Experiences in Teaching Network-Related Courses in Thailand: Past, Present with the Pandemic, and Future

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ABSTRACT
In this paper, we describe the lessons learned and experiences teaching computer networks-related courses in universities across Thailand over the years, namely Data Communications, Computer Networks, Wireless Networks, Mobile Computing, Computer Network Design and Configuration, Wireless Sensor Networks and Internet of Things, Broadband and High Speed Networks, Cloud Computing and Network Security. The COVID-19 pandemic has caused a sudden disruption to traditional face-to-face classes instructed in universities across Thailand as well as those around the world. Each instructor made their teaching approach choice. The choices taken were varied from live on-line lectures to on-demand video clips courses to courses. Different practices with a variety of tools assisting in providing the online course and the instructors' experiences are discussed on their pros and cons. In this paper, we compare and summarize the teaching experiences of instructors from four universities in Thailand. From the lessons learned, we then discuss what we can do better for the next semester to come during the pandemic.

CCS CONCEPTS
• Applied Computing → Education → Interactive Learning Environments; Distance Learning; E-learning

KEYWORDS
Network Education, Online Teaching, COVID-19 pandemic

ACM Reference format:

1. INTRODUCTION
Computer networks is normally a required course in most Computer Science programs and Computer Engineering programs at the undergraduate level. The contents taught covers from the physical layer to the application layer of OSI model and TCP/IP stack, some programs may divide the contents into multiple courses, such as Data Communication course and Computer Network course, while other programs may cover all layers in one course. In Thailand, offering the international programs, some universities provide those courses in both English and Thai. Some universities arrange the second semester period traditionally; during December to the end of March, while some follow the international educational calendar period; hence, their second semester is during January until May. A variety of computer networks related courses are offered as seen in Table 1.

<table>
<thead>
<tr>
<th>University</th>
<th>Courses</th>
<th>2nd Semester period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kasetsart University</td>
<td>Computer Networks (U:60), Data Communications and Network (U:50), Computer Communications and Cloud Computing (U:120), Basic Network Configuration Laboratory (U:40), Data Acquisition and Integration (U: 35), Wireless Networks (G:5), Wireless Sensor Networks and Internet of Things (G:10)</td>
<td>Dec-Mar</td>
</tr>
<tr>
<td>Mahidol University</td>
<td>Data Communications (U:200), Computer Networks (U:200), Wireless and Mobile Computing (U:200), Network Forensics (G:2-10)</td>
<td>Aug-May</td>
</tr>
<tr>
<td>Chulalongkorn University</td>
<td>Computer Networks I (U:120), Enterprise IoT Network Infrastructure (G:15)</td>
<td>Aug-May</td>
</tr>
</tbody>
</table>

Table 1: Some network-related courses offered by Universities in Thailand
Thailand’s Prime Minister announced an emergency decree on Thursday March 26, 2020 in response to increasing numbers of COVID-19 cases in the country [1]. Therefore, it affected the teaching continuity of our network-related courses at each university varyingly. That was because each university’s second semester period was different as shown in Table 1. In this paper, we compare and summarize instructors’ teaching experiences from four universities in Thailand – Kasetsart University, Mahidol University, Chulalongkorn University, and Asian Institute of Technology. Their teaching methods including a list of resources and tools, and the learning management systems before the COVID-19 pandemic are described. Next, details of the teaching approaches and practices, the exam management, and lessons learned during the COVID-19 pandemic are explained. Finally, we discuss the future plan to handle the classes in the next semester. We also conducted a survey gathering feedback from eleven instructors teaching network-related courses in various public universities throughout Thailand.

<table>
<thead>
<tr>
<th>University</th>
<th>Courses</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Network Laboratory (U:80), Network Design and Management (U:30)</td>
<td></td>
</tr>
<tr>
<td>Burapha University</td>
<td>Computer Networks (U:120)</td>
<td>Dec-Mar</td>
</tr>
<tr>
<td></td>
<td>Computer Networks II (U:30-60)</td>
<td></td>
</tr>
<tr>
<td>Prince Songkla University</td>
<td>Data communications (U:80), Broadband and High Speed Networks (U:10), Multimedia Networks (U:10)</td>
<td>Dec-Apr</td>
</tr>
<tr>
<td>Khonkaen University</td>
<td>Computer Network Design and Configuration (U:20)</td>
<td>Dec-Mar</td>
</tr>
<tr>
<td>King Mongkut's Institute of Technology Ladkrabang</td>
<td>Interconnected Communication Network (U:50), Practical Computer Networking (G:40)</td>
<td>Aug-May</td>
</tr>
<tr>
<td>Asian Institute of Technology</td>
<td>Computer Networks (G:10)</td>
<td>Aug-May</td>
</tr>
<tr>
<td></td>
<td>Advanced Topics in Internet Technology (G:10)</td>
<td></td>
</tr>
</tbody>
</table>

The majority classes are typically instructed in a lecture style using slides and some hands-on demonstration. Class interaction is a key for making the learning process effective. In Thai culture, the instructors rely on students’ gestures and facial expression and interaction between students in order to observe the performance of their teaching. Many students are quiet and shy to ask questions in class, but their facial expressions and gestures show if they have trouble understanding the materials. Having small-size activity-based courses, the instructors and teaching assistants are able to help students solve their problems at once which can take all students to the same pace of the course.

