

# Computer Science Graduation Project During Covid-19 Pandemic: Challenges and Solutions

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## Summary

The graduation project is one of the most challenging courses in the computer science curriculum since it combines all the skills that have been learned in the whole program. Covid-19 pandemic and all the consequences that come with it made teaching graduation projects burdensome. In this paper, the author documents the experience of teaching such a course in Covid-19 pandemic times including challenges, and solutions, and reflection on that experience. A compelling idea for the graduation project has been proposed to be implemented at the college. The idea includes implementing a cybersecurity lab, that has been divided into several teams, using old PCs at the building of the college of computer science and information systems, Najran University, Saudi Arabia. The challenges that arose during Covid-19 lockdown and fully virtual learning experience times have been documented. The solution to those challenges has been proposed, and a reflection on the whole teaching experience has been reported.

## Key words:

*Graduation Project; Covid-19; Cybersecurity Lab; Virtual Lab.*

## 1. Introduction

The computer science field is a growing discipline, and its history is a series of milestones that have advanced the field's development. In the last 50 years, computing has become one of the fastest-moving industries in the world, and it continues to influence nearly every other important field of study. As computer usage expands, so does the need for professionals to support this technology. A degree in computer science fields, regardless of your specialization, can provide you with a rich understanding of computers, and how they are used by businesses and organizations. In our university, the Bachelor of Science in Computation fields is a four-year degree program that combines both theoretical and practical knowledge. The curriculum is designed to develop in students an ability to design, implement and apply learned skills in their future careers.

During the Covid-19 pandemic, many countries including Saudi Arabia have shifted to E-learning which leverages the power of e-learning. E-learning could be simply defined as the use of computer technology to deliver

educational content. This can include online courses, virtual classrooms, and virtual labs, as well as computer-based training and performance support systems. E-learning can be just as effective as classroom training; it offers greater flexibility to learners, who can study in their own time and their environment. It also provides organizations with a cost-effective way of delivering training to employees or even customers.

In this paper, the author document the experience of teaching graduation project during the pandemic of Covid-19 and challenges that arose from such experience. The idea of the student's graduation project is to utilize the old PCs and implement a cybersecurity laboratory that could be used to train students on penetration testing, ethical hacking, competitive champions, and other usages. The rest of the paper is organized as follow: Section II is a literature review background study on the idea presented. Section III is a case study which presents the original idea, and alternative ideas and the reason of changing the graduation project idea to be implemented. Section IV presents the challenges and solution of the study, while the conclusion is presented in section V.

## 2. Literature Review

In this section, the author group the findings into five groups-First, computer science labs and education which demonstrate the importance of practical exercises in computer science education. Second, networking laboratories are presented to show design and implementation in the area of networking. Third, security labs are also taken into account. Fourth, the authors decided to add a section for virtualization, which includes some of the labs that depend on virtualization and simulation and are not covered in other sections. Finally, the other sections show labs that are not fit into previous groups.

### 2.1 Computer Science Laboratories and Education

There is no doubt about the significant impact of computer laboratories on education, and such a great example of this impact could be noticed in the implementations of an active learning laboratory in the computer science field. To enhance interaction and collaborative learning, regular

classrooms have to be designed in a specific way to achieve the desired goal [1]. That can enhance faster learning processes, increase group activities, and improve remembrance in gateway science courses.

And as implantation of an active learning laboratory in computer science, a significant study has been done at Indiana University South Bend, and the study has been done on the policies of the admission process to enter the college. And the overall results show that the retention percentage in computer science required courses could be as low as 50%, and the creative approach on dealing with this issue was by coming up with a suitable approach to design and developing innovative techniques for new computer science courses to create an active learning classroom to ensure that students get better engagement in solving complex problems [2,3,4].

Also, enhance their creative thinking and work collaboratively to eliminate students' stress and anxiety that is usually associated with being a new student [5], and the result of this designed approach showed that the student has been engaging much better both inside and outside the class also showed much better effectiveness on active learning due to the appropriate design and the support of the technology, which plays a vital part in this learning model [6]. Authors in [7] developed a software system DYNALAB, that supports highly visual and motivational lecture demonstrations and laboratory experiments in the department of computer science[7].

