How to Better Teach Computer Networks to First Year Engineering Students Post-pandemic, A Case Study

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Abstract

The COVID-19 pandemic has significantly impacted the higher education sector, leading to changes in the way courses are taught. In this study, we explore how the transition from remote learning to in-person classes can be leveraged to enhance teaching and learning in the post-pandemic era. Specifically, we present a case study that evaluates the implementation of post-COVID changes in a large computer networking course. We demonstrate that a switch from remote to physical labs, along with an increase in active learning and spaced practice, can yield positive results. Our findings indicate that while the overall impact on performance may be limited, the time spent on lab activities and student satisfaction improved in our case study.

Sammanfattning

COVID-19-pandemin har haft en betydande inverkan på högre utbildning, vilket har lett till förändringar i hur kurser lärs ut. I denna studie undersöker vi hur övergången från distansundervisning till undervisning på plats kan utnyttjas på ett klokt sätt för att förbättra undervisning och inlärning i en post-pandemisk miljö. Vi presenterar en fallstudie som utvärderar implementeringen av post-COVID-ändringar i en stor kurs om datornätverk. Vi visar att en övergång från distans till fysiska labb, tillsammans med en ökning av aktivt lärande och tidsfördelad repetition, kan ge positiva resultat. Våra resultat visar att även om den övergripande effekten på prestationen inte förbättras, så blir labbaktiviteter effektivare och tar kortare tid och studentnöjdheten ökar i vår fallstudie.

Keywords: *post-pandemic education; computer networks; active learning; spaced practice.*

1 Introduction

As a consequence of the unforeseen recent COVID-19 pandemic, many if not all higher education courses had to abruptly transitioned from an in-class model to being held online (Adedoyin & Soykan, 2020). Two years after its outburst, the reverse move is being implemented as courses forced-held online are returning to their on-campus version (Greenhalgh, Katzourakis, Wyatt & Griffin, 2021). Teachers can take advantage of this shift back to in-person learning as an opportunity to reflect on their teaching and learning strategies and learn from their experiences during the pandemic. In this context, this case study proposes to investigate the implementation and outcome of pedagogically designed post-pandemic changes in an introductory networking course given at Chalmers University of Technology. Our study focuses on the following research question "How can we better teach computer networks post-pandemic for first-year engineering student?"

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Motivation & Scope: Several studies have presented lessons to learn from the pandemic and the increase use of digital or hybrid education, cf. Fayed och Cummings (2021); Rapanta, Botturi, Goodyear, Guàrdia och Koole (2021); Zhao och Watterston (2021). However, for labs, relevant material appear lacking concerning the shift from remote to newly created physical content when the opposite move is well documented, see e.g. Corter, Esche, Chassapis, Ma och Nickerson (2011). This motivates the present study, focusing on student understanding of the cogs behind networking protocols and driven by measurable objectives. The challenging task of quantifying improvement in student understanding is avoided on purpose, but our reflections do provide some meaningful insights on the matter. The study aims to provide guidance for a better load-balance of student learning time in the post-COVID era. In particular, reducing the time spent on labs for equivalent *Learning Outcomes* (LO) reduces student frustration from being blocked on unnecessary hardware issues. Only compulsory course elements are used in the study. Due to lack of data, comparing changes with pre-covid times is out of scope of the present study.

Method & Objectives: To answer our research question, we implemented and evaluated several updates in the course activities taking advantage of the shift from online to on-campus or hybrid education. Updates were designed following three main pedagogical approaches: *Active Learning* (AL) (Freeman m. fl., 2014), *Practice Test / Spaced Practice* (PT/SP) (Dunlosky & Rawson, 2015) and *Peer Instructions* (PI) (Biggs, 1999). AL is used to activate students during all the course activities and in particular during the lectures. PT/SP is used in weekly exercises format for balancing students and *Teacher Assistants* (TA) time and improve learning. PI aims for students with different understanding level to help each other with known mutual benefits. After identifying specific areas of improvement that could benefit from on-campus education, we guided the design of the updates by the following three objectives. **[O1]** Setting-up new physical labs after pandemic years, with novel parts involving interactions between student groups to promote PI and AL. The update encourages different lab groups to "synchronize" with faster groups being led into helping out slower groups. **[O2]** Making useful in-class exercise sessions, with the adoption of a new format to better foster live PI between students, aiming to enhance a weekly training following a PT/SP approach. The sessions are designed to scale through using automatic grade reporting for groups. **[O3]** Switching to in-class quizzes during lectures, and evaluating AL between covid (online) and post-covid (in the classroom) lectures.