2. METHODS OF TEACHING BEFORE PANDEMIC

Network-related courses are instructed in either lecture-based or activity-based approaches. The Data Communications, Computer Networks, Wireless Networks, and Broadband and High Speed Networks courses are lecture-based courses with some hand-on assignments whereas Computer Network Design and Configuration, Wireless and Mobile Computing, and Wireless Sensor Networks and Internet of Things are more towards activity-based courses. Some undergraduate network courses use and/or adapt the materials from Cisco Networking Academy lessons using physical routers. Before the pandemic all classes were conducted face-to-face. The number of students in Computer Science, Computer Engineering, Information Communication Technology programs varies from 50 to 200 students yearly. Conventionally, the undergraduate classes are split into smaller sections of approx. 30-70 students, depending on whether the class is lecture-based class or activity-based class. The number of students in a section is relatively small, especially for activity-based classes, while the graduate class size varies from a few to 40 students.

a. Teaching Resources and Tools

For the hands-on labs or assignments and in-class activities, the following tools are selectively used in the courses mentioned in Table 1.

- APNIC Academy [2], Cisco Networking Academy [3]
- Simulators: ns3 [4], Opnet [5], Omnet++ [6]
- Wireshark [7], PacketTracer [3], iperf [8], OpenWRT [9], Traceroute, Netcat, Jupyter Notebook [10]
- Python/MicroPython, ESP32 board, SimPy, Node-RED [11], Web Scraper, OpenRefine [12], Swagger/OpenAPI [13], GraphQL [14]
- RouterOS, MikroTik Academy [15]
- OpenDayLight [16]

b. LMS Resources and Tools

The course Learning Management Systems (LMS) are mostly Google Classroom for sharing slides and submitting the assignments. Some universities also use their own Moodle systems [17], e.g. at Faculty of ICT, Mahidol University, the faculty provides their own customized Moodle e-learning platform for all instructors of the bachelor programs. These LMS platforms have been used in all classes in Table 1 much longer prior to the pandemic.
Thai users were skilled at using social media, voice and video calls using chat apps (one-to-one), and on-demand and live video streaming (broadcast) using popular social or web-based platforms like Facebook, Line, Instagram. For some classes, the instructors also created a Facebook group while some created a LINE group as one of the class timely communication channels.

Even before the pandemic, some instructors recorded their video clips and published them on YouTube for replays by students, but none had conducted live online teaching.

c. Custom tools, Python-based signal processing notebook, E-Labsheet

The custom tools have been developed and incorporated into hands-on activities, especially for lecture-based classes where students usually do not have access to physical lab equipment. For example, in the Data Communications and Computer Networks course at Kasetsart University hands-on activities provided as Jupyter Notebook / Google Colab documents running a custom signal processing library. Rather than looking at static plots on lecture slides, students have a chance to construct their own virtual signals and see them being affected by the channel whose characteristics can be configured using Python programming language. Figure 1 illustrates visualization of a digital signal getting distorted when passing through channels with different cut-off frequencies.

![Virtual signal visualization](image)

**Figure 1:** Virtual signal visualization in Jupyter Notebook / Google Colab

Even with points given, instead of asking the instructor or the teaching assistant, these students have a tendency to wait until the last minute and just copy other classmates’ solutions. To encourage students to do the work on their own, an automatic grading system, called E-Labsheet [18], has been employed. E-Labsheet was originally developed by the Department of Computer Engineering, Kasetsart University in 2009 for grading programming tasks and providing instant feedback, but has been extended multiple times to support more general types of tasks [19]. One of the notable features is the capability to take a single question template and produce multiple versions of the question with different contents. This is similar to Moodle's calculated (wildcard) question type [20] but with greater flexibility. As content variations are controlled by the Python-based backend, questions with complex solutions can be programmatically authored. Figure 2 shows an example of a task testing students for the concept of packet forwarding. The task template gets generated into multiple instances with different IP addressing configurations along with computed solutions in the backend. Therefore, students are forced to work on their own or ask for advice, instead of just copying another classmate's answers.

