

Adapting Teaching of a Software Engineering Service Course due to COVID-19

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Abstract—The COVID-19 pandemic has impacted almost every sphere of life. Higher education in Australia was similarly majorly impacted, and due to the sudden necessity of ensuring physical distancing, on campus teaching became impossible. Most of the higher educational institutes in Australia moved to using a distance education mode to continue delivery of teaching with barely a few weeks warning. This article presents experiences moving a data structures and networking course taught to Software Engineering students at an Australian university during COVID -19 pandemic to online delivery. Due to the nature of the course and student cohort, a number of challenges were faced teaching the course in online mode compared to that for which it was designed. We summarize key lessons learned and propose some guidelines for future course design to take advantage of online learning while maintaining learning outcomes.

Keywords—Distance Education, COVID-19, networking and security,

I. INTRODUCTION

Distance education is an alternative to traditional face to face teaching [8]. Distance education uses the facilities of information technology to deliver teaching content and conduct necessary assessments. This concept mitigates the need for students and teachers to be physically present at one location. Distance education has been used for many years, more so at some Universities than others. However, the benefits of this concept were extensively realised in the changed circumstances caused by the COVID-19 pandemic. Educational institutes all over the world had to shut down classroom-based on-campus teaching, sometimes with barely a few weeks notice. Most educational institutes rapidly introduced distance education as the only viable alternative to support continued teaching.

However, the suitability of existing courses to be delivered in online mode and student access to technology were major challenges that can restrict the success of this mode of education [1]. The experience of teaching existing courses designed for classroom-based on-campus delivery in distance education mode taught many teachers important lessons. This paper describes the first author's experience of teaching an IT course at an Australian university during the COVID 19 pandemic. From the lessons learned we propose some guidelines that can help improve design of such courses for the future.

We first provide a contextual overview of the case study course. We then discuss its traditional delivery approaches and (rapidly) revamped delivery approaches due to COVID-19. We discuss key challenges faced and lessons learned from this experience, related work, and conclusions from our experiences.

II. THE COURSE

We describe the experience of redesigning and teaching the course COS20012/COS70007: Data Communications and Security in Semester 1 2020 at Swinburne University of Technology at Melbourne.

A. The course

The course is about the basic concepts of digital data communication. The main concepts covered in the course are very broad, including introduction to networking concepts, details of the five layers of the communication model, ethernet and wireless communication, security of information and writing network programs. Undergraduate students can take this course as part of their Bachelor of Engineering (Software Engineering) (Honours) degree or Bachelor of Science (Computer Science and Software Engineering) degree. Post graduate students can complete this course as part of their Master of Information Technology (Professional Computing) degree in the Software Specialization. The course has “Object Oriented Programming” and “Technical Software Development” as pre- or co-requisite courses. All students thus enter with significant programming and basic software engineering knowledge. Students doing their Bachelor of engineering (Telecommunication and Network Engineering), Bachelor of Engineering (Electronics and Computer Systems) or Bachelor of Engineering (Robotics and Mechatronics) and Bachelor of Science (Computer Science and Software Engineering) may also complete the course.

B. Student Demographics

Undergraduate and postgraduate students who enroll in this course are familiar with different forms of digital communications and have some hands on experience with different data transfer tools. However they need to be taught how the underlying mechanisms work. Some students, especially from Software Engineering-related specializations, may have very limited networking experience.

C. Learning Outcomes

The expected knowledge we want the students to possess once they successfully complete the course are :

- Can explain the complete process of transferring data from one host to other within the same subnet and also using public network
- Can explain frequently used protocols

- Can define confidentiality, integrity and availability features of data
- Can recognize different security attacks
- Can devise measures to protect against the security attacks
- Can write network programs

D. Pre-COVID-19 Delivery

Old Engagement Model: The course was designed to be delivered and was historically run in a face to face mode with a very hands-on teaching approach. This is particularly important for many students from a software-focused background who may lack much experience with communication networks and security concepts. There is one two-hour long weekly lecture conducted in a lecture theater and three two-hour labs conducted in computer laboratories with diverse networking software and hardware installed on the computers. Students were expected to attend the weekly lecture and take one weekly lab. The teacher would provide a face to face lecture on a pre-specified topic every week. The lectures were video recorded for students to view later on. The lecture was scheduled on Monday at 10:30 am. The three labs followed at 12:30, at 2:30 and at 4:30.