## 2.2 Networking Laboratories

Developing and understanding knowledge in the networking area is essential for undergraduate students in computer science majors, and this is supported by the current guidelines of computing curricula guidelines published jointly by IEEE and ACM associations [8]. Therefore, an adequate networking laboratory is vital to the teaching and hands-on experience of computer networks, which is usually taught in one or more courses in the computer science curricula. Having that said, the networking labs are expensive to create, operate, and maintain with an estimation of \$110,000 for the hardware and software to start a networking lab with 20 seats [9]. Gerdes and Tilley [10] present a developed virtual networking laboratory (VNL) platform where complex networks can be implemented.

On the other hand, paper [11] presents the lab equipment complex used to teach networking courses at Vilnius University. According to the authors, this can be achieved by adopting Cisco Networking Academy program materials [12] and other readings [13-9]; although a hands-on experience with the real equipment would overcome the limitations of simulators such Packet Tracer, GNS3, IOU, etc. The authors claim that using simulators, real equipment, and remote access labs have successfully prepared highly qualified network administrators and designers [11]. Furthermore, Caicedo and Cerroni redesigned the computer networking lab facilities at the University of Pittsburgh by

implementing an efficient laboratory management framework and topology building process which in result allow the uses to take advantage of the wide range of the physical laboratory infrastructure and network configuration [17]. Their new design utilizes the distributed nature of laboratory infrastructure to allow multiple teams to work simultaneously. Also, the investigators concluded that because of their new design, the students requested the introduction of a new advanced networking class and flexibility in accessing the lab outside class times [17]. In addition, Yoo and Hovis [18] designed a lab for networking courses that use old PCs and convert them to IP routers with open-source software Zebra [18]. The goal of their research is to overcome the funding for the hardware, the physical space limitation, and accessibility of lab difficulties. Their remote access lab would allow only one student at a time to access the management station of their lab which guarantees the students will not mess the configurations of others, but it would also limit the access to the lab [19].

On the other hand, an open network laboratory (ONL) is a networking testbed that consists of high-performance routers and it is accessible remotely[20]. Similar to Emulab [21], PlanetLab [22], Xbone [23], and Schooner[24], this testbed is developed at Washington University at St. Louis to help both networking students and researchers who possess beginners and experts' knowledge in this field.

## 2.3 Computer Security Laboratories

Many studies emphasize that computer security education in computer science is vital to ensure safe computing and until this issue is addressed properly, breaches will continue to plunge computer systems [25-31]. Studying security through lectures and reading assignments is not enough for most students, and the student's engagement through laboratory exercise is essential, says Irvine [32].

Hill et al. [33] designed a computer security course where the project is the dominant part of students' grades. Their approach depends on dividing students into multiple gold and black teams. The gold teams are responsible for running windows, and Linux servers with many functionalities. They are playing the rules of systems administrators and trying to defend their systems. On the other hand, the black teams are trying to break into the gold team and other black teams systems. In addition, Schafer et al. [34] developed a completely isolated laboratory from the outside world to teach information security concepts to their students.

Many lab-based courses have been developed in the area of security including [35-38]. Based on observations, surveys, and course evaluations, all are agreeing that the students value the course and they realized more engagement from the students. Some of these courses require a completely isolated lab [36, 37], while others work just fine with a few machines that are isolated [35]. SEED

environment though requires a student's personal computer or public computer that can host a virtual machine to run the labs and do all ten experiments designed for this environment [38].

## 2.4 Virtual Laboratories

Virtual laboratories have been utilized to address the acquisition, operation, and maintaining costs of the physical lab's facilities especially in institutions that are limited by budget, and has lack technical expertise. According to Wolf, the learning occurs in the labs using virtual labs as equally as much (45.9%) as in classes (54.1%), and also prior experience in the subject being taught through virtual lab matters [39]. In this section, we are going to present some of the virtual labs in different disciplines. Hoffman et al. present a virtual lab that can be used in chemical and mechanical engineering computational experiments [40].