Evaluation & Results: Feedback was collected through an end of course evaluation survey and an additional short survey to gather lab-specific feedback, sent during the last study week on *Canvas*, the local *Learning Management System* (LMS). We evaluate the updates using a mixed-methods approach combining qualitative methods with semi-empirical data. Based on the collected data (from surveys, quizzes and LMS statistics), student feedback and the teacher's reflection, the proposed updates did succeed in reaching the set objectives. In particular, our case study highlights several interesting leanings when returning our computer engineering courses to campus-based education.

2 Methodology

Background The studied course is an introductory computer networking course held in 2022, part of the 5-year computer engineering curriculum with ca. 200 students. LO cover how packet switching networks and the Internet work around the most popular networking protocols. Due to the pandemic, the course was held entirely online in 2020 and 2021 following a traditional format (lectures, exercises and labs) coupled with an online exam. Quizzes during lectures were introduced in 2020 to enhance AL following Felder och Brent (2016) and Christie och De Graaff (2017). In 2021, automatically graded exercises held in the LMS were introduced to let the students practice asynchronously with the content.

Figure 1: Content of the student lab box[2].

Figure 2: Students in a collaborative lab.

Figure 3: Quiz views in the LMS for short questions: (a) before submitting, (b) after submission (score per question) and (c) after the session (guided solution).

Labs (O1) PI and collaborative labs were developed in the context of switching back to physical labs after the disposal of old hardware. New basic networking equipment[1] were acquired as presented in Figure 1. The physical labs[2] were mostly following the same content as the remote labs (half performed using the students network card, and half done in simulators). Additional parts were added to take profit of the on-campus setting to enhance collaborations between several lab groups up to the entire classroom (cf. Figure 2). The additions focus on including one problematic aspect which engages the group as a whole according to the concept of collaborative PI (Magin, 1982).

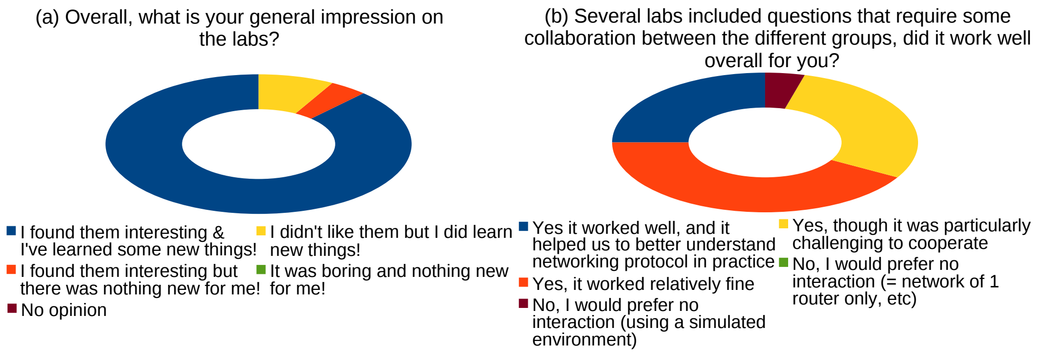
Exercises (O2) Conforming to proven experience (Crouch & Mazur, 2001), PI is best fostered in group exercises. Weekly exercise sessions aimed to review concepts from the lectures (short questions part) and apply the notions in concrete settings (problem part). The sessions were held on campus using automatic grading within the LMS and a TA helping students in solving the exercises and providing correction at the end of the session. Every student was allowed to submit and could see in return her/his correct and wrong answers (leveraging the different views in the LMS, cf. Figure 3). A grade was automatically calculated for each group based on individual submissions, and all exercises together provided up to 10% of the exam points as bonus points. The duration of the sessions and the difficulty of the problems made it essential for the students to collaborate in order to reach higher scores in the allocated time. Thus, the purpose was twofold: (1) to give an incentive to students to try the exercises on a weekly basis, and (2) to promote PI.