Students had to complete the lab within a time limit and get it reviewed by the lab tutor. If the lab work was partially done, the lab tutor usually gave instructions, such as compulsory remaining task and timeframe to complete, to individual students. The first lab was designed to set up the computing environment for the rest of the semester. Students were instructed to use their own computing device or use a Virtual Machine (VM) setup within the lab computers to install the necessary software. Although the lab computers had the software installed by the network administrator, students do not have administrative access to the computers due to security reasons. The lab was designed to provide students with hands on experience on how to set up this environment, and this was particularly important for students coming from software engineering courses.

Developing programs to address different network issues as well as run on layered network infrastructure is an essential part of the course. Most of the labs were designed to capture different network communication traces and to analyze these to solve preset network related problems. This was particularly crucial for software engineering students to get idea of network communication problems and to come up with solutions to address those. This was important to achieve intended learning outcomes related to understanding network communication and writing network programs.

Old Assessment Model: There were five assessments for the course: two tests, two assignments and a final exam. Test 1 and test 2 were paper based and were scheduled to be conducted in week 6 and 11 respectively, during the lab. Assignment 1 was divided in two sections: Research and Network Programming, submission deadline in week 6, and the demonstration of network programming part was scheduled to be done in the week 7 lab. Assignment 2 was divided in two parts: Network Trace Review and Network Programming. The submission deadline was week 11 and the demonstration of

network programming part was scheduled to be done in the week 12 lab. The final exam was a paper-based, in person invigilated exam to be conducted during formal examination period after the teaching delivery weeks. The assessments were designed to verify all intended learning outcomes have been met by each student. Since the course was taken by a diverse student cohort coming from software engineering, network engineering and computer science disciplines, the assessments were designed according to the Engineers Australia competency framework levels.

E. Post-COVID-19 Delivery in 2020

The first three weeks were conducted in traditional face to face teaching mode as planned. However, due to the COVID-19 outbreak in Australia, the university decided to shut down all its campuses in line with State Government directions. The university introduced distance learning for all its courses. After week 3 there was a “pause week”, where teachers and students had very limited time to prepare for the new mode of education. From the following week onwards, the semester continued with all courses being online.

Since the course content was prepared for a classroom-based on-campus teaching, changing all content to fit online mode within one week (the pause week) was very difficult. However, a number of changes were made for engagement and assessment. This was particularly challenging given the type and nature of the course content. Most of the students coming from software engineering and other engineering major disciplines are familiar with software and other infrastructure design and development concepts. They needed assistance to apply these concepts on network communication frameworks.

New Engagement Model: Due to the network requirements and bandwidth expenses a live lecture at a fixed time every week was considered not to be the best option to replace the classroom lectures. Instead a number of alternatives were adopted. Students were provided with a recorded full lecture video from the previous semester for the first two weeks of online teaching. The benefit was student could watch the full video at their convenient time. However based on student feedback, from week 6 onwards the lecturer recorded small videos on key topics every week and provided those to the students with the previous lecture recordings. A live discussion session was also arranged every week where the lecturer discussed about the key topics of that week and students provided their feedback. Online polls were used almost every week during the live sessions to get feedback from students.

Lab activity instructions were changed so that students could capture and record network traces on their own computing devices. Answers to the lab problems were modified to be open ended, as a modified assessment mode. A set of pre-captured network traces was also supplied to students to analyze and respond to the lab questions, if they could not or preferred not to capture network traces from their own devices. Answers were closed ended for this option. The submission deadline for lab work was extended a week, so students could complete the lab work anytime during the week. They had to however submit before the commencement of the next week.

