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Networks Security Lab Support: A Case Study for Problems Facing Distance Education Programs

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Abstract

Creating, supporting, and administering online laboratory experiences has become important in the pedagogy of learning environments for online networking courses. A case study is presented for an online laboratory environment used in a fundamental network security course that covers the competencies of the CompTIA Security+ certification. The online lab environment consists of virtual machines connected in an isolated virtual network managed by VMware vCloud Director. This online laboratory environment is used for both online and face-to-face lecture courses offered during the same semester. The emphasis in this case study is the support provided to the students and the continuous improvement cycle used by instructors to improve the educational experience. Challenges facing the students include both problems with the technical aspects of the virtual environment (e.g. corrupted virtual machine files, virtual environment slowdown due to heavy loads, or excess resource consumption by misconfigured virtual machines), and questions about the academic material being taught (e.g. why an error message is being given after a specific instruction). Several methods are used to provide support to the students including discussion boards, online video conferencing, announcements and instructions provided via the learning management system, individual emails, phone calls, and face-to-face meetings. Each of these methods of communication will be examined and feedback from students via a survey will be presented. The challenges of keeping laboratory exercises working and up-to-date will be examined and a list of suggested best practices for providing online support for students will be given.

Keywords: Distance Education, Network, Security, Lab Support.

Introduction

Distance education (DE) is becoming a more popular education model. Busy professionals that spend most of their day time in their jobs are highly attracted to DE programs. The fact that this programs resources are available on a 24/7 basis and students can access these resources to study and finish their assignments anytime and anywhere make them extremely attractive. Junior and senior level courses can be taken as DE courses in the program. A well-established DE environment infrastructure is needed to support the instruction of these courses. This environment hosts virtual labs for courses that require this kind of instructional resource. Any virtual lab environment requires both an academic and technical system to support its operations.

With the increasing demand on distance education (DE) and the availability of more online degrees, courses offered online for DE students need a continuous quality assessment. Same course materials are offered to both face-to-face (F2F) and DE students, however, the methods of delivering these materials to F2F sections and DE sections of the same course are totally different. The way of assessing the different experience for both types of students was examined by authors in (Almatrafi, Khondkar, & Aditya, 2015)[1]. The results in this study shows that there is a correlation between the students' use of the learning management system (LMS), in this case Blackboard, and their success in the course. The authors in (Saliah-Hassane, et al., 2011) show their proposed virtual lab environment based on the concept of software as service[4]. The authors aim to eliminate the need for university acquisition of facilities and local laboratories to host, manage and maintain the environment. A comparison between different virtualization environments is discussed by authors in (Li, Jones, & Augustus, 2011)[2]. An evaluation for system availability and usability was conducted and students show positive feedback about the system performance. Other issues like centralized versus decentralized approaches and the system usage analysis were addressed in the study.

Although most of the previous studies show a students' preference toward using virtualized lab environments, there is still a need to evaluate the performance of these virtualized lab environments and their effectiveness on delivering the proper learning experience to DE students. A three-dimensional evaluation model is proposed by authors in (May, Terkowsky, & Ortelt, 2016) to assess a material properties lab[3]. The three perspectives evaluated by the proposed model are the system, course, and individual perspectives. Results shows that the students appreciate the opportunity to perform the labs online.

The networks security lab discussed in this paper is used to support the instructions of a fundamental network security course offered to sophomore students. The course is used to introduce computer networks and information security principles, devices, and applications. The course is designed to meet the needs of students who want to master practical network and computer security. This course, the textbook, and associated lab exercises also provide a comprehensive guide for any student looking to take the CompTIA® Security+ Certification Exam. The following specific topic coverage includes an introduction to Security, overviews of system threats and Risks, protecting systems, network vulnerabilities and attacks, and network defenses. The main learning objectives and expected outcomes of the course are monitored and evaluated using quizzes, labs, exams, required discussion boards threads and posts.

The technical concepts taught in this course include many subjects such as: what is information security, who are attackers, the different threats facing information systems including malware and social engineering attacks, application and network-based attacks. The different ways to secure hosts, application and data are also presented in the course in addition to basic and advanced cryptography, network security fundamentals and administering a secure network. Other technical concepts addressed in this course include wireless network security, mobile devices security access control fundamentals, authentication and account management. Finally, concepts of business continuity, risk mitigation and vulnerability assessment are additionally presented to the students. The course is divided into two sections; course lectures and laboratory exercises. The students show a high interest in admission to the course and they usually end the semester with a good awareness about these areas in information technology. The enthusiasm provided in this course to the students is one of the factors that increases the number of students willing to purse a specialization in information security during their junior and senior years.

This paper will discuss the continuous improvement of lab environment to provide a successful learning experience to students. The continuous improvement cycle investigates the problems, addresses the solutions and proposes the practical implementation for the updates required to both the academic and the technical support systems. A case study is used to investigate the different issues that may hinder the educational process. The challenges facing the students and their experience using the lab are evaluated using the lab discussion board that was set up in Blackboard to supply a place for students to post questions relating to the lab exercises for the network security fundamentals course taught at East Carolina University (ECU). The students' feed-back through the discussion boards are analyzed to investigate the students' educational experience and to identify the possible improvements that can be applied to the virtual lab environment to achieve the course objectives. A survey is conducted to measure the students' satisfaction level, their ability to learn from the lab exercises, the quality of the lab materials, and availability of technical resources. The analysis of the discussion board threads shows that it is a helpful tool in terms of technical support to students; however, more interactive support using visual tools like virtual online web conference lab sessions provides a better experience to students. The study shows that a thorough evaluation for the technical environment resources, lab materials (questions templates and manual), operating systems, software applications and programs are required at least every two years. Due to the continuous advancement of technology, the different resources, systems and tools used to implement the network security lab environment must be regularly reviewed to ensure that the lab environment reflects the current technology used in industry.

The rest of the paper is organized as follows. In section two a background about the lab model including lab structure, components, lab support system and the tools used are presented. Section three demonstrates the evaluation methodology. Analysis of the student survey, and feed-back regarding their lab experience during the course and the lessons learned from this analysis are established in section four. Finally, in section five the study conclusions are drawn.

Lab Model

In this section the lab architecture, lab manual exercises, instructions and questions template will be presented to show the structure of the lab of the case study.

Lab Architecture

The lab consists of four main components that are explained in details in this section. The main components of the lab are:

1. Lab manual providing the lab steps.
2. Lab structure including the core system, the clients, and the virtualized environment
3. Lab questions templates for testing the students' abilities to understand the labs
4. Lab support system used to help students as they perform the labs.

