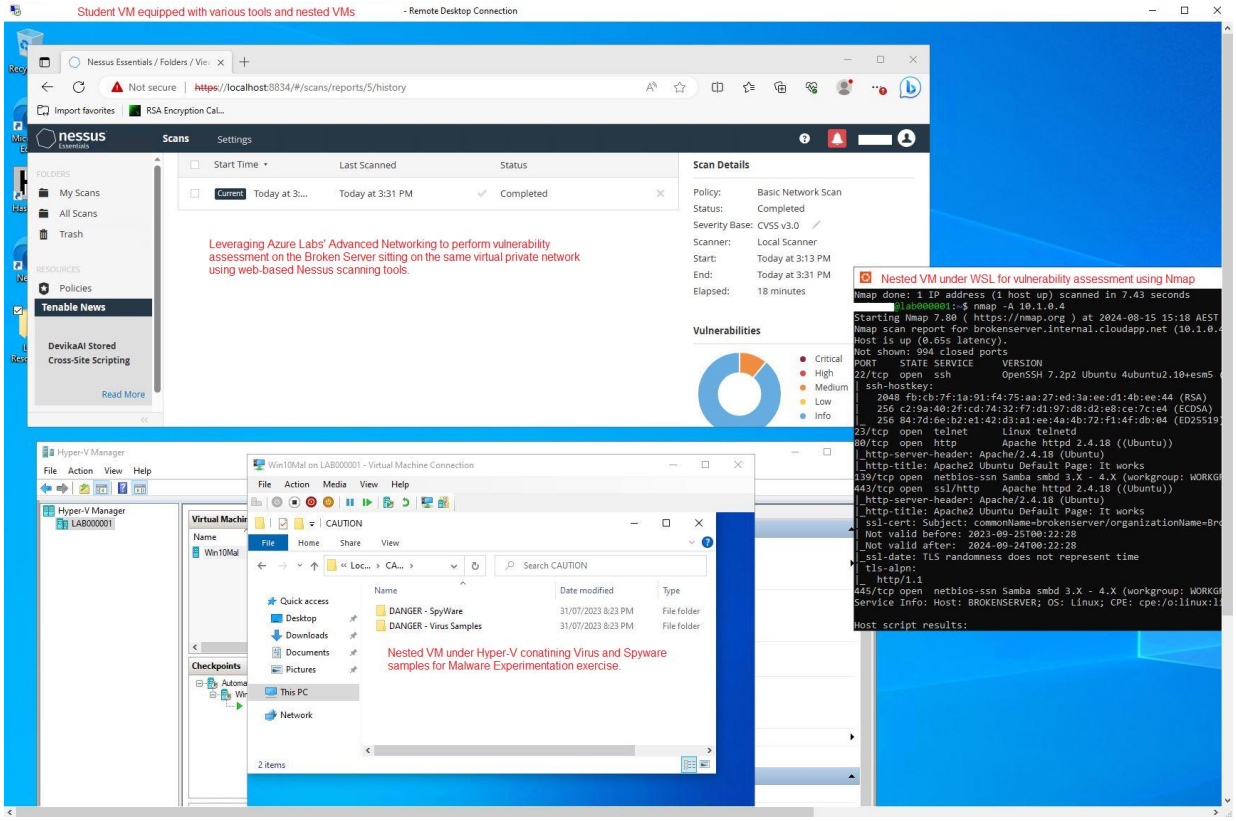

Figure 2: Snapshot of vulnerability assessment activity leveraging advanced networking feature

Through this setup, students can perform detailed vulnerability assessments by scanning various ports and analysing the threats and vulnerabilities present on the broken server. This approach not only enhances student engagement by providing a tangible, real-world problem to solve but also ensures that learners develop practical skills that are directly applicable to the field of cybersecurity (Sigholm et al., 2019; Zhu, 2018). The ability to simulate and analyse attacks in a controlled, isolated environment is crucial for effective cybersecurity education, and the VLP provides the necessary infrastructure to support such activities.

ALS also incorporates Azure Role-Based Access Control (RBAC), which is essential for managing access and maintaining security within the lab environment. By assigning specific roles and permissions to different users, institutions can ensure that students, instructors, and administrators have appropriate access to resources without compromising security or efficiency. Furthermore, all content within the cloud is encrypted using Microsoft-managed encryption keys, providing an additional layer of security that is critical in the context of cybersecurity education.

The platform's versatility, combined with its advanced networking features and robust security measures, makes it an ideal choice for educational institutions aiming to provide comprehensive, practical cybersecurity training. As cloud-based solutions continue to evolve, the integration of virtual labs in educational settings will likely become increasingly prevalent, offering students the opportunity to gain hands-on experience in a secure and flexible learning environment (Gercek, 2016).

Integration with Learning Management Systems (LMS)

By integrating the VLP into Canvas, the LMS used at University of Canberra, we were able to offer a seamless experience where virtual lab environments are directly accessible within the same interface that students and educators use for their other unit activities.