A virtual lab is designed and implemented to support model development for computer graphics models [41]. In different circumstances, a virtual electronic lab (VILAB) has been developed as an intelligent tutoring system [42]. With the VILAB, the students can experiment with the four programming paradigms: procedural, object-oriented, functional, and logical programming, using C, Java, Lisp dialect Scheme, and Prolog, respectively. Therefore, the last four steps (utilization of knowledge, feedback of controlled results, evaluation of learning success, ascertaining of knowledge saving, and knowledge transfer) of the instructional design by Gagne et al. [43] theory steps are applied in VILAB.

## 2.5 Others

In the most recent time, the popularity of the open-source laboratory for operating systems has been increasing rapidly—these open-source operating systems untapped lots of possibilities for developing and modifying various projects. At Worcester Polytechnic Institute (WPI), a project has been presented on configuration both the hardware and the software for an open-source laboratory for approximately 2800 undergraduate students. The main goal of this project is to provide these students with a much better insightful understanding of the operating system than the knowledge gained in the traditional operating source courses and to become more confident in their ability to write more creative operating systems codes [7]. This approach had been influenced by three other laboratories to adopt it. These laboratories are the advanced systems Lab at Michigan Technological University, ALAMODE, a lab at Colorado school of mines for distributed environments, and Linux-based laboratory at Auburn University [6]. With the global comparative in technology, an interdisciplinary laboratory for teaching artificial intelligence and manufacturing [45]. The main goal of Artificial Intelligence and Manufacturing (AIM) is to expose and educate students

from the college of engineering and computer science; the integration between computer systems and engineering manufacturing industries is also used to assigned for several projects where computer systems and manufacturing systems cross each other [46].

The AIM laboratory uses two primary systems to meet the desired goal and satisfy the educational mission [47]. These two systems are called the intelligent Manufacturing Cell and the intelligent Factory. The evaluation of the Oakland University students' rating is excellent and based on the students' comments, that (AIM) laboratory is helpful to more real-world applications, exciting learning experience as a change from theory-based engineering to reality-based engineering [48].

In another aspect of the correlation between computer laboratory and multidisciplinary field and graduate studies [49-50]. A tremendous multidisciplinary effort by researcher scientists of Virginia Tech's Departments of Computer science, College of Engineering, College of Education, Learning Resources Center, and The Department of Geography to improve and develop computer-aided education software called GeoSim a GIS-based simulation Laboratory for Introductory Geography [49]. This program emphasizes and enhances interactive learning by gathering and combining the data of the Geographic Information system (GIS) with several techniques of computer simulation. The project is based on five fundamental themes of Geography. These themes are location, place, environment, movements, and regions [51].

## 3. Case Study

The college of Computer Science and Information Systems CSIS at Najran University has many old and outdated labs. The new labs are not enough when it comes to the number of classes conducted simultaneously. While the number of students in the college is getting larger every semester at fast a rate, the incoming students within the last two semesters are double the number of the students in the whole college, and that is partially due to the attention the computation fields are getting from the media including social media in Saudi Arabia in the recent years. Also, there are many old PCs in CSIS that have not been put to good use. It would cost CSIS a fortune to design, purchase, and implement new laboratories.

### 3.1 Original Plan

At the first, the project assigned to students aims to rebuild a lab to be used for courses such as network administration, distributed systems, computer security within the college of CSIS. The project will make good use of old, and outdated PCs available at the college with a very limited budget that doesn't exceed three thousand dollars. The ultimate goal of the project is to use what is available of devices to create an attractive educational environment. The project was intended to deliver: a complete blueprint for the lab design,

implementing that design, a guide for the users of the labs, and documentation of the work.