![Packet Forwarding](image)

**Figure 2:** (a) a computer network-related task generated from a task template, and (b) another task instance with different IP addressing configurations and question phrases
Notebook-based hands-on activities are often incorporated with E-Labsheet tasks so that students are required to work on Jupyter Notebook to find an answer, then submit and verify the answer via E-Labsheet. Figure 3 shows an example of a task asking students to determine characteristics of the provided, randomly chosen, analog signal in a Jupyter Notebook session. Grading results are displayed immediately once answers are submitted, so students have a chance to verify their understanding in a timely manner.

Decoding 16-QAM Signal
Open a new Jupyter Notebook session and run the following code:

```python
import urllib

from urllib.request import urlopen

url = 'https://www.epm.ku.ac.th/~rgp/201825/gp-3-24.wav'

x = signal.load_file('gp-3-24.wav')

x.plot_time()
```

The cell will show an analog signal representing 12-bit digital data modulated with a 16-QAM scheme based on the constellation diagram below. The carrier frequency is 300 kHz.

(a)

The cell will show an analog signal representing 12-bit digital data modulated with a 16-QAM scheme based on the constellation diagram below. The carrier frequency is 300 kHz.

(b)

Fill in the answers
- The symbol rate of the signal
- The bit rate of the data transmission
- The original 1/3 bits of data

Figure 3: a task requiring students to perform calculation using Jupyter Notebook: (a) the task displayed in E-Labsheet, and (b) the task being worked on in a Jupyter Notebook session

3. LESSON LEARNED DURING PANDEMIC

All Thai universities were ordered to be closed due to the pandemic starting the third week of March 2020. Hence, all the classes had to switch to online classes. Universities which the second semester period is during December to March were not affected as much as those which the period are during January to May. Following the breakout news in China in February, Thai universities had about a week or two weeks' time interval to arrange for the class conducting process.

a. Preparation

The effects from COVID-19 pandemic are different between each academic program in each university, because our academic calendars are somehow different as revealed in Table 1. For example, At Kasetsart University, fortunately the instructors had to conduct online classes for only one or two weeks before the semester ended. Then the students took the final exam and had the summer break. Thus, online classes were arranged for one to two times and were not much affected by the COVID-19 pandemic. The instructors chose to do live online lectures partly because there was not much time to prepare for the recorded lectures.

The medium of providing online classes are Cisco Webex, Microsoft Teams, Zoom, Facebook Live, and YouTube. Two approaches chosen were on-demand video clip lectures and live lecture. This medium and the approach were decided by the classes’ instructor(s). Having not much time, instructors picked up the tools with which they were most familiar. It is interesting to note that though the LMS used is mainly Google Classroom, instructors choose others instead of Google Meet. Below are interesting practices from different universities that were affected more on the COVID-19 pandemic.

At Chulalongkorn University, the instructors observed the pandemic and ran several experiments in February before the university announced that the campus would be shut down in late March. The goals of the experiments were to

1. get familiarize with the tools and best practices for video conferencing as well as preparing their computers for the task, and
2. understand the challenges and gaps prior to making a decision on how best to offer online instruction.

In February, a virtual department meeting with all faculty members was done using 2 video conferences tools considered to be the most accessible for students. The first tool was one of the most popular chat apps that everyone used and the other was a browser-based video conference tool. The LINE chat app failed miserably in terms of
performance and scaling as depicted in Figure 4. The browser-based app worked for most of us after a few reboots, but video conferencing etiquette was still a challenge. While none of this experience was smooth, it was tolerable except for sound quality. Built-in microphones on some laptops were not functioning or had extremely poor sound quality. The department bought and distributed every instructor their own individual microphone as a solution.

In the first week of March which was the midterm week, there were 2 cases of COVID-19 on-campus, but midterms proceeded with strict mask-wearing. It was directly observed as an exam proctor that controlling the pandemic would mean that the university would inevitably shut-down shortly after midterms.

At Mahidol University, right after the midterm exam, there was news on the COVID-19 breakouts in Bangkok and faculty members started working from home before the official shutdown. At the time the lectures still had to be offered for seven more weeks. Hence, the ICT faculty was closed for a week in order to provide workshops for educating instructors and staff on how to use Cisco Webex and Microsoft Teams. Some instructors bought a new IP camera, a headset, a microphone, or even a Wi-Fi dongle to support live online classroom from home. Instructors were requested to teach via either Cisco Webex or Microsoft Teams in the physical classroom with empty chairs in the first week of online teachings, as shown in Figure 5. After that, they were allowed to teach from home.

