Moving to Timed Remote Assessments: The Impact of COVID-19 on Year End Exams in Chemical Engineering at Imperial College London

Vijesh J. Bhute[#*], James Campbell[#], Andreas Kogelbauer, Umang V. Shah, and Clemens Brechtelsbauer*

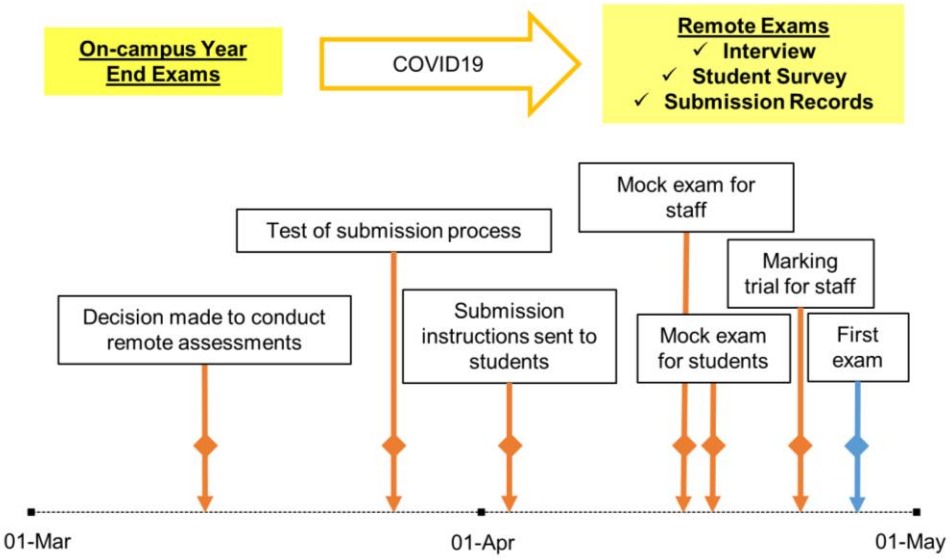
Department of Chemical Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK

[#]These authors contributed equally

ABSTRACT

Summative year end assessments are a major component of student assessment at the Department of Chemical Engineering, Imperial College London. More than 600 students participate in over 40 different exams during the summer term. At the end of the spring term, the college moved to fully remote operation due to COVID-19, leaving the academic community with the challenge of delivering examinations remotely. At the time pandemic hit the UK, teaching for all modules in the department had been completed, the exam timetable had already been published and all exam papers passed the mandatory external quality review. To implement time-limited remote exams as stipulated by the university, the department decided to proceed with an existing VLE platform for submission of answer-sheets. This study highlights stakeholder reflections from the academic and student community during the implementation of this approach culminating in a mock examination to gauge readiness of the infrastructure as well as the student population. Our survey found that the majority of students (>80%) managed to follow the written instructions and readily engaged with scanning technologies and the uploading process. In the main, students did not have to adapt their learning or writing style. All stakeholders provided constructive suggestions at the end of the mock exam resulting in a relatively smooth transition to this new mode of examination. This study highlights challenges and reflections on making the summer year end exams remote in a very short timeframe in a large and diverse Chemical Engineering department at very short notice.

GRAPHICAL ABSTRACT



KEYWORDS

Graduate Education, Chemical Engineering, Assessment, Remote delivery, COVID-19

INTRODUCTION

Online assessments have been shown to improve learning outcomes by providing students with instantaneous feedback on learning,[1,2] making them suitable for formative assessment.[3,4] Teachers can also use this information to understand the students' point of view on concepts which they find difficult.[5] Electronic quizzes can also reduce candidates' anxiety as compared to an in-classroom setting thus improving performance,[6,7] and have no significant negative impact on performance[5,8,9] or self-efficacy.[5] Additional advantages for assessors include a reduction in workload with regards to marking and feedback.[10]