This integration allows also educators to create and manage virtual labs directly from within the Canvas platform. Once the ALS app is added to Canvas, instructors can set up lab environments as part of their unit content. These labs can be customised to meet the specific needs of the unit,

whether it’s a computer science class requiring coding environments or a cybersecurity unit involving vulnerability assessments. Students can then access their lab virtual machines (VMs) alongside their other unit materials, quizzes, and assignments within Canvas.

Student Perception of the Virtual Lab Platform

Analysis of Survey Data

A short survey was administered to students at the end of the semester to collect data on student experience using the VLP for their computer lab classes. The survey focused on several key areas: perceived ease of use, accessibility/ubiquity, consistency of service, and recommendation on adoption of the virtual lab platform. Students were also provided an opportunity to provide further comment in addition to the following four questions:

Q1. I found the virtual platform easy to use and convenient for completing computer lab activities.

Q2. The virtual platform provided me with ubiquitous access to engage with learning activities.

Q3. I had a consistent experience completing practical activities on the virtual platform, whether from home or on campus.

Q4. I would recommend use of the virtual platform for computer lab classes in my other units.

A summary of the number of enrolments in the unit offering (N), participants in the survey (n) and the corresponding response rate is given in Table 1 below. Table 1 below summarises the number of enrolments in the unit offering (N), participants in the end-of-semester survey (n) and the corresponding response rate.

Table 1: Summary of responses in end of semester survey

Number of enrolments (N)	362
Participants in the survey (n)	271
Response rate	74.8%

The data from the survey provides valuable insights into students' perceptions of the VLP, highlighting its impact on their learning experience. The survey responses reveal overwhelmingly positive feedback, with the majority of students expressing strong satisfaction with various aspects of the platform.

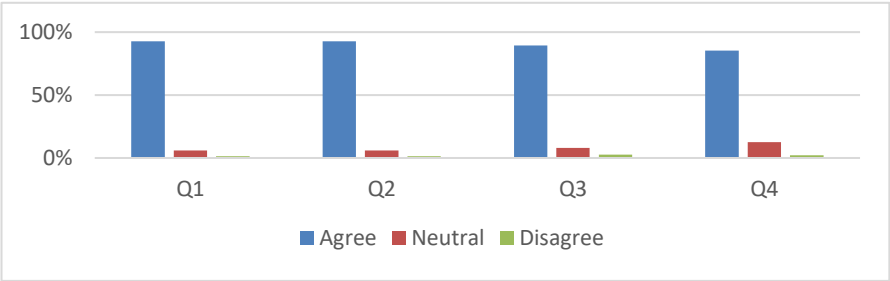

Figure 3: Student experience with the Virtual Lab Platform

One of the key findings is that 93% of students agreed that they found the virtual platform easy to use and convenient for completing computer lab activities as shown in Figure 3. This high level of agreement suggests that the platform's user interface and overall functionality met the needs of the students, making it an effective tool for facilitating their lab work.

Moreover, 93% of students agreed that the VLP provided them with ubiquitous access to engage with learning activities. This response underscores the significance of flexibility in students' learning environments. The ability to access the platform at any time and from any location allowed students to engage with the material at their own pace, which is particularly important for IT students who may have other commitments or prefer to work outside of traditional lab hours.

The 6% of students who were neutral and the 3% who disagreed may represent those who encountered technical difficulties or performance issues due to slow internet connection, though this is a minor fraction of the cohort.

In terms of consistency, 89% of students agreed that they had a consistent experience completing practical activities on the VLP, whether from home or on campus. This is a critical finding as it indicates that the platform was mostly reliable and provided a uniform experience regardless of the students' location. The 8% of students who were neutral and the 3% who disagreed might have experienced variability in their internet connectivity or encountered isolated issues with completing the lab activities. However, the overall positive response suggests that the platform successfully bridged the gap between on-campus and remote learning environments.

Finally, 85% of students agreed that they would recommend the use of the virtual lab for computer lab classes in other units. This indicates a strong endorsement from the student body for widespread adoption of the VLP for computer lab classes. The 13% who were neutral and the 2% who disagreed may have reservations about the platform's applicability to other subjects or simply preferred the traditional lab environment. Nonetheless, the high level of agreement demonstrates that the platform has been well-received and could be beneficial in other subjects that require computer lab activities.

Student Feedback and Additional Insights

Many students praised the platform for its convenience, flexibility, and ease of use. Some students highlighted the platform's role in allowing them to balance their studies with other responsibilities, while others appreciated the ability to revisit lab activities outside of scheduled class times.

Azure Labs making it easier to learn.

Azure labs service provided a great environment to experiment with unit content - would be great to see it across other units.

Usually, I am not a big fan of lab activities, however, Azure Labs was super easy to use, and I enjoyed all the lab activities we did.

I found that Azure Labs was a good choice for a virtual box experience, as it was quite easy to navigate, and it performed well not only on the school desktops but also on my laptop, which made it easy for me to complete any unfinished lab work or just mess around with in my free time.