For the students, some universities, e.g. Chulalongkorn university and Mahidol University provided free net sim cards to all students while some universities e.g. Kasetsart University, the help was done at faculty-level. Some universities help students who lack the necessary equipment e.g. Kasetsart University offers students to buy an iPad with a 10-month installment. The students have to register for the help but it took a month to actually get the sim cards and longer to get an iPad. Therefore, the students who lack the resources had trouble catching up with the live online classes. Though the sim card help comes in time for the Final exam. However, most computer science students usually own a laptop computer. Only a few with limited resources had trouble at the beginning of the pandemic outbreak (mid March). They missed the classes, so video recordings help them to learn at their own convenient time.

A colleague at the Computer Engineering department, Chulalongkorn University created a Facebook group named “Teaching during COVID-19” [21] to provide support for faculty members. The group grew from beyond the department to the entire teaching community in Thailand consisting of instructors from various universities and schools. Faculty members in the group shared their thoughts and experiments in the group so as to support one another in finding the right teaching style and tool for this unprecedented situation.

b. Teaching

Live online lecture-based sessions are conducted with Microsoft Teams, Zoom, or Cisco Webex. Zoom lifted the 40-minutes cut-off restriction at the beginning of the pandemic but later on some universities acquired licenses for their online classes. Some instructors recorded their video clips and published them on YouTube for replays by students.
At Kasetsart University, the live online lecture approach was chosen and carried on via Microsoft Teams and Cisco Webex. That was partly because it was two weeks until the semester ended and the instructors wanted the students to continue taking class at their class schedule slots. However, due to some resource limitation, about one-third of undergraduate students in the Computer Networks course attended the live session. Therefore, the live lectures had to be recorded for later views. The interaction between instructors and students was done using the chat room. It was difficult for an instructor to sense whether the content materials were well understood by the students without seeing their faces and listening to the interactive comments. The chat room did not quite compensate for that matter.

At Asian Institute of Technology, there were 12 students from five countries from Asia and Europe enrolled in the class. Some returned to their home countries in the middle of the semester. The class schedule had to be readjusted to the time period that worked for everyone. The class was conducted as live online lectures via Zoom. During the course, at the beginning of the pandemic, APNIC academy’s virtual lab on OpenFlow was used as an exercise in class; however, due to high demands during April, only a few students could get in.

Although some activity-based courses were not affected much by the pandemic because the assigned activities were performed virtually online anyway, the courses like Network Laboratory or more instructions and tutorials had to be created to supplement the lab exercise.

At Chulalongkorn university, two teaching experiments were done.

**Experiment 1: Test and select an appropriate teaching delivery model**

Next, an instructor made choices and decisions for how they delivered two of the undergraduate classes, computer networks and cloud computing, as they were more challenging as they were either larger or typically required more hands-on interaction. The selection criteria were based on the following requirements:

1. **Minimize everyone’s stress levels, students’ and the instructor’s, to maximize learning effectiveness.** Everyone is under different pressures. Some students needed to physically move out of their Bangkok dorms to their homes where they may not have the proper resources and environments for learning. Students need time to adapt to their new environment, let alone the new tools they would need to use. The instructor also needed time to adapt at home and rework her classes.

2. **Maximize accessibility, considering that students may have low bandwidth environments and poor mobile Internet coverage.** Furthermore, all potentially scalable video conferencing platforms are cloud services without domestic infrastructure. International bandwidth would be scarce as demand (from Thailand and other countries) increases and performance would likely be intolerable for live/real-time delivery models.

(3) **Ensure that students who would be graduating this semester would be able to do so without any delays.**

**Experiment 2: Tuning the in-class activities and going live**

While the computer networks class proceeded as planned with very few changes, the cloud computing class had to be adjusted. The instructor prioritized material that was suitable for on-demand delivery first. For the remaining in-class activities that required technical assistance and was difficult to run on-demand, she switched to live. At this point, students had some experiences with video conferencing with other classes and understood their own time, computing, and environmental constraints. She tried two delivery modes, (i) on-demand lecture and live in-class activity, and (ii) live lecture and in-class activity. Given that the class sizes were relatively small, both methods worked well. Student feedback for live vs. on-demand lectures were the same. Students enjoyed the live in-class activities, even though it was much more difficult to get everyone on the same page than in-person. For example, one in-class activity in the cloud computing class, the students typically spend a few weeks learning about blockchains and distributed ledger technology. The material in first class is an introduction to blockchains and a ‘blockchain bankrupt game’ activity that the instructor developed. The lecture format remained the same using an on-demand 1.5-hour video lecture that students need to watch before attending class. However, the in-class activity needed to be modified.