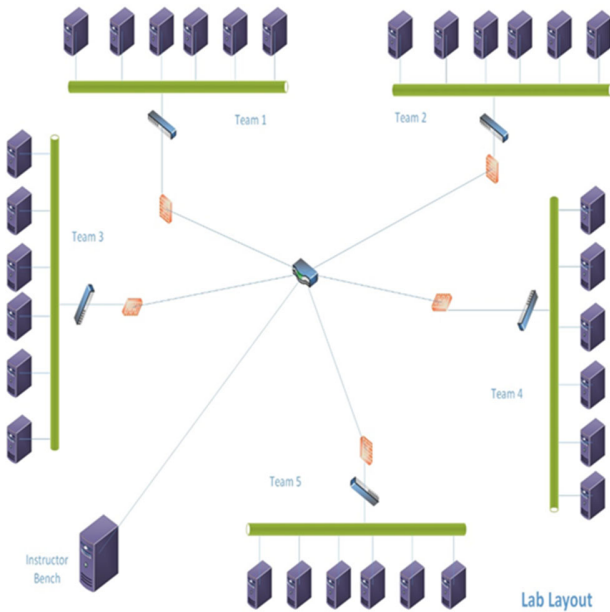


Fig. 1. Original Design of Graduation Project Idea

Figure 1 shows the original design which includes: five teams that have been connected to the same network with the instructor bench. Each team consists of six devices: Linux server, windows server, Linux client, windows client, penetration tester, intrusion detection system (IDS). Every device has its own purpose within the network, and every team is offering a range of services depending on what organization they are mimicking which includes: hospital, bank, pharmacy, and online shopping companies. The network services offered include primary and secondary DNS, email server, NTP server, User management, SSH server, DHCP server, VPN for secure access, and FTP server. Table 1 shows one example of the services that our plan included for one team, and all other teams have similar setups with different purposes. Figure 2 illustrates a setup for one of the teams. The instructor bench is intended to check the student’s progress throughout the course.

Table 1: Services Offered by One Team

Name of computer	Operating Systems	Services
Windows client	Windows XP	A legacy system to assure the network is vulnerable for the other teams to hack
Linux client	Ubuntu	To be used as a client to test services installed and assure all servers are up and running.
Linux server	Ubuntu Server	primary DNS, email server, NTP server, an FTP server, VPN for secure access, SSH server, and webserver

Windows server	Windows Server 2016	Active directory, Secondary DNS, Users management, and file server, secondary webserver.
Penetration Tester	Kali Linux	Include penetration testing tools to penetrate the team’s system and identify the vulnerabilities and apply defense mechanisms.
Intrusion Detection System (IDS)	Ubuntu	Snort IDS to monitor network traffic and detect dangerous payloads

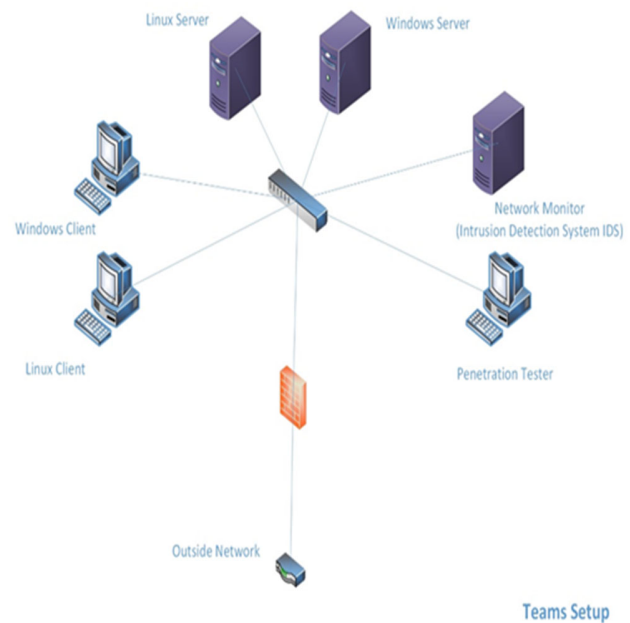


Fig. 2. Illustration of One Team Setup.