Lab Manual

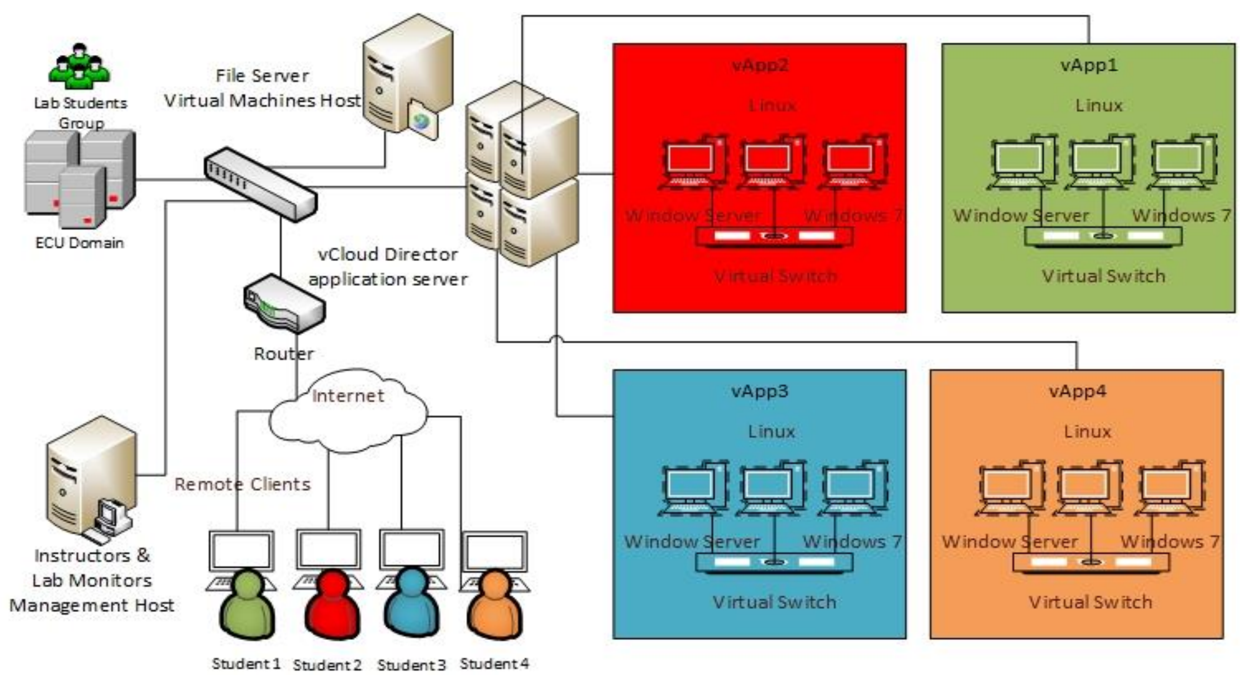
The purpose of this lab is to provide a hands-on learning environment to the sophomore students as a part of their network security fundamentals course. The course discusses the fundamentals of security in different areas such as malware, social engineering, cryptography, access control, wireless and business continuity, etc. The students learn about the concepts related to these security areas during the course lectures. A lab is dedicated to each of these areas to allow the student to gain hands-on experience. Using the lab manual, each student is guided through number of steps to explore the security threats, attacks, defense mechanisms, and procedures related to one of the network security areas covered in the course. The lab manual is divided into several lab exercises with each exercise identifying a few objectives. By the end of each exercise the student should be able to understand a new security concepts related to multiple operating systems operating in a local area network (LAN) environment.

Lab Structure

To provide the students with the necessary resources to perform the required labs in the lab manual, a virtual lab environment is set in place. Figure 1: Lab Structure shows the structure of the lab environment used at East Carolina University to support the network security fundamentals course.

The lab system infrastructure is built upon virtualization of the services needed by the students to perform the labs. The following components are used to build the virtualized lab environment:

Figure 1: Lab Structure

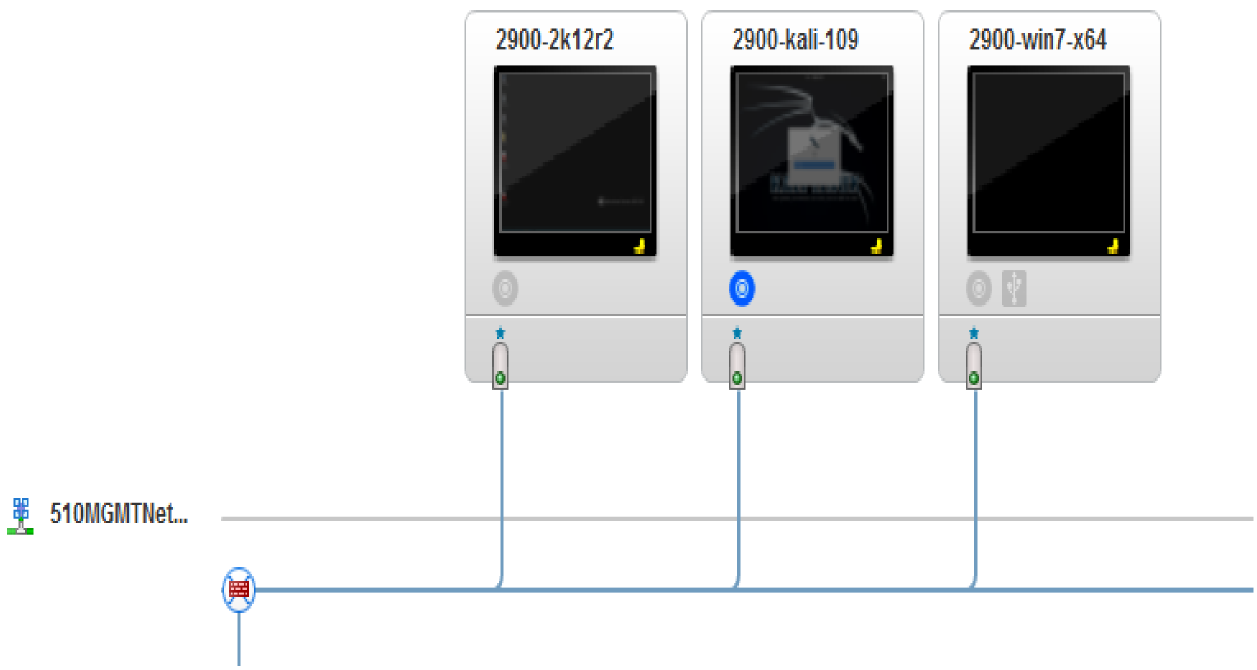


- Hardware: the system is hosted over different HP blades that provide the processing, memory and disk space resources for the virtual environment.
- Centralized Core System:
    - VMware vCloud Director: The VMware Cloud Director Application Server is used to host multiple Virtual Applications (vApps). Each vApp is dedicated to one of the students. The client licenses of the VMware vCloud Director are available for students' use under the VMware Academic program (VMAP) agreement.

- Domain Controller system: ECU domain controller is used to authenticate the students to the vCloud director system and allow the vCloud admin to grant the adequate privileges on the vApps to the users according to their roles (administrators, instructors, lab monitors, students).
- File Server: the file server allows the hosting of the students' and maintenance team Virtual machines (VM) and the control of the disk resources to vCloud director.

- Distributed Systems:
  - Student remote Clients: the remote clients are used by the students to access the cloud web-based lab environment. Each student uses the client to access his/her vApp to perform the lab exercises and finish the answers for the lab questions template.
  - Instructors and lab monitors management: the instructors and lab monitors use the management hosts to control the resources on virtual environment supported to the students, create master vApps for cloning purposes (e.g. after each lab), produce vApp replicas to students with failed vApps and provide online/offline remote assistance to students on their vApps.