Prior to COVID-19, the activity format is an in-class activity. The instructor provides a brief recap of the lecture. Then, the activity starts by having all students connect their notebooks through physical switches in the lab. The instructor walks the students through all the steps by demoing on-screen. Everyone installs Ethereum and joins a single private Ethereum network, together. Everyone creates their account, announces their ID’s on a shared document, practices mining, and sends transactions. Then the ‘blockchain bankrupt game’ starts. The goal of the game is to compete for who will have the smallest balance in their accounts by sending/bombarding others in the class. This is a fun class where students will verbally challenge each other, coming up with different strategies collaboratively and competitively to win. Having the entire class work towards a ready state at the same pace (i.e., ready to compete) is usually challenging and requires a lot of manual troubleshooting looking at everyone’s screen, but do-able.

The instructor adjusted the activity for online instruction during COVID-19 as follows. Everyone joins the live session. The instructor provides a brief recap of the lecture, and starts the activity by having all students create a cloud-based VM in the same region. She walks the students through all the steps by demoing on-screen, expecting students to follow similar to before but much more difficult
to debug. Students used the chatroom to request help, but it was difficult to understand the problem, so the instructor had students share their screens and speak out. Other students shared their fixes with each other. The instructor had the support of one teaching assistant for the 20 students. It took about an hour longer than the in-person version to get everyone ready. The instructor needed to slow down during the demo as students needed to switch screens between the video conferencing tool vs. their own terminals to work on their set up. After everyone was ready, all ran the game and students still enjoyed it similar to previous years. Students also said they liked this class a lot more than the others that we had on-demand.

From this experience, the teaching assistant and the instructor had to use extra effort to prepare and test the activities before class. But, the experience for the students made the extra effort rewarding. The instructor then switched from on-demand to live for the rest of the semester for the cloud computing class.

At the end of the semester, for their project presentations, students presented their final projects live and the experience was also as natural as an in-person presentation.

At the Faculty of ICT, Mahidol University, the live online lecture approach was chosen and carried on either via Cisco Webex or MS Teams, since the university bought both the Webex and MS Teams license. Instructors can select to use either one. Students who are absent from the live lecture can see the recorded video later. The undergraduate courses affected during the COVID-19 pandemic were the Data Communication course, Wireless and Mobile Computing course, and the Special Topics in Computer Networks courses. In the Data Communication course, the instructors used Cisco Webex at the beginning of the pandemic period in Thailand, but they found that Cisco Webex was sometimes unstable. Thus, they had to switch to Microsoft Teams starting the second live online session of teachings as seen in Figure 6.

![Figure 6: An online lecture session via MS Teams](image)

For the live online class, some instructors taught from home experienced electricity power outages during the class. Fortunately, many instructors live close to campus, so some instructors drove to the university and were able to continue teaching the class. They were able to inform and communicate with students via LINE group chat on the matter. Not only did the instructors experience power outages, they also experienced the Internet connection unavailability via their ISPs. Pop-up quizzes during the live class were given some time during the live lecture session in order to check on students’ attention and actual presence.

The advantage of delivering online live lectures was for master program classes which normally start at 6 pm. The enrolled students are mostly full-time employees. In the normal situation, many students arrive at the university late because of Bangkok traffic congestion. Therefore, sometimes the instructors had to wait for them and shift the class’s starting time to 6:30 pm and finish the class at 9:30 or even as late as 10 pm. However, during the COVID-19 pandemic, whether some students still had to work at their companies or some others worked from home, they can manage to attend the online course on time.

For lab-based courses, on equipment-wise, some instructors ended up having more than one computer with an extra-large screen to check the students’ lab progress. The instructors need to ask students to share their screen or sometimes even allow access to their desktops to help them solve the problem. Looking at the students’ shared screen, the instructor cannot zoom in when the font size was too small. Some instructors even bought an extra-large monitor. Some of them used two computers: one for accessing students’

University has a regulation that requires students to attend at least 80% of the class in order to take the final exam, the attendance was checked from the participants list of Webex meetings and the view history of the recorded videos. Therefore, around 80-100% of the students attended the live lecture. Figure 7 shows the example of an online classroom via Cisco Webex.

![Figure 7: Example of online classroom via Cisco Webex](image)
shared desktop screens and for broadcasting the class instructions, and another for checking the chat conversion between the students. For the Network Forensics class with hands-on labs for almost every session, the students could not use the computer labs provided at the Faculty, therefore they had to prepare the lab environments in their computer, for example, the virtual machine and installed required software tools for the lab. Because the lab exercises required many VMs, their computer must have enough CPU and memory to run the exercises.