It was very good experience using Azure. It is available remotely and perhaps can be used in many professional works.

I really enjoyed using Azure Labs. As someone who uses macOS and did not have consistent availability to Microsoft, I find this tool very good.

I had a great experience with the Azure lab, which was my first encounter with a cloud platform.

My experience with Azure Labs was enlightening. The activities were fun, and I learnt a lot from this unit. Thank you.

Azure labs is very easy to use and setup, and I like how it can be access from anywhere which is its strongest point. The flexibility Azure labs offer makes this unit very easy to handle.

I strongly agree that Azure is a great choice for using virtual machine as Azure VMs are highly reliable and offer a 99.9% uptime as well as it offers a variety of security features to protect users' data.

Azure labs made it so easy to access lab resources as it can be accessed via the web which helped for engaging with activities from home.

I find Azure labs perfect for student to use, I can access from anywhere, also I don't need to install virtual machine on my laptop, just using the remote controller app, I can access to virtual machine on the cloud already. I find it is very useful for me.

However, a few students mentioned challenges related to occasional technical issues, such as the VLP taking longer to start, or unstable connections as captured by the following student comments:

The virtual machine is sometimes unstable and hard to connect.

To get started, Azur takes a little more time than expected, I suggest the team look at it for faster service.

Overall, it was very easy and simple to use however the only downside that I had with it was that sometimes it was very slow to boot.

Azure Labs was great, less clunky than virtual box and I would definitely recommend. The only downside was the time it took to start the VM, but that's a minor issue. Once it started, it was a breeze to navigate through. Loved working through the labs.

These concerns highlight areas for potential improvement, such as optimising the platform's performance and ensuring robust technical support. Educators can enhance performance by selecting VMs with higher specifications during lab setup, tailored to the practical activities of the unit. However, it's important to note that performance issues can also stem from the quality of the end user's internet connection, which educators and IT managers cannot control if students are using home Wi-Fi.

Overall, the data and feedback indicate that the VLP has been a highly effective tool for enhancing the student learning experience and engagement in computer lab activities. The overwhelmingly positive perception of the platform, coupled with constructive feedback, provides a strong foundation for the continued use and development of virtual lab environments for teaching computer lab classes in IT and Engineering curricula.

Impact on Student Engagement

The data on student engagement in computer lab activities before and after implementing the virtual lab platform shows its positive impact on student participation. Student engagement in computer lab activities was measured by marks awarded for participation and completion of weekly lab activities. There was a total of 10 marked computer lab activities during each teaching period.

As shown in Figure 4, before the implementation of the VLP, only 40% of students were fully engaged in all 10 lab activities during the semester. This figure increased significantly to 80% after the introduction of VLP. This substantial rise suggests that the VLP has effectively provided students with greater flexibility, enabling them to participate consistently in all scheduled lab activities.

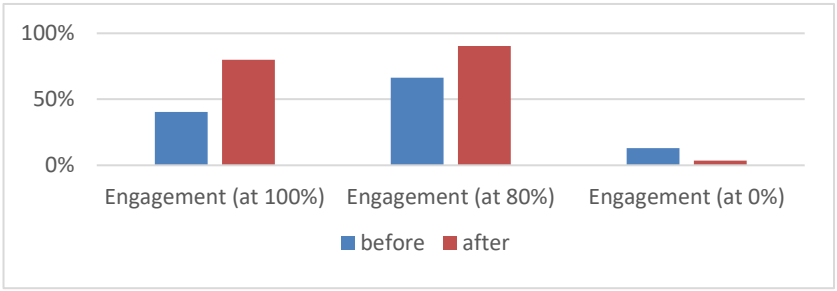

Figure 4: Comparison of student engagement with practical learning activities

Moreover, student engagement in at least 7 lab activities also saw a notable increase from 66% to 90% after the introduction of the VLP. This indicates that the platform has made it possible for those students who may have missed lab sessions due to extenuating circumstances to remain engaged throughout the semester. The ability to attend online lab sessions and complete lab activities remotely contributed to this improvement.

The decrease in the number of students who did not engage in any lab activities from 13% to just 4% after the introduction of the VLP further underscores the platform's effectiveness in improving student engagement with learning activities. The reduction in non-engagement can be attributed to the removal of barriers such as the need to physically attend labs on campus, which may have previously discouraged or prevented some students from engaging. The VLP has thus played a critical role in making lab activities more accessible and accommodating to a wider range of students.

Conclusion

The findings of this study underscore the significant benefits of using a VLP for cybersecurity education. Cloud-based labs enhance student engagement, improve learning outcomes, and increase accessibility to educational resources. They also offer a cost-effective solution for institutions and address security concerns associated with practical cybersecurity exercises. The successful implementation of a VLP paves the way for future advancements in cloud-based education environments, contributing to the growing body of literature on innovative educational solutions.

Future research will investigate the effectiveness of cloud-based labs in delivering practical classes for fully online programs and the considerations needed to ensure these virtual environments provide learning experiences comparable to those in mixed and on-campus delivery modes.

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