Students were encouraged to review the different lecture recordings provided for a specific week's learning and the lab requirement in the morning. The first online session every week was scheduled at 12:30 every Monday, with a view that the students review the contents before the session and bring their questions and/or key topics to discuss to this session. The lecturer usually discussed the key topics from that week in the first sessions on Monday. The next session was scheduled at 2:30 Monday. In this session the students discussed their lab work with their lab tutor. In the next one or two sessions scheduled later the week, students brought their questions and these sessions were conducted as more like an interactive session driven by the students.

In weeks 5, 10 and 11 some extra sessions were scheduled to discuss about the tests and assignments. Adhoc consultation sessions were scheduled during a week earlier than the assessments were due and also on request

New Assessment Model: Tests were modified to be conducted using an online platform. The first test was conducted as a time boxed online quiz that contained short free form open ended answers. Students had to write their answers on the rich text editor provided by Canvas LMS platform. The second test was conducted to be a time boxed offline test, where the questionnaire was provided as a document. Students could write the answers in the document or print and write the answer on paper copy and then scan and submit it. The test was time boxed and had to be submitted within a given time limit.

The submission deadline for assignment 1 was extended to week 7 due to the disruption caused by the COVID-19 outbreak. Initially the lecturer decided to execute the programs offline and conduct assessment. Instead, due to challenges described in the next section, a number of online sessions were arranged where students demonstrated their programs. The online sessions used the "break out rooms" feature from Collaborate Ultra on the Canvas LMS platform to create these demonstration rooms. Students were called one by one to these rooms and to share their screen with the lab tutor and demonstrated their program. Based on experiences from assignment 1, the demonstration was planned and announced to be done online for assignment 2. Three sessions were scheduled in week 12. A list of students who need to attend which session was published well before week 12.

III. KEY CHALLENGES

With the introduction of adhoc distance learning within a notice of one week, delivering this course online was very challenging. The content of the course was designed to be delivered in synchronous way, and distance learning is usually more suitable for asynchronous learning approaches. All necessary redesigning of the contents could not be done within a week. Therefore, we took an iterative approach where the students were considered as the drivers of the changes. Students were encouraged to share their experiences every week. The lecturer spent some time every week in the first live session, discussing and particularly asking students about their learning experience in new environment.

A. Challenging Engagement

As found by Ouhbi and Pombo [11], engagement is a major challenge in distance-based computer science and software engineering education. From the experience of teaching this course for past 4 years, the teacher thinks that this is a major challenge even in face to face classroom-based teaching. To improve engagement, the teacher hosted online quizzes through Kahoot.com in every lecture. This improved student engagement during lecture over the past few years. With the introduction of distance education this type of interaction became more difficult. Student engagement became the most challenging aspect of teaching this course in 2020.

B. Stressful Transition

The first announcement came from university that the campuses will be shut down and no face to face teaching will be provided during semester 1 2020, instead all teaching will be moved to distance mode. Students were advised that the teaching will be paused one week across whole university while the teachers would prepare for the new mode of teaching. This transition time period was stressful for some students. A number of student comments obtained through a brief survey conducted by the university illustrated this. Examples of challenges include lack of clear messages, how to use the online systems for labs and assignments, how the unit would progress, the changed submission dates, and concerns about how they would be able to achieve learning outcomes and passing grade.

These comments indicated that the limited communication media available between the students and the teacher needs to be used more efficiently to reach out to all students. It also indicated that students need to be frequently reassured. To address this, at least three routine announcements were sent every week summarising the week's activity, describing what is coming next and reminding of the forth coming assessments. Students were sent a number of reminders before every assessment was due. They were also frequently reminded in the live sessions to regularly check the new announcements and to turn on notification for new updates to this course.

C. Asynchronous Learning

The recorded videos from previous years were too long, and it was difficult for some students with limited internet connectivity to download the full two hour recordings, as indicated by the student comment: "*We are not having proper internet connectivity. If you can help me in achieving the same*". Newly recorded short lecture videos on key topics were well received by the students for first three weeks. Then they reported that it was difficult to keep motivation to watch these offline, as they preferred more interaction with the teacher.