Figure 2: Lab vApp Environment



- Virtual lab Environments System:
  - Figure 2: Lab vApp Environment shows an example of the Lab vApp environment used by each student and consist of three VMs:
    - Windows Server VM
    - Windows Seven VM
    - Kali Linux VM
  - Virtual switch connecting the VMs to create a LAN.

- Operating systems and tools required to boot the VMs and perform the labs.

Since this is lab exercises are used to aid the instructions of a fundamental network security course, only basic security systems with their advanced features are used to introduce concepts like access control, windows firewall, primitive encryption techniques, storage availability and network traffic scanners. Advanced network threats detection devices like intrusion detection and prevention systems are not included in the scope of this course.

Lab Questions Templates

In addition to the lab manual that walk the students through the different lab steps, a lab questions template is prepared by the instructors to test the students' ability to follow the instructions and produce the required outputs from the lab. Each of the 5 templates group multiple labs together from the 13 required lab exercises. Students are required to answer the questions in the templates and submit the completed templates as assignments to the learning management system.

During each lab, students are asked to take snapshots or answer questions after finishing several lab steps. The student answers are then evaluated and graded manually to provide students with feed-back regarding their answers to the questions in the lab templates.

Samples of lab questions:

The following are samples of the lab questions that students are required to answer and submit for their lab work:

- Sample question from Lab 1: Show if sigcheck is digitally signed or not.
- Sample question from Lab2: Show the security log failure event similar to figure 4-9 in the lab manual.
- Sample question from Lab 3: Show the hosthash file with both hashes from the sha256deep command.
- Sample question from Lab 4: Show the new minimum password length in the Group Policy Management Editor.
- Sample question from Lab 5: Take a screenshot of the Zenmap window after the scan has completed

Lab Support System

In order to support the students, a support system is set in place to help the students perform the labs. Both face-to-face (F2F) and DE students are supported through asynchronous discussion boards in Blackboard and synchronous video conferences using Saba Meeting. However only F2F students are supported through F2F lab help sessions.

Lab sessions & Saba meetings

Each week in the semester, two lab help sessions are offered in the evenings. These sessions are available both in a face-to-face format and an online web conference format. The instructor or lab monitor leading the help session uses an open classroom, but also logs into the university supported Saba Meeting web conferencing system. Thus, both face-to-face students and online students can join the discussion and ask questions. Students in the face-to-face lecture also have the option of using the web conferencing system to attend the help sessions. Lab monitors are undergraduate student workers paid by the department to provide laboratory monitoring, laboratory support, and tutoring for undergraduate students. Students attending the sessions are able to interact directly with instructors and lab monitors to discuss issues and ask questions related to their lab work progress. Each session runs for 3 hours and questions are addressed to resolve any student issues.

Discussion Boards

Due to time limitations for some F2F and DE students, a second support option through asynchronous discussion boards is also provided. A 24/7 discussion board is available for students to log their problems and seek assistance. The discussion board is a collaborative system provided by the Blackboard LMS and is monitored by the instructors and the lab monitors to ensure timely feedback and the correctness of the information provided by peers. Students are able to interact with each other, instructors, and lab monitors using the discussion threads. Students are instructed to first search the discussion board when they experience a problem with the lab because the same problem and its solution may already be posted.

Discussion board thread samples:
This section shows some samples of the discussion board threads that students' use to discuss any issues or seek support from the instructors or their class mates.

- Lab Access Discussion Forum: Ethernet Cable Unplugged in VM.
- Lab A Discussion Forum: Lab 2.1 Step 3 - Problems Downloading eicar.com File.
- Lab B Discussion Forum: Lab 6.3 - Can't generate certs.
- Lab C Discussion Forum: Lab 7.2 - WinRM Prevents Web Server IIS.
- Lab D Discussion Forum: Lab 11.3 - Should we change security permissions.
- Lab E Discussion Forum: Lab 13.3 - VM Player causes VM to freeze.

Lab Evaluation and Analysis

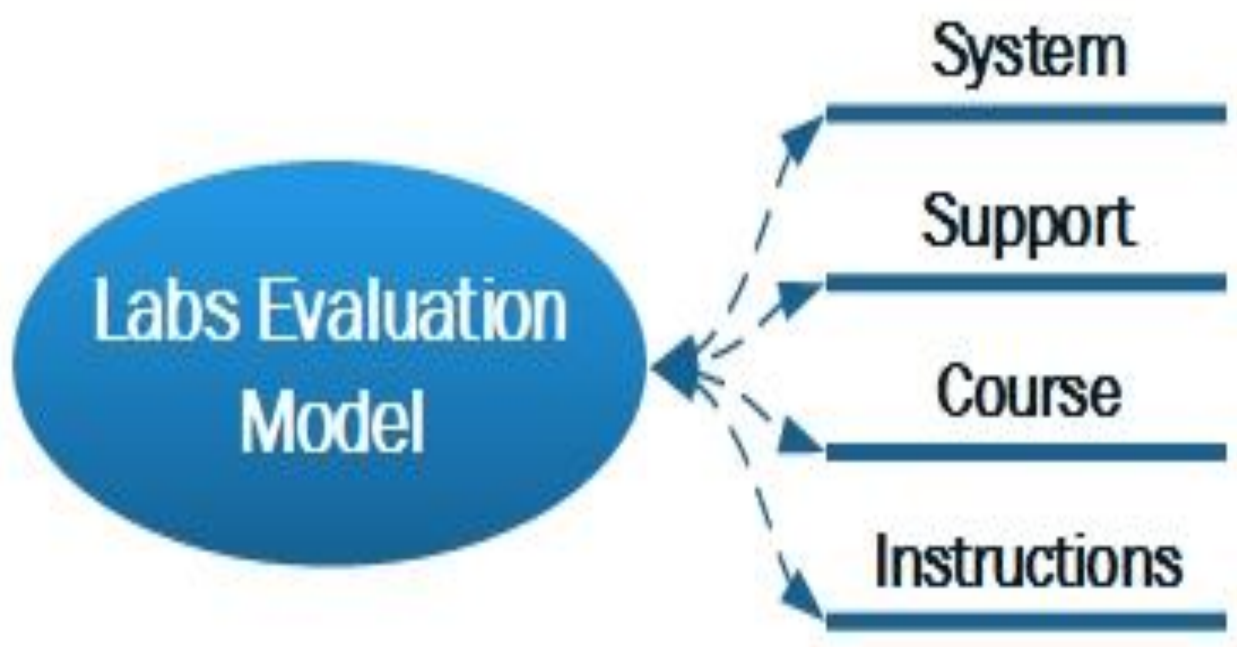
The lab evaluation methodology and the different lab environment challenges are discussed in this section.

Evaluation Methodology & Analysis

In order to evaluate the performance of the lab, a four aspects evaluation model is proposed to study the different challenges confronted by the students during performing the labs.

The evaluation model in this study is summarized in Figure 3: Evaluation Model. The four aspects addressing the lab challenges are system, support, course, and instructions.   The system refers to the infrastructure: the physical servers, the operating systems, the network connectivity, and the applications. The support refers to the avenues for students to receive help when they had problems. The course refers to the ability of the students to achieve the course outcomes. And the instructions refer to the instructional materials initially provided to the students.