c. Changed Assessment and Exams

Traditional computer network exams are typically what-why-how questions. The undergrad students are not familiar with open-ended questions as typically assigned on take-home/open-book exams. During the pandemic the final exam had to be arranged online as well via Google Assignment. The students were required to take a mock-up exam to run through the exam process in order to make sure that the final exam process would run smoothly. The open-book, open-notes and looking-up-on-the-Internet exam limiting to three hours was chosen for Computer Communications class of 100 students at Kasetsart University along with a live session on Microsoft Teams. The students were required to turn the video on at the beginning. But due to the limitations on the network bandwidth, they were able to turn the video camera off after an hour through the exam period. Interestingly, via the video, one of the students spoke while working on the exam, it turned out that he used the voice typing function to type the answer on Google Document. The students could ask questions via Microsoft Teams chat room, but everyone would see all the messages. The instructor could make an announcement to all students via Microsoft Teams during the exam. When grading the exam, it was speculatively noticed that some students might collaborate with others by sharing the URL of the reference to the questions. Even so, the average score was below 50%. It is believed that the students are not familiar with the open-ended exam question style. Therefore, the students were requested to work on an extra report on IP address subnetting. The total score and more weight were given for assignments/labs/projects versus the final exam.

The open-book, open-notes and looking-up-on-the-Internet exams may not work for the undergraduate students. However, for the graduate students of the Computer Network course at AIT, the students enjoyed working on open-ended questions. The exams were given as a Google Class assignment. The students also participated in a Zoom live session with the camera on for an hour and were able to ask questions via private chat with the instructor.

At Chulalongkorn university, for cloud computing, the instructor switched to an online exam format. The objective of the class this year was more practical and industry-driven than previous offerings, so upon completion of the class students are expected to potentially become cloud-certified. Therefore, the instructor required students to

(1) watch a few online-learning videos offered by a cloud vendor’s certification program to fill in parts that were not covered in class but needed for certification, and

(2) take the online practice exam offered by a cloud vendor’s certification program.

For computer networks, the instructors had a number of meetings to discuss all the challenges involved in an online exam. In particular, ensuring academic integrity was one of the more pressing factors that led us to our final solution. The questions were multiple choice but required students to do some problem solving before selecting the right answer. Instructors created a large enough exam bank in order to support offering multiple versions of the exam to different students. Permuting and randomizing questions and answers were minimum requirements to support preserving academic integrity. While we could not completely prevent students from sharing with each other, we also used a time-pressure exam format where we split the exam up into 4 parts. Each part was 20-minutes long which was just long enough to complete the work. During the exam, 4 groups of students were online in 4 video-conference sessions with their cameras on. Between each of the 4 exam parts, the instructors gave students a short bio break. We held two practice sessions prior to the exam to familiarize students with the video conferencing tool and the exam format on our LMS. Students were given emergency contact numbers in case anything came up. Overall, the exam went smoothly and only 1-2 students experienced network difficulties participating in the video conference. However, the instructors were not happy with the multiple-choice exam format as they all preferred a method that could better reflect students’ design and problem-solving skills.

At the Faculty of ICT, Mahidol University, the final exam was conducted using the Moodle platform. A separate Moodle website was arranged for the final exam. Students were requested to set up two devices; one for accessing the online exam website, and another for connecting to the Webex exam room. The students were asked to turn on their camera throughout the exam period. Each Webex exam room was organized to accommodate twenty-four students, and two proctors were assigned to monitor students in each room. The Webex private chat permits students to only communicate with the proctors.

Prior to an actual exam, the Faculty of ICT had arranged an online exam trial run allowing students to familiarize themselves with an online exam environment and process. In addition, students had to complete an agreement form (to agree to an honor statement, and exam regulations) before taking an exam. Some of the online exam regulations include:
The students must enter an online exam room half an hour before the exam time to properly set up their camera, and to log in to the exam website. To verify student identity, students must show their face and their student ID on camera for attendance checking. During the exam, students can communicate with proctors or ask questions via a private chat. Proctors must check if students have submitted their online exam before giving students permission to leave the Webex exam room.

For the wireless and mobile computing course with 200 students, a total of eight Webex exam rooms were set up as shown in Figure 8. During the exam period, some of the students experienced poor Internet connection causing a lagging video. However, their connection mostly recovered in a few minutes, and all of the students could maintain their Webex session until they finished the exam.

![Figure 8: Cisco Webex with 25 students per room for proctoring final exams](image)

**Online Exam Question and Format**

The traditional paper-based wireless and mobile computing final exam is a three-hour closed-book exam, which largely consists of short-answer questions (requiring three to four sentences for an answer). However, the online exam was chosen to be an open-book exam, and the exam time was limited to an hour and a half.

During an online exam, it is necessary to lessen the probability of student collaboration through the use of isomorphic questions and randomization, which provide each student a different (but almost equivalent) set of questions. In order to conveniently create and grade multiple versions of the final exam, multiple-choice and fill-in-the blank questions were randomly selected from many question pools. We avoided questions on a level of definitions or generic questions that can be looked up quickly. Furthermore, we reduced the exam availability period to diminish the time students can spend searching for answers, and to prevent students who finish the exam early to share their answers with their peers.