Implementation of online summative assessment requires educators to tackle some additional hurdles, especially concerning the integrity of the examination. Several approaches have been used in the past to ensure this with sufficient rigor. One method is to mimic on-campus exam conditions by using video technology for invigilation.[11] This requires access to relevant software as well as high-speed internet connectivity for students which may not be available to everyone – a distinct issue for a diverse cohort drawn from all over the world. Alternatively, examinations can be administered via

specifically designed platforms.[12,13] Moodle, a course management platform, has been used to set assessments with multiple choice questions (MCQs) and numerical answers.[14] Similarly, Mobius and WeBWork offer the same functionality plus the option to include graphical questions.[15,16] The ability to randomize question parameters for different students reduces the probability of cheating and timing answers offers an additional layer of feedback to students and educators.[13] Disadvantages of these online assessments are that the software relies on internet connectivity throughout and questions need to be coded to support the various functionalities.[13] Despite the many advantages of online examinations, their application at our university is not widespread as implementation requires significant divergence from the usual academic teaching approach in addition to careful planning and specific question styles. Moreover, familiarizing students to these platforms as well as testing and validation can take some time.[5]

The department uses a three-terms a year operating model, where all teaching is completed within the first two terms (Autumn, and Spring) and the Summer Term is reserved for some revision lectures and end of year examinations. During the Summer Term, a total of 42 exams were planned to be delivered in a traditional exam hall setting. Figure 1 shows the typical end of year examination process timeline for AY 2019-20. Preparations started in December 2019, the exam schedule was announced in early March 2020 and by the fourth week of March, the exam papers had been vetted by external examiners.