Figure 3: Evaluation Model



Lab Environment Challenges

In order to evaluate the effectiveness of the labs, student satisfaction and clarity of the lab materials, a student survey is conducted. The survey consists of twenty-six question aimed at evaluating these four areas. For the questions that used a Likert scale, the following five levels are used: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree.

System Challenges

Three challenges are investigated to identify the easiness, reliability and availability of the lab system used by the students. The following Likert scale questions are answered by the in the survey to address the system challenges:

1. Lab access to VMware vCloud Director is easy and straight forward.
2. The Lab environment in VMware vCloud Director was reliable.
3. The Lab environment in VMware vCloud Director was available when I attempted the lab exercises.

Support Challenges

The necessity for lab support and the performance of the two methods of support are investigated in this category of survey questions. The second category of survey questions tries to highlight the lab support environment by addressing the following Likert scale questions:

4. I was able to understand and finish lab A without any support.
5. I was able to understand and finish lab B without any support.
6. I was able to understand and finish lab C without any support.
7. I was able to understand and finish lab D without any support.

8. I was able to understand and finish lab E without any support.
9. Does lab support discussion board help you solve your lab issues.
10. Does Saba support sessions help you solve your lab issues.

Course Challenges

In this category benefits from finishing the labs in understanding the course contents are studied. Also the number of hours spent by the students in finishing the labs in contrast with the total number of hours dedicated to study for the course are investigated. The third category of the survey consists of the following multiple choice questions.

11. The Lab exercises helped me understand the course material. [Likert scale]
12. On average, how many total hours did you spend on each lab (A, B, C, D, E). The average is the total time spent the entire semester divided by 5. [Less than 3 hours, More than 3 but less than 5 hours, More than 5 but less than 7 hours, More than 7 but less than 9 hours, More than 9 hours].
13. On average including the lab exercises, how many total hours per month did you spend studying or working on the course? (e.g. listening to lectures, taking quizzes, reading the textbook, doing the labs, etc.). [Less than 5 hours, More than 5 but less than 10 hours, More than 10 but less than 15 hours, More than 15 but less than 20 hours, More than 20 hours].

Instructions Challenges

The last category discussed in the survey is addressing the quality of the instructions manual and the template used by the students to perform the different lab steps and return their lab work for grading. The following Likert and free form questions are answered by the students to investigate the instructions clearance:

14. The lab access instructions are clear.
15. If the lab access instructions were not clear, please explain.
16. Lab A instructions are clear.
17. If the lab A instructions were not clear, please explain.
18. Lab B instructions are clear.
19. If lab B instructions were not clear, please explain.
20. Lab C instructions are clear.
21. If lab C instructions were not clear, please explain.
22. Lab D instructions are clear.
23. If the lab D instructions were not clear, please explain.
24. Lab E instructions are clear.
25. If the lab E instructions were not clear, please explain

Discussions and Results

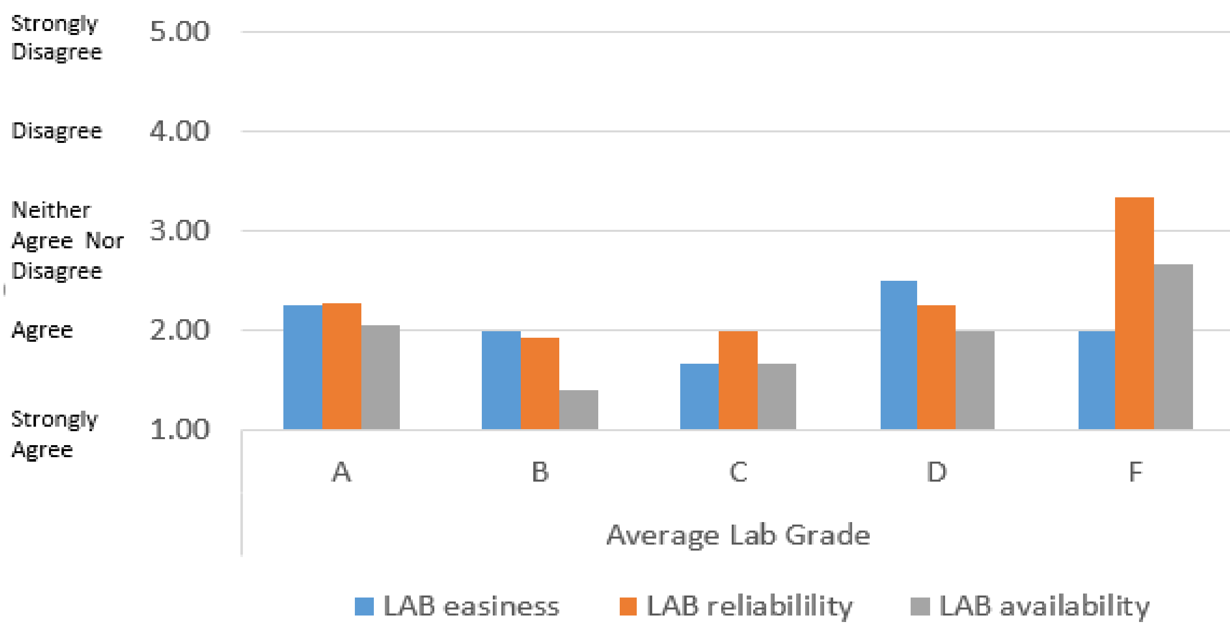
The lab discussion board threads analysis and the student survey results are presented in this section. The effectiveness of the lab is evaluated and recommendations for future and continuous improvements are suggested.

As previously mentioned, the student survey focuses on four aspects of the lab environment. The results and findings from surveying 71 students are analyzed and presented respectively.

Category 1: Lab System

The results in Figure 4: Lab system evaluation shows the response of the students regarding the easiness, reliability and availability of the lab environment. The vertical axis represents the average Likert scale value chosen. It is clear from the results that all students agreed that the lab access is easy and straight forward except for students with a "D" average lab grade that don't totally agree nor disagree on the easiness.

Figure 4: Lab system evaluation– Average of Likert scale response to questions 1 through 3