To address this, a flipped classroom approach was adopted instead. Based on this, from week 6 onwards one extra catch up session was added where students selected the topics and the teacher gave small talks on those topics. The full length lecture recording from previous semester, smaller new videos on key topics, live discussion session and a catch up discussion session – all those available resources were helpful for the students and facilitated asynchronous learning. A student comment reflects this: "*<Name of the teacher> is doing a fantastic job with this*

unit despite the disruption! I actually like the approach of listening to the lectures in our own time and then having a discussion session to make sure we understood the material. I'm really enjoying this unit and I look forward to learn more".

However it was noticed that the students gave up on studying the topics themselves and listed almost all the topics and requested the teacher to go through these in the catch-up sessions! The catchup sessions were welcome by the students, some comments indicate that: *"Thank you so much for taking the time to review the material with us!"* and *"Yeah it helped a lot, thank you very much for your time and this catch up lec(ture)"*.

Students had more flexibility in terms of completing their lab work. However it was difficult for the lab tutors to verify the lab submissions were done on individual student network traces. The students were asked to submit the traces with their lab submissions to help the tutors. It was also noticed that most of the labs were submitted just before the (modified) due time.

D. Offline program demonstration

For the network programming part in assignment 1, the teacher initially decided to execute the programs offline and conduct the assessment. While reviewing the network program offline, a lot of exceptions were generated that needed explanation from the students. Lab tutors wanted the students to clarify (and sometimes modify) bits of code to make overall assessment. However, this was not possible in the offline mode. When the experiences were shared with students, one student proposed to conduct the demonstration online: *"It sounds like you have a lot of extra work having to run the code yourself. In one of my other subjects, we were asked to do a demo through collaborate ultra and it worked really well."*

Based on student requests, a number of additional online program demonstration sessions were arranged. This modification was student driven. However, it took two weeks to come in to effect and as a result the publication of first assignment marks were two weeks delayed. The experiences helped to better administer the demonstration and assessment of the second assignment.

E. Open Access Tests

The tests and the final alternate exam were conducted through an online platform in Canvas and as such had to be treated as open book access. During reviewing of the test answers, it was noticed that due to the open accessibility of resources during the test, students often provided information that was not directly taught in the course. Since the course is network communication and security related, a lot of information is available on the internet. Sometimes the validity of the information provided in the responses to the tests was difficult to validate by the teacher. From this experience students were asked to provide references in the final alternate examination, if they provide any information outside of the reference book or the teaching materials provided.

F. Nature of assessments

The initial plan pre-COVID-19 was the final assessment would be an in-person, invigilated paper-based examination. However due to the impact of COVID-19, conducting

invigilated paper based examination was impossible. A number of alternatives to this assessment were reviewed including problem solving online questionnaire, practical task, team/individual project, research task, continuous assessment and oral unit defense.

A continuous assessment would best suit the nature of this course. However this was not practical to implement after week 6 when the final assessments were reviewed. A problem solving online questionnaire was chosen to replace the invigilated paper based examination. Preparation of this test was another challenge. A lot of the assessments were initially related to network communications basics and possible security threats. Designing a problem solving questionnaire for these concepts was difficult. A lot of effort was devoted to design imaginary network communication and security related problem scenarios where students could apply learned basic concepts to solve the problems. The problem scenarios were difficult to come up with in the limited time we had.

G. Distribution of grades

The overall distribution of the final grades was almost evenly distributed with skew towards Distinction and High Distinction grades. This is very similar to the previous semester when the course was delivered in face to face mode of teaching. However a major difference noticed was that, there were almost half the Distinction grades and almost double the Credit grades compared to last semester.

A potential reason for this difference in grades is that some students may have struggled to cope up with the changed mode of education. Those students may have been more comfortable with classroom-based learning and as a result could only secure Credit grade in distance mode of education. Students may have struggled to keep focused given the limited interaction with the teacher in new mode. The reason can also be that the later student cohort was different. The actual reason for this is impossible to be verified. There was slight (4%) increase in the course fail rate as well. This was mostly the drop outs who didn't continue after the first assessment.