[1]On Figure 1: Raspberry Pi400 "keyboard/computer" (1), Pi4 (2), 5-ports switch (3) and 3-ports router (4).
[2]All labs manuals are available at `http://www.cse.chalmers.se/~duvignau/datakom/`.

Lectures (O3) To activate students after 10-15 minutes of lecturing time, quizzes are used for AL in the physical lectures. Each AL question relates to the previous lecturing point (usually, the most important element to understand). We use statistics extracted from the quiz application (mentimeter) as basis for our analysis. Our evaluation allows a reflection if the return to on-campus education triggered any challenges that should be addressed.

3 Results

Figure 4: Student feedback on (a) general labs impression and (b) the collaborative parts.



O1: Collaborative labs Table 1 summarizes the aggregate answers to the lab-specific survey. Concerning student satisfaction and learning (cf. Figure 4), a large majority (88%) of the students found the new labs interesting and assess that they have learned new concepts through them. For most students, the collaborative parts worked well or relatively fine with some students reporting better understanding of network protocol in action but also some challenges in collaborating on those parts. The total number of lab re-submissions was almost halved between 2021 (online labs) and 2022 (physical labs). Concerning completion time, students reported an average of 4h (matching the intended target), but we note large differences between the labs and among student reported answers. Contrary to previous pandemic years, no excessive lab duration was reported in the final course evaluation. Most students reported a difficulty adapted to an introductory networking class. TA also reported less hours spent on grading the labs as part of the check was done during the physical sessions. Student feedback (SF) praised the labs in the course evaluation:

SF: *The labs were great, and it was fun to learn-by-doing. [...] this was also fun because it definitely deepened my understanding of how networks work.*

SF: *I have to say the labs in this course have done a really good job of building more of an understanding and intuition for the concepts covered.*

SF: *I think the labs were great. The labs give a more practical view and understanding of the theoretical knowledge.*

SF: *I enjoyed the labs. They made me understand the material better, and it felt like what we learned during them was something you actually could have use for outside of school.*

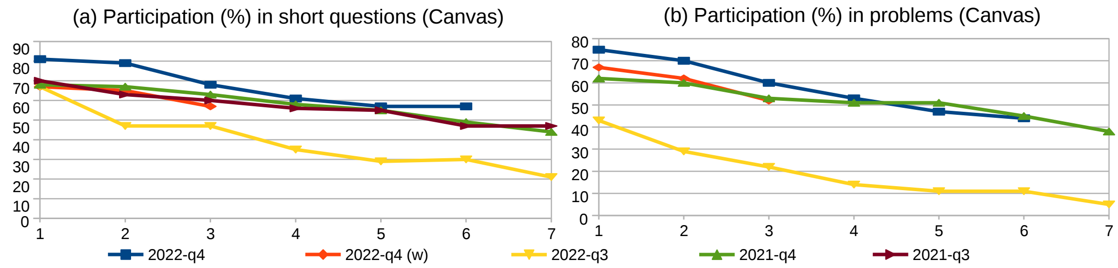
Table 1: Summary of the new labs with student reported time and difficulty (2022).

Lab	# of tasks	# of questions	# of coop. tasks	Average duration (h)^a	Average difficulty 1-5^a	# of resub. 2021	# of resub. 2022
1 – HTTP/DNS	7	24	0	3.67 ± 1.24	3.08 ± 0.56	8	3
2 – TCP	8 + 1	23 + 2	1	4.5 ± 1.2	3.17 ± 0.72	5	2
3 – Routing	7 + 2	25 + 2	5 + 2^b	4.13 ± 1.26	2.89 ± 0.95	6	5
4 – Switching	10	30	5^c	4.05 ± 1.1	3.11 ± 0.92	3	0
5 – SDN	7	22	0	3.59 ± 1.27	2.81 ± 1.06	7	6

^{a} ± Standard Deviation. ^{b} Tasks require 4 lab groups. ^{c} Tasks require the entire classroom.