The overall exam results were lower than expected. Only 2% of students submitted the exam before the end of the exam period, but these students did not perform well in the exam. The average score of the exam is 37%. These outcomes may be due to

1. The limited exam period since most of the students could not complete the exam in time.
2. The style of the exam questions, which require students to analyze multiple statements before choosing the most appropriate answer, or select multiple answers that apply.

Although different control measures, together with the increased level of difficulty of the exam can be effective to some certain extent, there are still significant challenges with online exams:

1. It is impossible to be ascertained that there is no exam misconduct, e.g., students can still share their answers through different means, or search for answers online without proctor’s awareness.
2. The costs associated with exam arrangement and in-person supervision can be considerably high, e.g., students were required to set up two devices for the exam, and sixteen proctors were used to monitor students.
3. The online exam format designed to diminish exam dishonesty, and the difficulty level of an open-book exam may affect the effectiveness of student assessment.

4. **STUDENT VOICES**

At Chulalongkorn University on the Computer Network class of 120 students, on the lab assignments, the instructors gave a tool briefing at the beginning of the semester before the lockdown; but some students did not remember about that and voiced it on social networks. That caused the teaching assistants and the instructors to record the lab exercise instruction video clips for reviews as well as offer a live two-hour Webex session with teaching assistants. The instructors then did a survey on the online class management and received the students' feedback. Two weeks after making the video clips available and adjusting the class management from the students' feedback, the live two-hour Webex sessions were no longer needed. That helps put the online class to run smoothly without any complaints.

At the Faculty of ICT, Mahidol University, a survey after the end of semester was conducted from around 200 undergrad students. It was found that the satisfaction toward the online learning program via Cisco Webex received an average score of 3.5 out of 5, while that via Microsoft Teams received 4 out of 5. MS Teams received a higher score due to yielding better video quality and providing other collaborative tools, which help improve student interaction with the instructors and their classmates. Based on the information on Cisco Webex website [22], Webex maximum
bandwidth consumption of sending and receiving video is between 0.5 and 3.0 Mbps depending on the video quality. For the MS Team [23], the maximum bandwidth requirement is only 2 Mbps for HD Group video calling, and only 30 kbps for peer-to-peer audio calling. As a result, students residing in the dormitories and using shared Wi-Fi experienced better MS Teams’s video quality than that of Cisco Webex. Moreover, based on the information from Cisco colleagues in Thailand, due to the unexpectedly high workloads at the beginning of the COVID-19 shutdown, Cisco Webex meeting servers experienced performance degradation. Although later on this issue had been resolved, some instructors already migrated to MS Teams. Some instructors also prefer using MS Teams because of many embedded collaborative tools. However, in terms of the ease of use, Cisco Webex allows instructors to conveniently schedule and create a meeting room, and enables students to join the classroom without any login. In contrast, for MS Teams, instructors have to create a team and invite students to join the created team. Then, instructors can start a video call.

In addition, seventy six percent (76%) of students preferred studying in the classroom to the live online classroom. Most students feel more stressed in-class studying. Regarding the problems or obstacles during studying online classes, 68% of students answered "the Internet connection", 61% answered the "class interaction", others were on equipment, online class software and the study time. For the final exam, most students were satisfied with the multiple choices/short answer format exam that we provided through the Moodle LMS. However, they prefer in-class examinations to the online ones. The biggest obstacle during the online exam was the Internet connection. The shortened exam time, the interaction with the instructors during the exam, equipment readiness are also their obstacles. Many students could not finish all the questions in the final exams because the instructor shortened the exam time in order to prevent students from copying the answers from their friends.

5. LOOKING FORWARD

For activity-based classes like cloud computing, we will proceed with a mix of live and on-demand lectures. Running live activities enables students to have a more natural interactive experience as though they are in the classroom. No changes to the class projects are needed. Moreover, assessment should reflect work done during the semester with less emphasis on paper-based exams.

Specifically for computer networking, we need to rework the labs to provide students with a more realistic environment. The experience using the virtual machines met the learning objectives, but students did not enjoy it as much as when they were working with real devices. We also need to rethink how we will assess students using exams. We are still debating how to proceed next year if we still need to offer the class online.

Student feedback during the first few weeks of online instruction were to have a single learning environment and single video conferencing tool for all their classes. Due to limited time and resources, the university is not able to host a video conferencing system that can scale. We do not even use a single LMS. There are at least 4 different systems in use prior to COVID-19. After explaining a bit of distributed systems and good risk management practice, students understood the benefits of having multiple environments. I still believe this is important as we go forward that we do not rely on a single platform, but rather use a primary and a backup platform for both coordination (signaling) and for video conferencing.