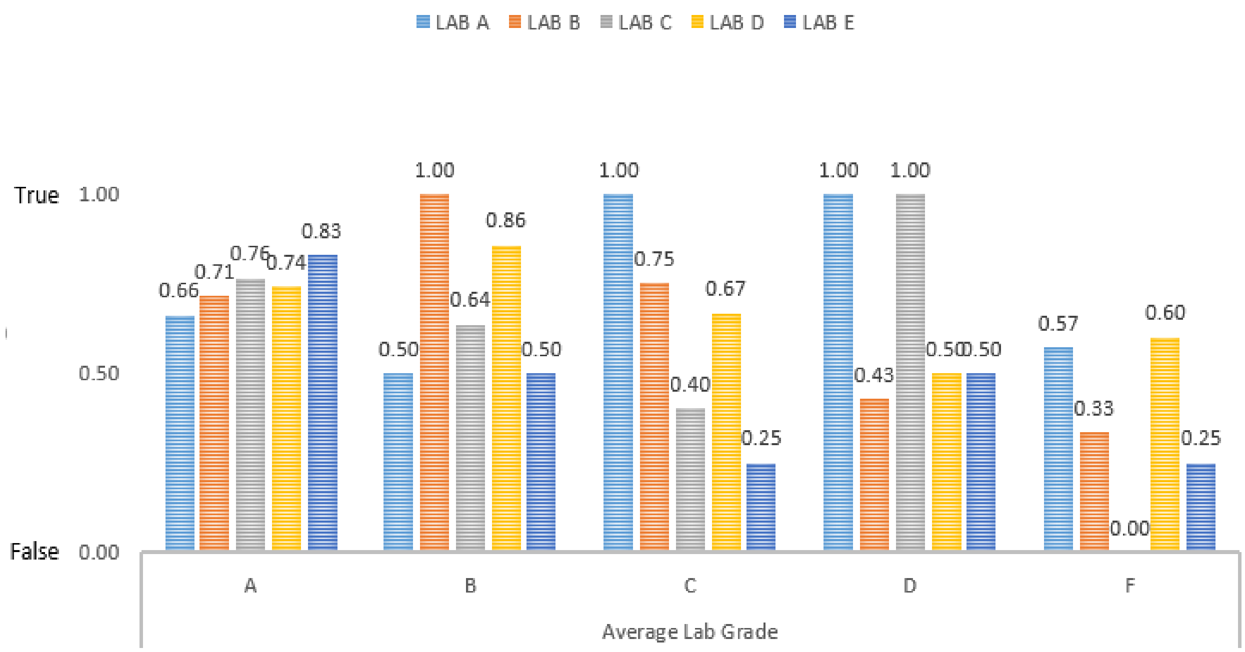


The second element evaluated in Figure 4: Lab system evaluation is the reliability of the lab environment. The results show that all students agree on the system reliability except for students with an "F" grade who show more disagreement that the lab environment was reliable. The results in Figure 4: Lab system evaluation shows also the availability of the vCloud director system. Most students agreed that the system is available when they attempt to access the system except for students with an "F" grade indicating that they neither agree nor disagree with the system availability.

In order to know if some students had unreliable systems and thus failed the labs as opposed to students trying to find excuses for failing the labs, an analysis to the number of students in each grade level of the average lab grade shows that the "F" grade group consists of 3 students only. Further reviewing the course grade for those students showed that they are 2 of them failed the course while one passed the course. Since the lab environment setup, hardware, and operation was identical for all student, the authors conclude that most probably these students are trying to find excuses for failing the labs and that the lab reliability and availability is not one of the reasons for failing the course.

In general, the students' replies infer that the vCloud director system was available, reliable, and easy to use which shows that the system is operating with high performance.

Figure 5: Support Required by Lab – Average of response to questions 4 through 8



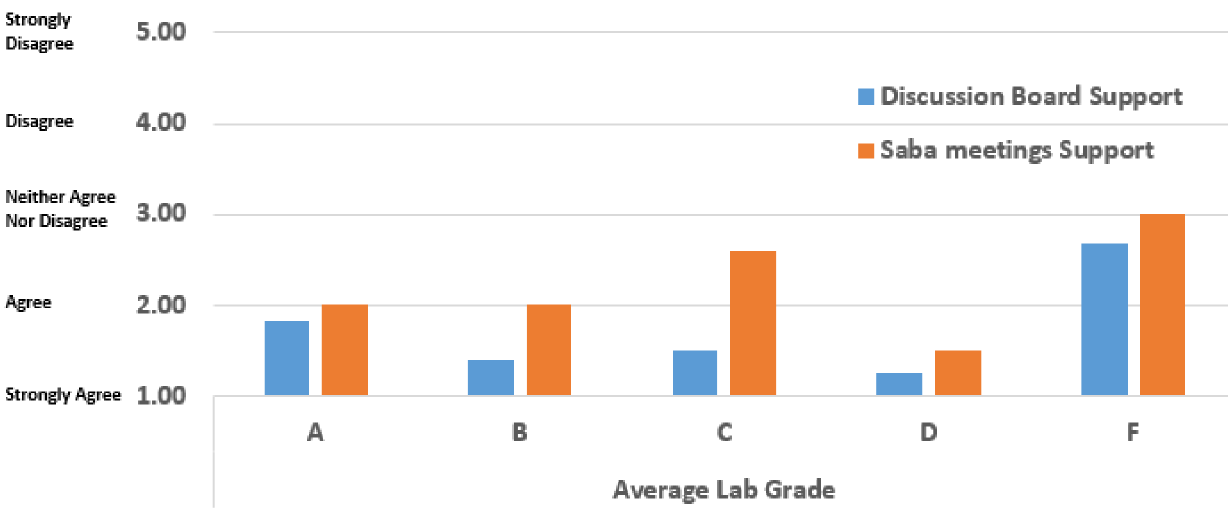
Category 2: Lab Support

The results in Figure 5: Support Required by Lab shows the need of support by students in each of the five required labs. The students' responses in each lab are categorized by their grades, results indicate that support is mostly required by all students except for students with a "F" grade that shows a requirement for support only in the lab "A" while the number of requests decline in later labs. Generally, lab "E" required the least amount of support and Lab "A" required most amount of support as expected since the students get to learn more about the lab environment, following the lab steps and representing their answers in the lab answers template as they finish more labs.

A comparison between the utilization of the two tools of support available for the lab is shown in Figure 6: Support Tools Comparison. The comparison shows that students agree on the importance of both support tools, however using the discussion board is favored over using the Saba meetings.

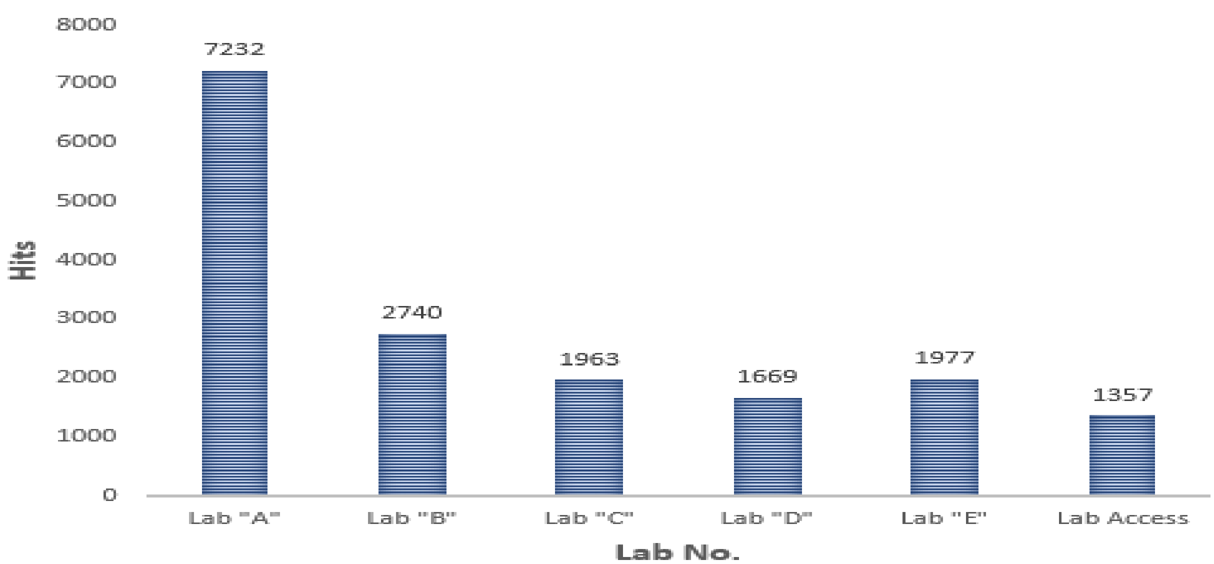
This result is aligning with the nature of the lab DE delivery method. The discussion board gives more flexibility to the students due the 24/7 availability while the optional Saba/F2F meetings are conducted for 3 hours only at fixed times twice a week. Some of the suggestions from the students include recording the Saba sessions, giving more information about the Saba meeting, and mandating the F2F weekly sessions.