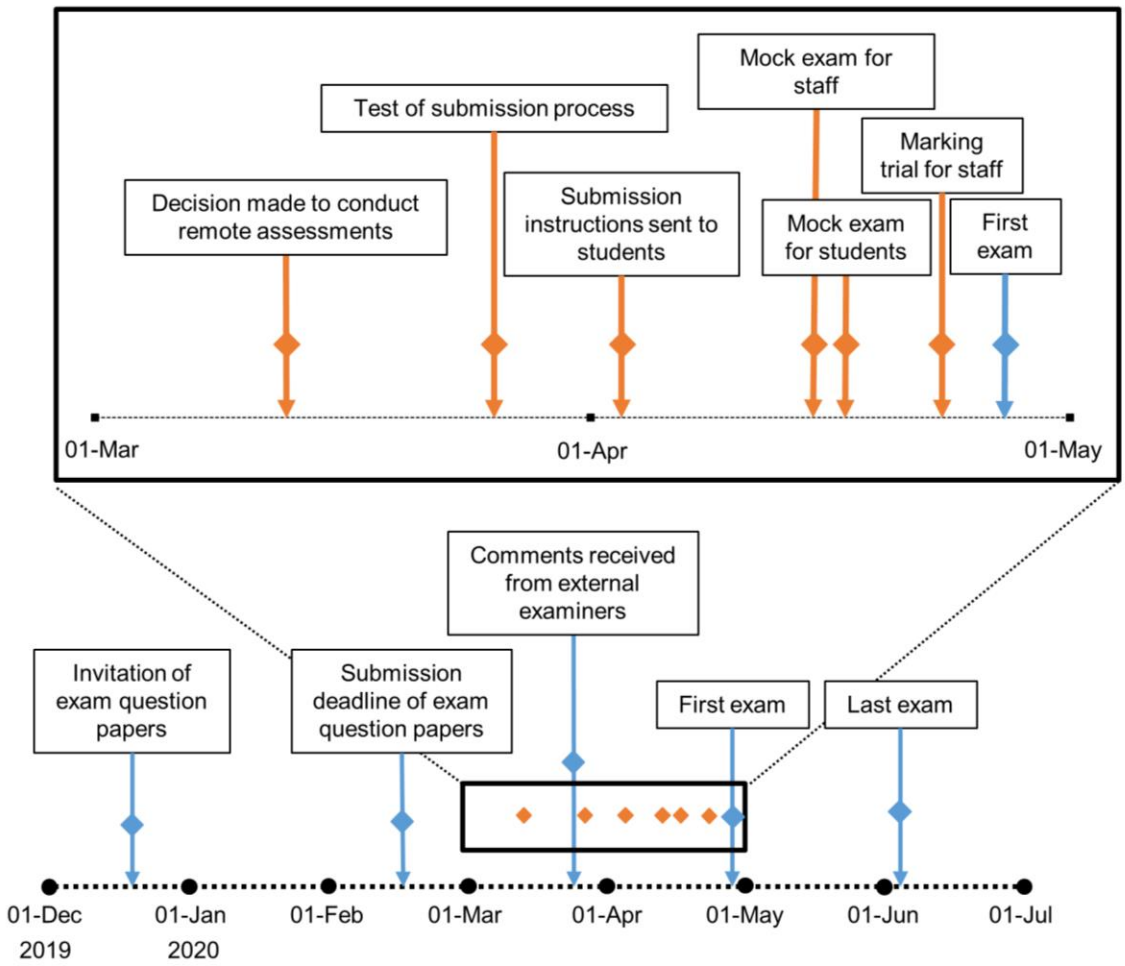


Figure 1: Timeline for a traditional end of the year examination for AY 2019-20 (blue arrows) and adaptations made as a result of COVID-19 (orange).

The academic community in the department now faced the challenge of delivering end-of-year examinations remotely by keeping closely to the original process. Prime concern was to cause as little additional disruption as possible for all stakeholders. This study discusses the solution developed by the teaching team to achieve remote end-of-year examination for 42 modules and more than 600 students from more than 65 countries within the limited timeframe of 45 days from the day of the university lockdown to the day of the first exam. We highlight key challenges in the process and how they were overcome to arrive at a broadly successful remote examinations process using existing VLE tools.

IMPLEMENTATION OF ASSESSMENTS

Assessment Methods

Our undergraduate degree programs are modular and incremental, where each year contributes to the overall degree outcome with later years contributing more. Students work on different coursework-based group projects throughout the year in teams of two to twelve. All coursework assessments for all four years had been completed by the end of March 2020, and all corresponding formative and summative feedback had been shared with students before the commencement of the Summer Term. The individual component of demonstrating learning outcomes is achieved using individual written end-of-year examinations, which in a lecture-based module carry on average >80% of the overall module mark. First year students appeared for eight, second year students for nine, third year students appeared for five, and fourth year students for one core chemical engineering examination. Third and fourth year students also took part in different technical and business elective examinations. In a typical exam paper, students perform calculations using chemical process data and then interpret the results to demonstrate concept-based understanding. The presence of pure factual recall type questions in our exams is very limited.

Student Demographics

The student population in the department is very diverse. Typically, 120-155 student register each year for the four-year Master's in Chemical Engineering program, 50% of which are international students. In the current academic year, 149 first year, 135 second year, 118 third year, and 114 fourth year students took part in the core chemical engineering examinations. In addition, the department also offers a one year taught postgraduate MSc program to 120 students who get examined in elective modules which are shared with the undergraduate program. During summer 2020, more than 600 students from 69 different countries participated in the examination process. Figure 2 shows the geographical distribution of student population.