IV. LESSONS LEARNED

Neither students nor teacher was at all prepared for this change of mode of education. A number of lessons were learned from the experiences of making this rapid change. The main approach taken was that the students needed to be the driver for any new measure taken. Students were frequently asked to comment on how they perceived the way teaching was delivered. Improvements were made based on this student feedback. Thus, all the measures taken to teach this course in a distance education mode could not be decided at once. Every measure was taken based on evolving teaching and learning experiences and were discussed with the students before being brought into action. Some measures used were proposed by the students themselves. Figure 1 shows how an incremental approach, driven by student feedback, was adopted to improve the course delivery in distance education mode. Every experience taught us valuable lessons. A major realisation was that every course should be designed to fit with a mixed mode

of teaching, so that if there is any sudden change in mode of teaching delivery, this can be done with minimum disruptions.

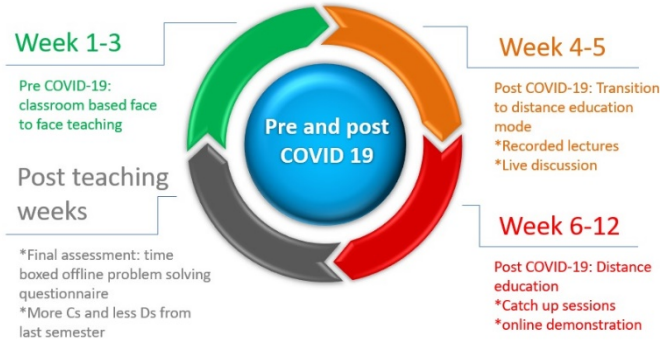


Fig. 1. Highlights of changes

A. Communication from the teacher is critical

During week 3 and 4 students were very stressed about the transition, while the teacher was working in line with university guidelines to prepare for distance mode of teaching. Meanwhile announcements that came out from university to all students were not sufficient. Students needed reassuring messages from the teacher. As soon as this was mentioned in a student feedback, the teacher posted number of announcements indicating how we will cope up with the situation.

Lesson 1: Students should be clearly communicated with about any changes made to the mode of teaching by the teacher in line with University announcements

B. A regular pattern of communication can do the trick

The first few weeks of distance education indicated students were not getting information needed through announcements. The reason was they were not checking the announcements and resultant emails. Having all other modes of communication shut down, the online announcements with emails sent to all students was the only effective medium. The teacher sent frequent announcements and soon derived a pattern of announcements, i.e. every Monday morning greeting message, every Thursday evening next task list and so on.

Lesson 2: As soon as the students knew when new information announcement (and email) is coming, they started checking at that time and soon conveying information became easier.

C. Long lecture videos are too bandwidth expensive

Full length recorded lecture videos were too long and bandwidth expensive for students. Most students couldn't or wouldn't want to download and watch the long videos.

Lesson 3: Lecture materials should be prepared in a way that reduces the necessity of recorded videos. If recorded videos are absolutely necessary, those need to be smaller.

D. Recorded videos were less motivating

Student feedback indicated that they struggled to keep motivation up while watching the recorded videos. To address this, an additional catch-up session was arranged every week, where students could discuss about their learning. The teacher

also gave an overview of the week's contents in a regular discussion and Q&A session.

Lesson 4: If possible recorded resources should be replaced by interactive sessions. If it is absolutely necessary to record videos, those should be made in a way that students do not lose motivation.

E. Assessment of open access tests is challenging

Since the tests and the final alternate assessments were open access online and offline tests, students could access different resources other than the course contents only. Due to the nature of the course topics, a lot of information are available on the web. Students sometimes provided information in response to the open access tests that fell outside of the scope of the course topic. Verification of the quality of such information provided was challenging for the teacher.

Lesson 5: As soon as the difficulty was realized in the first test, appropriate instruction was provided to students for further tests. The instructions stated to provide references to any information they provide outside of the scope of this course in the successive assessments. We recommend that any open access assessment should instruct respondents to provide appropriate references.