Figure 6: Support Tools Comparison – Average response to Likert scale questions 9 and 10



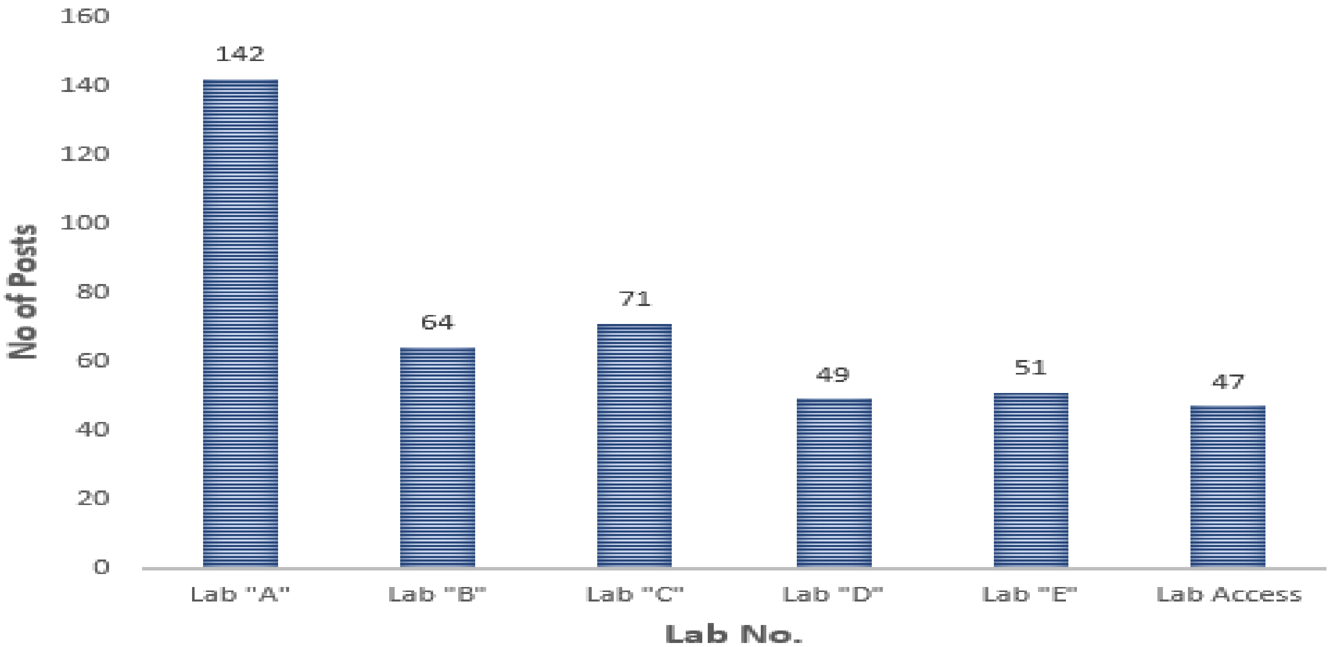
To measure the effectiveness of the lab discussion board, an analysis to the number of accesses and the number of posts is presented. The discussion board is segmented into six areas. The first area relates to accessing and using the lab environment. The other 5 areas are one for each of the 5 labs. The number of hits on the discussion board in Figure 7: Lab Discussion Board Access shows a great decrease from lab “A” to the lab “B” and decreasing trend for the rest of the labs. A hit is defined as a student accessing or submitting a single post to the discussion board. The results present the increasing demand of the students to get support with the first lab to understand the process of following the lab manual instructions, performing the lab on the VMs, reporting the lab in the answers template and submitting the lab assignment.

Figure 7: Lab Discussion Board Access



The lab discussion board posts numbers analysis is shown in **Error! Not a valid bookmark self-reference.**. The results presented follow the same scheme of the number of hits, lab “A” shows the greater post activities in one forum. However, there is an increase in the number of posts in lab “C”. A review of the posts in this section showed that this bump in the data is a result of a lack of clarity in the instructions for lab “C”. This resulted in students’ confusion and an increase in the number of posts by the students.

Figure 8: Number of Lab Discussion Board Posts

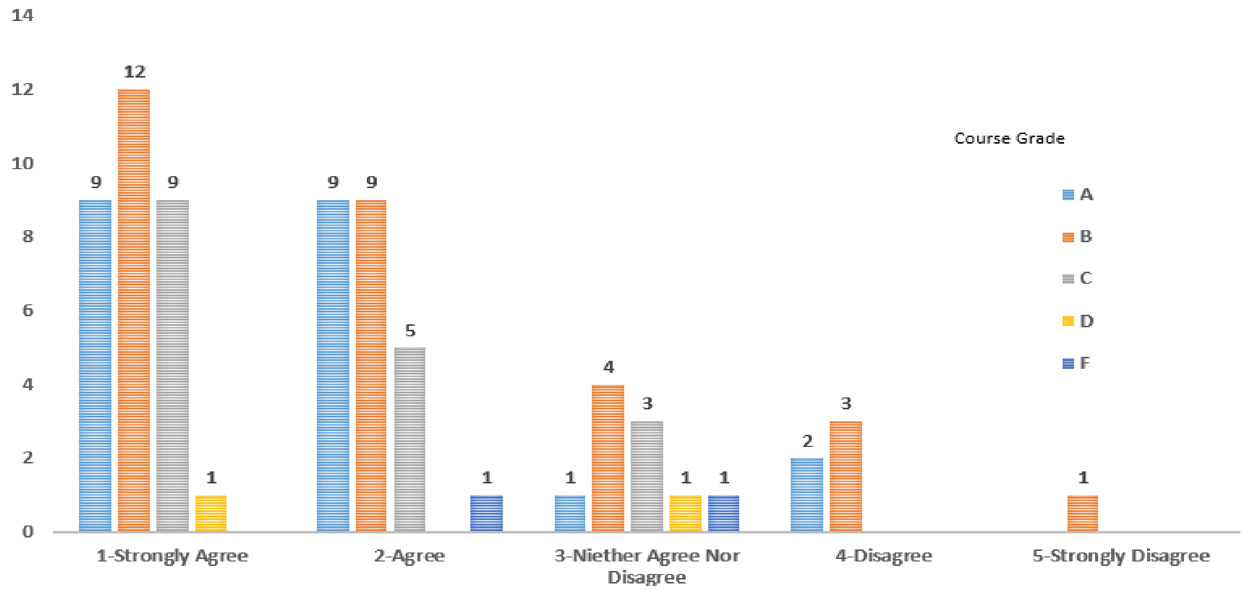


Category 3: Lab Course

The role of the lab in understanding the course materials is inspected in the survey. According to the analysis of students responses in Figure 9: Lab Role on Course Understanding– Count of Likert scale responses to question 11, the majority of the students either strongly agree or agree that the lab exercises helped them understanding the course content. About 7% of the students disagree with this opinion and they consider that the lab is disconnected from the lectures.