On the other hand, after four weeks of starting the semester, the coronavirus Covid-19 pandemic started to take effect on people’s lives in Saudi Arabia and the rest of the world. In Saudi Arabia, the government initiated a curfew, and attendance at the university laboratory became impossible, so the author had to conceptualize an alternative plan for the project.

### 3.2 Alternative plan

Due to the pandemic, the original plan has been modified to an alternative plan which relies on the student’s PCs and laptops. In addition, the alternative plan needs to consider the student’s devices capabilities, and at the same time, the alternative plan must not abandon the core idea of the project. So, the teams have been divided into two groups: the Linux group and the Windows group. The Linux group is asked to implement the requested services on the Linux server of their choice, while the windows group is asked to implement the requested services on the windows server of their choice. Figure 3 illustrates the implementation of one team of Linux groups where the

students used Oracle Virtualbox software on their PC, which is running Windows 10 OS, to host three virtual machines VMs: Linux server, Linux client, and Kali Linux. The services offered at the Linux server VM include web server, DNS, User management, SSH, file server, and intrusion detection systems IDS using Snort software [52]. The Linux client VM is used to test the offered services by the server, while the kali Linux VM is used as a penetration tester for the system. Figure 3 illustrates the idea in detail.

On the other hand, one team of windows group used Oracle Virtualbox virtualization software to implement three machines: Windows server which is with MS Windows Server 2016 operating system, and Windows client which runs MS Windows 10, and a penetration tester that uses Kali Linux operating system. On a Windows server machine, the services that are installed include active directory, DNS, DHCP, user management, file server, website, NTP, and Snort the IDS software. While the other two machines are used to test the services that are offered by the server. Both teams were asked to assure that their virtual networks have two network interface cards (NIC): one is to connect their devices, and the other is to connect these private networks to the rest of the world.

#### 4. Challenges and Discussion

The students had many challenges while trying to adapt to the new arrangements due to the COVID-19 pandemic including personal and technical challenges. The challenges that the student might face on a personal level include, but are not limited to, stress, social isolation, mental health, fear of the future, and dealing with myths of COVID-19. Some students reported that they are going through so much stress due to the sudden and unplanned changes in their lifestyle. In addition, after the curfew went into effect in Saudi Arabia, social isolation became mandatory which became astonishingly hard on energetic and dynamic young adults. One student reported that he broke the curfew many times, some of which he got penalized with around a three thousand dollars fine from the government police. Mental health is another challenge where students could suffer personally or with their relatives. The students in this project are about to graduate and their future of graduating, finding a job, and shifting from student life to employee life has met a new and unexpected situation which made the future uncertain. Also, dealing with the myths of COVID-19 is another challenge, where the students, like all other young adults who are using social media on regular basis, are exposed to a huge amount of information about COVID-19 and not all of this information is reliable. Dealing with the myths of COVID-19 especially for those whose loved ones are vulnerable and categorized as high-risk individuals, is very hard. On the other hand, the technical challenges include students devices capabilities, internet connectivity, software

licensing and availability, and e-learning experience. Devices students use don't have high capabilities such as fast CPU, or higher RAM. Most students use regular devices that can be bought off the shelf. On the other hand, the internet connection became a serious issue during COVID-19. There was a lot of pressure on internet providers to provide the internet with high bandwidth to accommodate all the services that is been provided by the government and private sectors. The students faced many connection interruptions, having that said, I can firmly conclude it is one of the factors that contributed to students' knowledge gaining. Some of the services we had needed to implement required some licensing and it was very hard to get those licenses for the students: money and technical wise. In addition, e-learning experience and the adoption of e-learning mode were not easy for students.

#### 5. Conclusion

In this paper, the author describes his experience of teaching a graduation project course during the Covid-19 pandemic. An original and compelling idea has been proposed to be implemented as a graduation project at Najran University. The idea utilizes the old PCs available at the university to implement a cybersecurity lab. An extensive literature review that studies similar ideas has been accomplished. The original plan has been adjusted to accommodate the consequences of the Covid-19 pandemic. The author discusses the challenges, suggests solutions, and reports the reflection of the teaching experience.

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