F. Designing problem solving questionnaires is difficult

Due to the nature of the course topic, designing a long problem-solving type of questionnaire test was difficult. The teacher had to devote considerable extra effort to design imaginary scenarios where the subject topic could be applied.

Lesson 6: Nature of assessments should be selected in a way that this should not depend on the mode of teaching. Assessments could be designed well before the semester commences to fit different circumstances.

G. Program demonstration should be done online

Any program developed by students is best to be demonstrated by the students themselves and be assessed in front of them. The teacher ran into environment related problems while checking the problems offline.

Lesson 7: If not possible to be conducted in the physical presence of the students, program demonstration sessions need to be arranged online where students will be present and can explain their code. The teacher also has the flexibility to request students to change their code if needs be.

H. Students should be taught to setup own environment

The first lab was designed to help students to setup their own environment with necessary network configurations parameters. Due to not having administrative access on lab computers, they were advised to do this on their own computing device or VMs. This hands on experience of setting up their own environment was really helpful, specially for software engineering students, in the new mode of education. This reduced the number of requests for assistance from students.

Lesson 8: For programming and other technical courses requiring hands on experience, students should be taught to setup their own environment.

V. RELATED WORK

With the advancement of Internet technologies, “distance education” has spread widely. Distance education refers to a teaching and learning arrangement where teachers and students do not need to physically be present at the same place. This is a variant of traditional “correspondence education” [8], where students do not need to physically meet with the teacher, but correspond via learning materials sent to them. Students usually learn at their own pace. In distance education teachers prepare learning materials as well as schedule learning and teaching activities. This is not as flexible as in correspondence education. Students need to respond to the learning and assessment activities according to the schedule. The learning materials are provided through online platforms. A wide-spread benefit of this approach is that students can complete learning and assessment activities from their own home. Due to this benefit, distance education has gained massive popularity. Most universities now offer courses as distance education. There are universities all over the world who offer online courses only.

Massive Open Online Course (MOOC) [10] is a related concept built on distance education. In a MOOC environment along with predefined recorded lectures, learning and assessment materials, there are also forums and other platforms to get in touch with the teaching team and other students. This also facilitates quick and continuous feedback process on student work. Online MOOCs have been trialled to teach aspects of software engineering [14].

Various approaches to teaching aspects of software engineering at a distance have been attempted, particularly in recent years [13]. These include teaching process e.g. eXtreme programming [12], projects [3], capstone projects [9], and studio subjects [1]. Indeed as software engineering is often practiced at a distance, learning distributed, collaboration skills could be argued to be a highly valuable outcome of a SE degree [7]. Other engineering disciplines have experimented with distance teaching. This includes computer network teaching, often using significant virtualised infrastructure to deliver student outcomes [5][4].

There are however some serious limitations to distance education. Access to relatively high speed internet and reasonable laptop/desktop computer are needed. This can increase the digital divide for students without such access [6]. Failure of network connection or computer can interrupt lectures, practicals and online assessments [1].

VI. CONCLUSIONS

The course was designed to be delivered as a face to face learning experience. However, as soon as adhoc distance learning was introduced, a lot of assumptions were changed. A continuous feedback process was implemented and based on student feedback, a number of adjustments were made on how the course was delivered during the semester. These adjustments were driven by students, and many indicated they were satisfied with the outcomes from the changed course.

The experience of teaching the course in pre COVID-19 scenario and in the changed context due to COVID-19 helped us to identify many areas of course improvement for the future. A software engineering course design can follow our proposed

guidelines to make the course more suitable for a diverse student cohort, including those who prefer classroom-based learning as well as those who prefer distance learning. This will also ensure that minimum disruption is caused to teaching due to any changed circumstances, such as COVID-19 pandemic.

Delivering a course on networking and security to software engineering students in distance mode is challenging when many have limited networking background, some limited ability to capture and analyse their own network traces, and when a course designed for “hands on” learning becomes very hands-off. We couldn’t leverage virtualize networking platforms [5] in the time available for our course redesign, but want to incorporate these more fully in the future.

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