Faculty of ICT, Mahidol University also conducted a survey about the next semester that will start from 10th August. We found that only 40% of students travel to the university via their own private cars, while the rest use public transportation.

We asked students whether they have any problems if we teach off-line at the campus. Some students are concerned about the longer waiting time for the public bus because since the COVID-19 pandemic they have reduced the number of buses. Some students worry about receiving the virus from public transportation. Some worry about wearing masks all day during the off-line learning. It makes them feel sick. However, some of them would like to come to the university, but requires a temperature scan before entering the faculty.

Based on the student’s feedback, the Faculty of ICT has arranged a smart classroom, which offers a hybrid learning environment. To maintain social distancing, a physical classroom will contain approximately twenty students. The class will also be available either via Cisco Webex or MS Team as well. The lecture will also be broadcasted to another classroom next to the main classroom, as well as being broadcasted online. This setting facilitates both students who prefer to study on site with a face-to-face interaction, and students who have traveling and location constraints, and choose to study online.

For the computer network course, which includes almost sixty students per class, an extra classroom will be provided with a live broadcast of a lecture if students could not fit into a live classroom. We will proceed with the same course structure, i.e., the course will consist of lecture-based classes, and multiple lab sessions. To provide better hands-on experience and collaboration, physical labs and co-working spaces will be organized for the students with safety measures in mind. However, the labs will need to be readjusted for students who may want to study from home. Furthermore, we need to rethink about student assessment methods. While online exams are still necessary for evaluating student performance, labs and assignments could as well be utilized to assess if a student has achieved the
learning objectives. Another important aspect is to devise strategies to promote academic integrity and minimize cheating in online learning and exams.

6. COMPARING DIFFERENCES BETWEEN FOUR UNIVERSITIES

Table 2 summarizes and compares the difference of teaching experiences during the COVID-19 pandemic among four universities in terms of the preparation, students' support, tools, and how the exams were conducted.

Table 2: Comparing between four universities

<table>
<thead>
<tr>
<th>Topics</th>
<th>Asian Institute of Technology</th>
<th>Chulalongkorn University</th>
<th>Kasetsart University</th>
<th>Mahidol University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparatio n for online teaching</td>
<td>Announcements on scheduled Zoom class meeting setup for instructors and Exam.net for examination s.</td>
<td>Instructors shared teaching experience via their FB group.</td>
<td>Instructors shared their problems experience s through meetings via MS Teams</td>
<td>The faculty provided workshops for online teaching and instructors shared their problems experiences through MS Teams</td>
</tr>
<tr>
<td>Teaching Tools</td>
<td>Zoom</td>
<td>MS Teams, Cisco Webex, and Zoom</td>
<td>MS Teams, Cisco Webex, Google Meet</td>
<td>MS Teams and Cisco Webex</td>
</tr>
<tr>
<td>Free Internet SIM card for students</td>
<td>-</td>
<td>Offered by the university</td>
<td>Offered by the faculty</td>
<td>Offered by the university</td>
</tr>
</tbody>
</table>

7. CONCLUSIONS

We have learnt from the COVID-19 pandemic that most students would prefer face-to-face learning to online classes. However, students are also saying that online classes give them chances to review recorded lectures whenever they like, which is something they were unable to do before in most classes. This, therefore, suggests that students should be given course materials in forms of lecture videos apart from lecture slides and textbooks. In addition, a survey conducted by Kasetsart University shows that a majority of students prefer pre-recorded lectures to live sessions because they can adjust their viewing speed to best suit their learning behaviour. Face-to-face meetings that maintain proper social distancing or live broadcast sessions should then be used for hands-on activities where interaction between instructors and students are required.

It is almost a consensus among network-related course instructors that learning computer networks cannot be truly complete without working with real equipment. Hence, physical lab work is still necessary. When social distancing is mandatory, it is unavoidable to limit the number of students participating in physical class. Some courses adopt a hybrid approach where students take turns attending physical class. Each week, half of the students work on the lab on site, while the other half practice the lab in a simulation tool such as Cisco Packet Tracer [3].

The online open-book, open-notes exams were proven to fail as a method to evaluate the undergraduate students’ learning performance. For the next semester to come, different evaluation methods are needed for assessing student’s class performance. While examinations have been a norm for evaluating students' knowledge for a long time, they are not the only means to assess students’ learning outcomes. A survey shows that many students prefer project-based assignments to taking examinations because they believe it is a better measurement for how well they can materialize what they have learnt from the class, even before COVID-19. In addition, as feedback should be given quickly and more frequently, short weekly assessments should be encouraged instead of waiting until the midterm and the final exam. Existing tools that facilitate automatic grading and discourage student cheating should be leveraged as much as possible.

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