Suggestions from students to improve the lab role in understanding the course content include adding some discussions about the lab in the lecture time, shorten the length of the labs and distribute them on more labs, concentrate on one major concept and use appropriate tools to enforce students’ understanding. Also mandating students’ attendance in part of the lab sessions may increase the students’ participation in the lab and enforce collaboration between students during the lab sessions. However, this idea will add more time dedication for the course from DE students, but it may help the instructor to deliver important discussions that can relate the lab to the course content.

Figure 9: Lab Role on Course Understanding– Count of Likert scale responses to question 11



In **Error! Not a valid bookmark self-reference.**, an analysis for the number of hours spent by the students on each lab is presented, the majority of the responses indicate that they spend between 3 and 7 hours with the range of 3 to 5 hours being the most specified. Knowing that each lab due range from 3 to 4 weeks, the average number of hours spent per week by students' ranges from 1 to 1.5 hours weekly on lab work. Although some of the students' comments refers to shortening the labs, but the analysis shows that the average amount of time spent on the labs is reasonable.

Figure 10: No. of Hours Spent on Lab Work

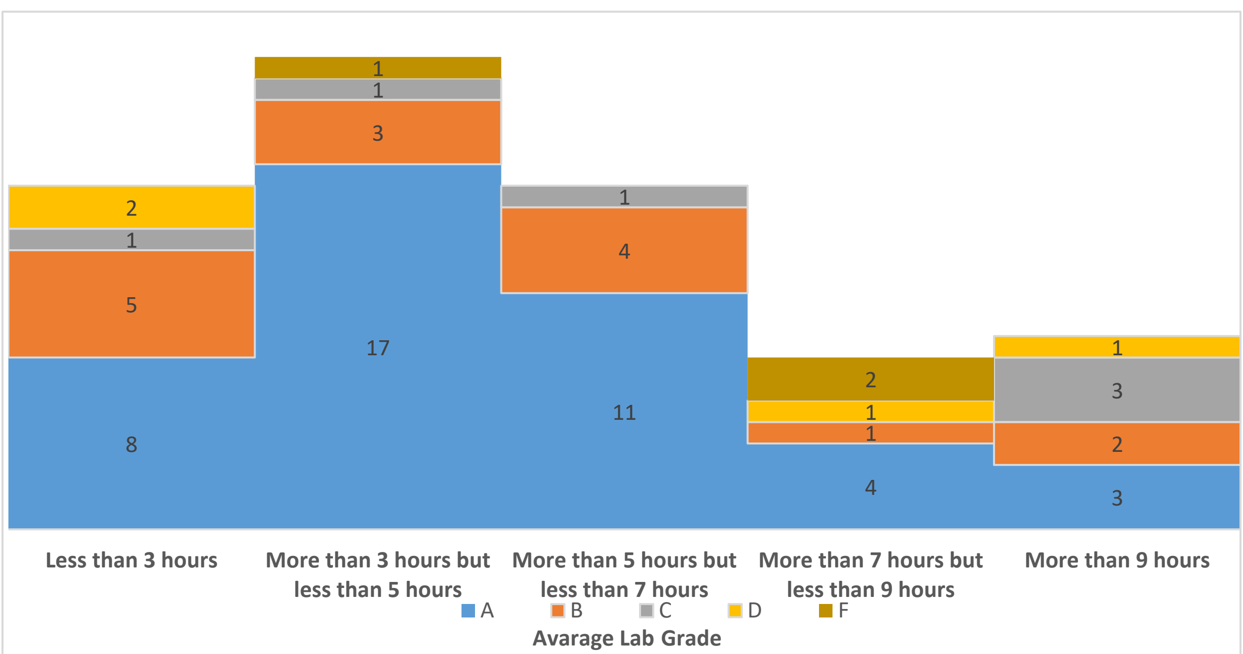
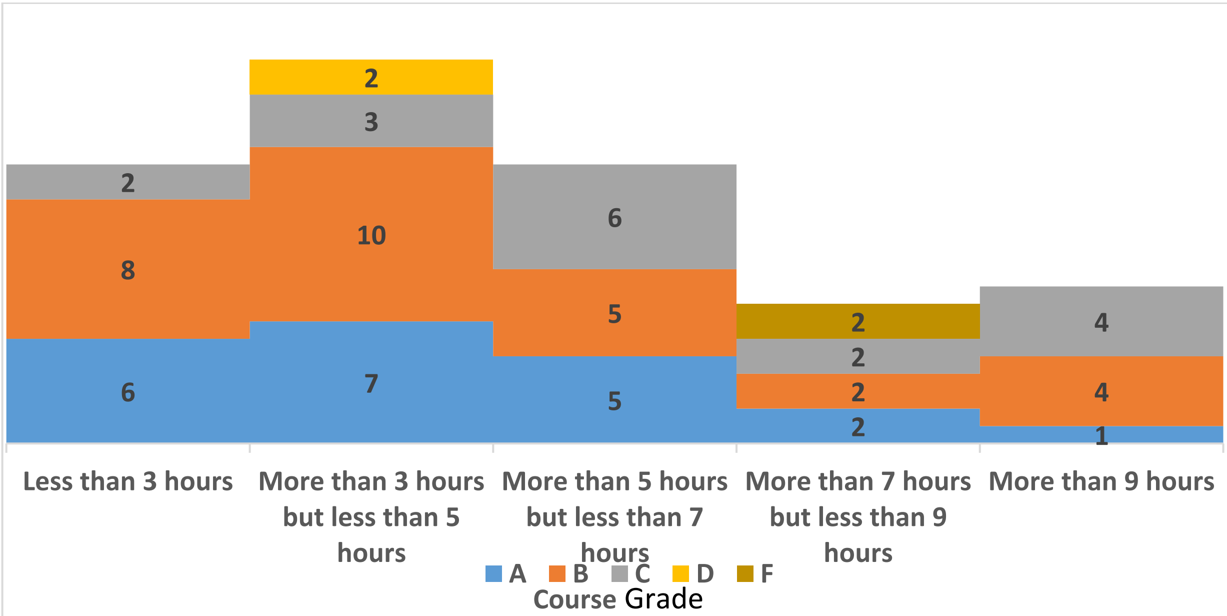
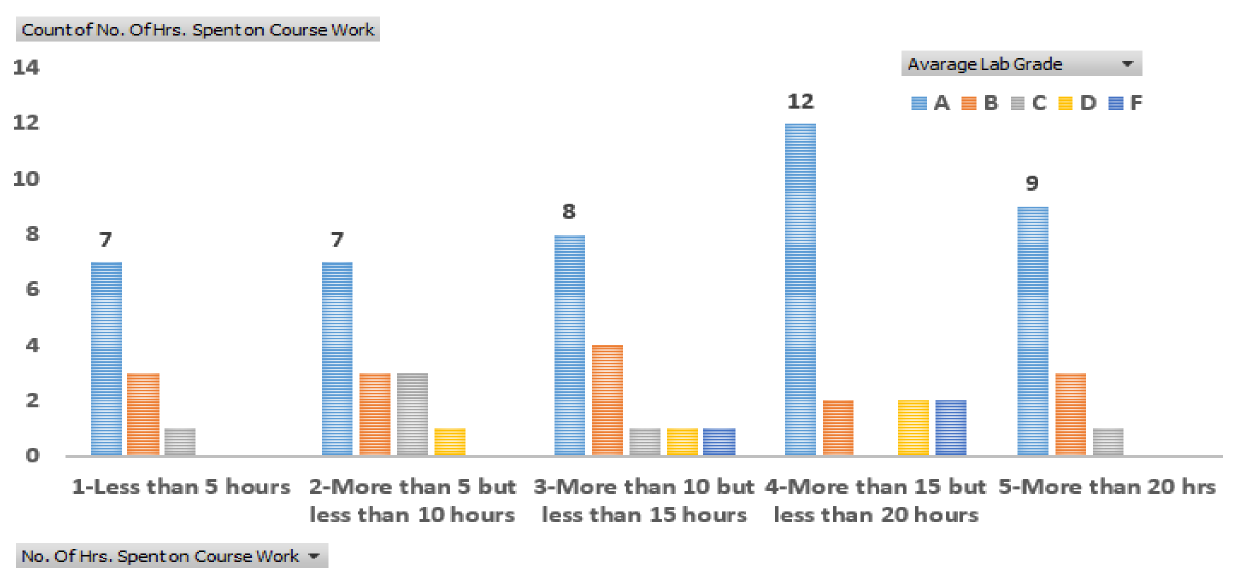