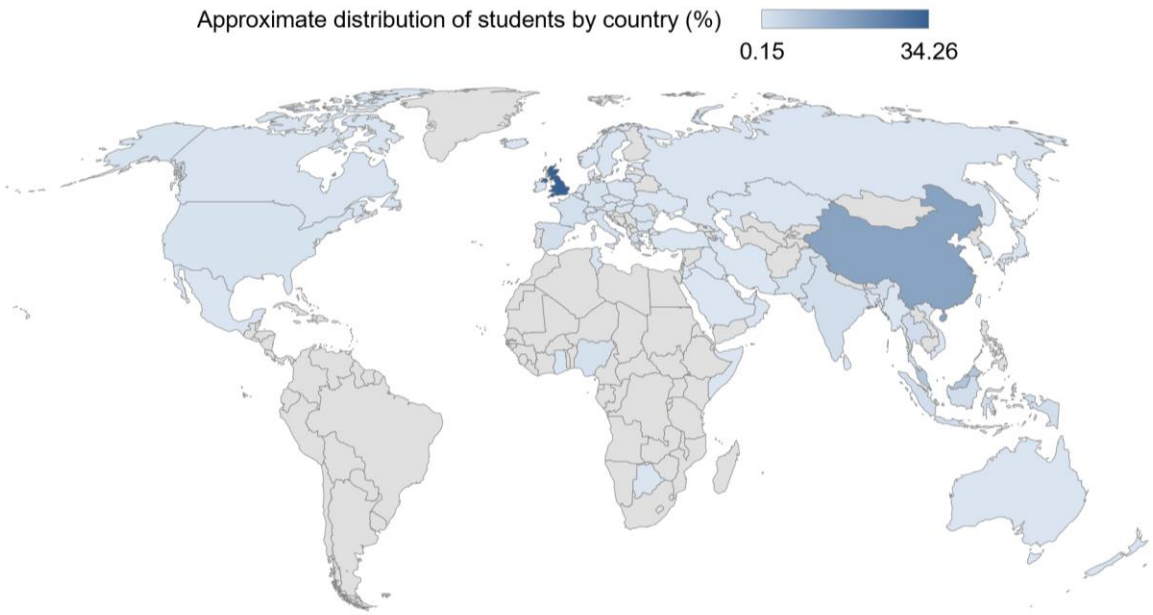


Figure 2: Approximate distribution of students by country (%) participating in remote examinations. Map was generated using Microsoft Excel's Map chart tool.

Remote Examination Process Overview

Following the college's lockdown announcement on March, 13th, the department acted to deliver the exams to the originally published schedule but now remotely. Student examinations were due to start on 27th April, 2020. The important parameters which were affected by COVID-19 and their impact on exam delivery are summarized in **Table 1**. These factors had a number of associated challenges that had to be addressed in order to ensure fairness and rigor of the remote examination.

Table 1: Comparison of Fixed Parameters for Different Examination Modes

Exam Parameters	Traditional summative assessment	COVID-19 effected summative assessment
Location	Exams are conducted on campus	Exams conducted remotely off-campus
Invigilation	Active invigilation during exam (Addressing student questions in real time)	No invigilation (No provision for asking questions during the exam)[a]
Format of Delivery	Printed question papers	Online PDF file
Required Resources	Required resources are supplied (A4 sheets, calculator, etc.)	Students will be expected to organize their own resources
Assessment Timing	1.5 - 3 hour assessments at fixed times	1.5 - 3 hour assessments at fixed times
Assessment Guidelines	Departmental policy	Guidelines distributed by email

[a]Students were not allowed to ask exam specific questions during the exam. The email address provided was to ask submission process specific questions and was only monitored by the UG Team and not subject experts.

The chosen online platform to deliver the remote examinations was the department's Virtual Learning Environment, Blackboard. Students were already familiar with it, as they used it regularly

throughout the academic year for submission of coursework and receiving assessment and feedback. For the remote examinations, the exam paper was made visible on the day of the exam within the module folder at the specified time of the exam. Students downloaded the paper and then generated handwritten solutions which had to be scanned and uploaded to Blackboard for submission using a special link. Assessors had the option of marking digital answers using Blackboard's grade center or downloading them and annotating files offline.

Once the first guidance document on this process had been drafted, it was alfa tested with a 10-member sub-group of the undergraduate (UG) teaching team on March, 26th. The feedback from the team was incorporated in revised guidelines which were sent to students on April, 3rd. A mock examination was conducted on April, 17th as beta test in which more than 500 students participated. A survey collected student's views afterwards. Instructions for remote marking of digital exam scripts was also tested with the UG team before being rolled out to all teaching staff in another trial on April, 23rd. The live remote examinations commenced with a first year module on April 27th, 2020 and concluded with a third year module on June 3rd, 2020.

Location

The key difference between examinations pre-COVID-19 and those affected by the pandemic is the location. As the university campus was closed due to lockdown, the majority of students including most of the international students returned to their homes in their respective countries. This meant that the remote delivery had to be implemented in a manner that would allow students to be able to access exams globally and for staff to undertake remote marking from their homes, all with minimal infrastructure requirements.

Invigilation

Invigilators ensure exam integrity, provide students with necessary additional resources, and address student queries. Remote invigilation using e.g. video conferencing tools would have been desirable. However, considering the diverse cohort and distribution across the globe they were simply not practical and very quickly ruled out. To avoid distractions and maintain a consistent form of communication, only queries regards the process (but not the question paper) were permitted through a monitored email address. This allowed students struggling with the down- or upload to flag issues

early for prompt resolution. To avoid handing out additional resources during the exam, all module leaders edited or removed any questions that could not be completed without access to material supplied in advance.

Since there was no possibility of real-time invigilation, traditional closed book exams cannot be implemented as such and all exams were set in an open book format. Papers were adapted to be less reliant on rote learning and contained more conceptual problems. Students were asked to write their solution by hand using pen and paper, then scan their scripts into a PDF format for submission. This ensured that solutions are individualized and added a reassuring layer of authenticity to the exam.