O2: Efficient in-class exercises Participation in online quizzes within the LMS has risen in 2022 by 10 pts on the first sessions; cf. Figure 5, observe that the student cohort is different in quarter 3 (Q3). The updates have been successful at bringing students at the exercise sessions despite having an exam in a different format. By tracking participation on a weekly basis, we observe that students have better spaced their practice. Individual scores obtained by the students were in line with previous years.

Figure 5: Participation in (a) short questions, (b) problems and at week 3 for 2022 (w).



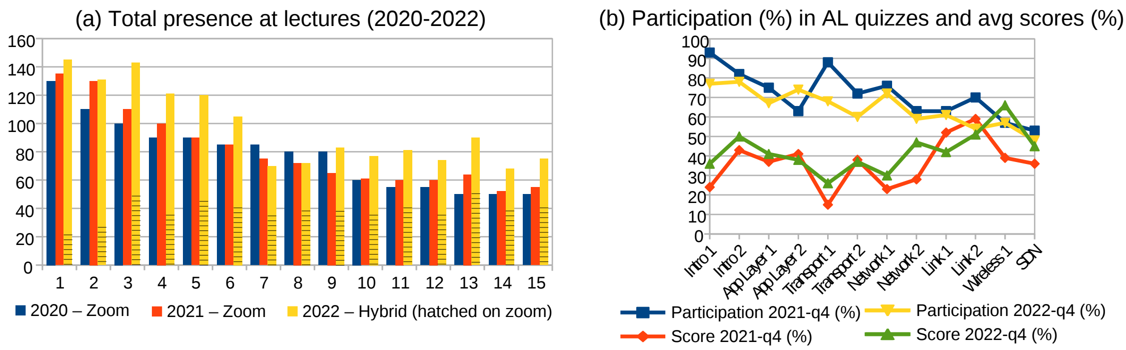
O3: AL in physical lectures We note that the hybrid format brought slightly more students to the lectures (cf. Figure 6). When analyzing the fraction of students taking part in AL quizzes, we observe similar trends in 2021 and 2022. We only note a -6% difference of student taking part in the quizzes which may be due to some students preferring not to switch focus between their lecturing notes and their mobile phone in physical versus a remote environment. Students have often praised the quizzes used in lectures for providing break, maintaining their focus and helping with teaching and learning, e.g.

SF: *I liked that during the lectures questions on the currently covered topics were asked in a quiz. This assisted in the learning of the course's contents.*

SF: *The quizzes during lectures kept me alert and motivated me to stay focused.*

SF: *The [...] quizzes especially since they force you to be focused and present during lectures.*

Figure 6: Presence in lectures and participation in AL quizzes (%) along AL scores (%).



4 Discussion and Conclusions

Our results advocate that well-designed on-campus activities can make student time more efficient with a workload more spread throughout the study period, reduce student frustration and raise student satisfaction, with comparable learning scores to the online setting (assessed by exam, lecture quizzes and exercises). The collaborative physical labs worked well and were more efficient. As an instructor, the teacher did notice PI taking place between more advanced groups and slightly slower groups. Using synchronization points did encourage PI behaviors among students but their challenging nature makes us advise to limit them to e.g. 4 lab groups. Concerning the exercise sessions, the format did favor PI that was observed during the exercises and succeeded in bringing more students to the sessions and making them evenly space their training practice. At last, let us note that the overall impression is quite positive by the students at the course evaluation survey with mostly positive feedback (with an average of 4/5).

To conclude, we presented a case study on teaching computer networks post-pandemic. Such a case study gives concrete insights for enhancing student learning experience in a post-COVID context and showcases tools and methods with proven experience and supported by empirical data. In this context, we orchestrated a shift from using remote labs to physical labs, adapted the exercises format to promote peer instructions and reflected on how to further improve active learning during lectures. We show here that despite computer networks being the very infrastructure that made remote and hybrid education feasible during the pandemic, a physical environment for labs and exercises does help to improve student learning on how networks work.

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