Figure 11: No. of Hour Spent on Lab Work



The number of hours spent on the lab work was also compared in Figure 11: No. of Hour Spent on Lab Work against the course grade to identify how spending more hours on the lab work affect the students overall grade. Results show that more hours spent on lab work doesn't influence the students' grade and students spend extended times on their lab work did not perform well in the whole course. A remark about this finding in future classes may be beneficial to alert students that spent extended times on finishing their labs and advise them to discuss this issue with the instructors.

Figure 12: No. of Hours Spent on Course Work



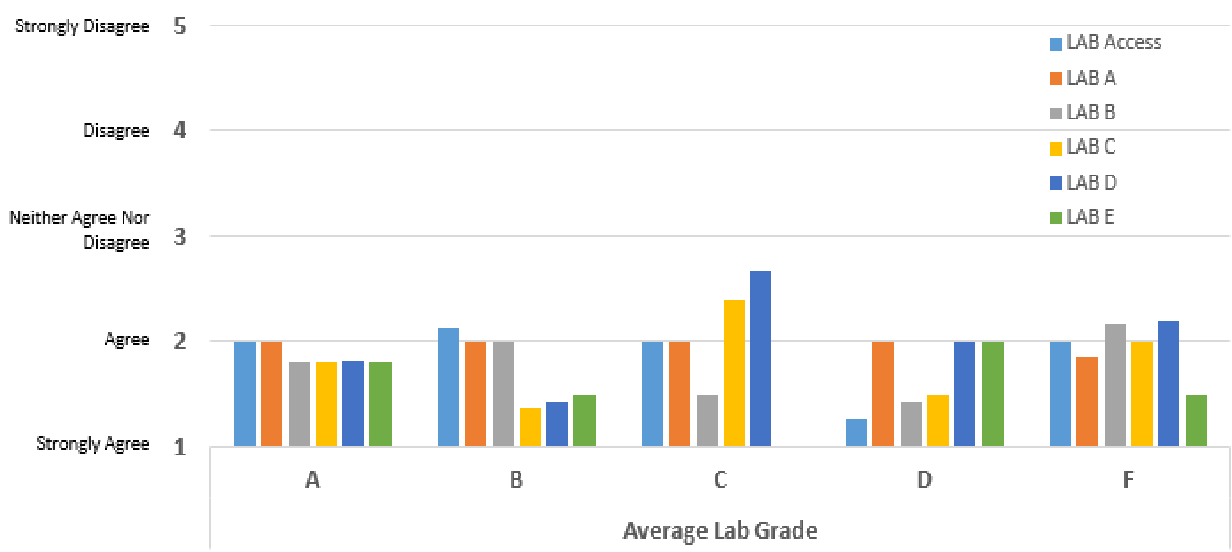
Another question is asked in the survey about the total numbers of hours spent on studying for the course to identify the load of the lab as part of the course work. The analysis in Figure 12: No. of Hours Spent on Course Work shows that the total the average number of hours is between 10 and 15 hours. This finding, when compared to the number of hours spent on the lab work, clarifies that the students spend 35% of their course study for the finishing the lab work. This is considered a proper percentage of time knowing the importance of the lab work in delivering the objectives of the course.

Category 4: Lab Instructions

The last category analyzed in this study is the efficiency of the lab instructions. Evaluating the students' responses shown in Figure 13: Lab Instructions elaborate that the majority of the students agrees on the clarity of the lab instructions. However, for labs "B", "C", and "E" some of the students indicate the existence of some vagueness and ambiguity in the instructions. Proof reading for typos and instruction review will be done to improve the quality of the instructions. Also rearranging the instructions is suggested to provide some of the notes to the readers before finishing certain instructions.

Finally, the analysis of the students' comments shows areas of potential improvements in the lab model including all aspects of system, support, course and instructions. These will be reviewed before the next offering of the course.

Figure 13: Lab Instructions Clarity– Average of response to Likert scale questions 14 through 24



Conclusions

The student support venues specific to a sophomore level networking security laboratory-based course were reviewed. A lab evaluation model classifying the evaluation of four aspects of the student perspective was proposed. The four aspects are system, support, course, and instruction. These aspects were used to categorize the assessment of the student experience.

Both the availability of synchronous support through face-to-face and virtual conferences, and the asynchronous support through discussion board support were effective and useful to the students. An assessment of these support venues included both a survey at the end of the course, and also a numerical analysis of the discussion board posts and frequency of access. Analysis found that the lab C instructions were not clear and needed improvement. Investigation of the relationship between average lab grade and use and satisfaction with lab support showed no strong correlation with the exception of the few students that had a failing laboratory grade score were less satisfied with the support.

The paper also presents a format for using shared resources to concurrently support two groups of students: face-to-face students and distance education students. The lab help sessions offered concurrent support for both groups of students by having a walk-in location for face-to-face students where the lab support persons kept a web conference instance running that was available to distance education students. Additionally, the lab help discussion boards were combined for both groups. This allowed for problems and solutions experience by one group to be immediately available for all students.

Further analysis of the data can be done to look for differences in face-to-face versus distance education students which was not done in this study. Also Since this paper focus on the technical challenges related to the lab delivery, further analysis for measuring the effectiveness of instructional contents is planned in our future work.

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