Format of Delivery

Owing to the compressed timescale, using online assessment platforms or converting exams to multiple choice type quizzes was infeasible. Therefore, it was decided to largely leave the content of the paper examinations unchanged and only change their mode of delivery to digital using Blackboard. At the start of the exam, students received access to a download link for the PDF exam papers. Additionally, papers were emailed to students as a backup. Students then carried out the assessment, scanned their script in PDF format and submitted via Blackboard. Email submissions were also permissible in case of technical difficulties.

Required Resources

Resources available to students differ significantly when working off campus, especially with regards to access to printing or scanning equipment. To reduce the pressure on printing for a timed assessment, students were given early access to any ancillary material that had to be drawn onto directly (e.g. graphs). For scanning, students were given a range of options, including using their own scanner or several smartphone Apps such as Microsoft Office Lens, Microsoft OneDrive or Adobe Scan. The ubiquitousness of the smartphone proved to be a major pillar of the approach, as it also served as backup to a reliable internet connection.

Examination Timing

Due to the significant diversity in locations, with students both to the west in the Americas and to the east in Asia, there was a vast local time difference to account for in the cohort. To ensure that no students were advantaged, exams had to be held concurrently for all. The original start times of

1000 AM and 1400 PM British Summer Time were considered a suitable compromise. Students were given an additional 45 minutes to scan and upload their written answers. The additional time appears generous at first glance, however when considering the number of pages, scan resolution, compilation and conversion of file types, scanned file size and the heterogeneity in internet upload speed, it was found to be appropriate, which trials with students confirmed. Students who submitted late or those who had substantial difficulties were permitted to apply for mitigating circumstances, which were then reviewed by the departmental mitigation board in the usual manner.

Examination Guidelines

Students were provided with detailed guidelines regarding what resources they needed, how to submit their solutions and who to contact prior, during and after the exam in case of difficulties. Step-by-step instructions explained using different software e.g. how to convert images of answer pages taken on a smartphone to a merged PDF for submission. This part was much agonized over by the teaching team but surprisingly, students felt quite comfortable with the technical aspects of the submissions process. Any received queries before the exam always only related to whether exam questions would change, never about the technology to compile and submit the answers.

IMPACT OF IMPLEMENTATION: RESULTS FROM SURVEY AND INTERVIEWS

Since the process was untested, the department conducted a mock exam on April, 17th. When asked to summarize its purpose, the staff member tasked with implementing timed remote assessments (Director of Course Operations, DCO) said "[it was to ascertain] whether we would be able to deliver the exams at the right time, to the right people and make sure that they [the students] have perfectly understood what is expected [of them]". The main objectives of the mock exam were to ensure that:

- Guidelines and instructions were clear
- Students can identify and assemble required resources
- Students can successfully access and download the exam, write on paper, scan to PDF, and upload their scripts
- Extra time provided for scanning the exam was sufficient
- The submission system was robust

- Staff could try out electronic marking

Student Perception of the Mock Exam

Each year group (out of four undergraduates plus one year of taught postgraduates) was given the opportunity to undertake a mock examination selected from one of the modules they would be taking in the exam period, and approximately 500 students participated. A voluntary survey was distributed to gain student feedback and 51 students (~10%) students responded.

Students were asked to indicate whether the guidelines were comprehensive (or not) and easy to follow (or not). Multiple selection was allowed for this question. The results from this question are shown in the form of a Venn diagram (with circles proportional to the % response) in **Figure 3a**. The majority of the survey respondents found the instructions were easy to follow (80.4%) or comprehensive (64.7%). This indicates that assessment guidelines were suitable. Since the scanning of exam scripts and converting it to PDF format is a key differentiating parameter, we asked the students about how they did it and how long it took (**Figure 3b**). While Microsoft Lens was the recommended app, the majority of students used alternative means (**Figure 3b**). It was reassuring that 92% of students found the extra time for scanning to be sufficient (**Figure 3c**).

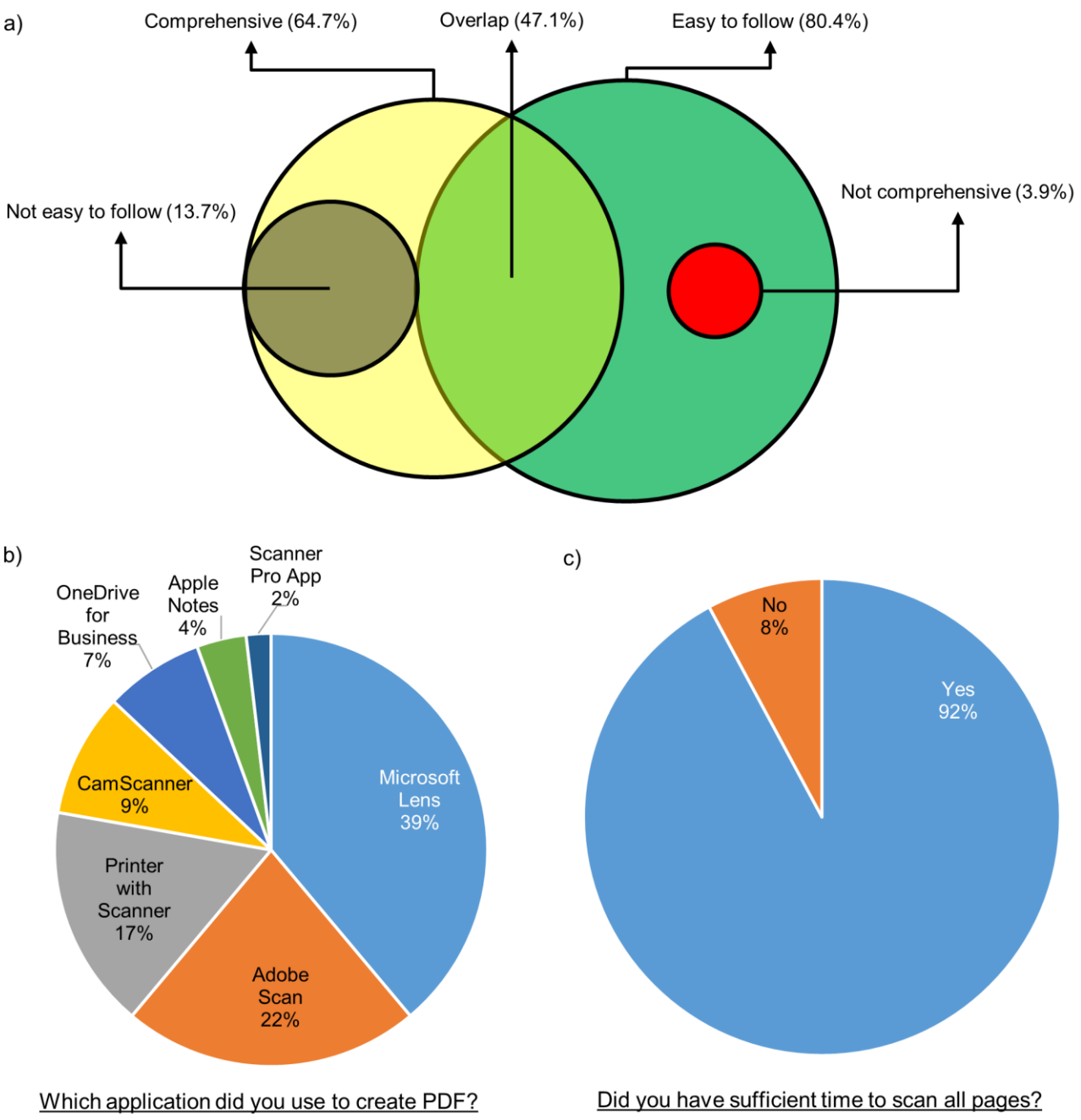


Figure 3: Student response to questions on quality of instructions and scanning methods. a) Venn diagram representing student responses to the question related to instructions. Pie charts representing b) different tools used to create PDF and c) response to whether scan time was sufficient.

While more than 60% of students reported to have everything they needed in terms of resources, 39% students highlighted concerns (**Figure 4**). These could be placed into two sub-categories: environment and devices/connectivity. A lack of printer and related accessories was a worry for

several as students were advised to download and print a copy in case of internet disruption. According to students, a lack of a printed question paper “makes it harder to refer between pages” and “It is hard to read questions on the screen for a long time”. While these are valid concerns, it was impossible to remedy them centrally. Other concerns were related to slow internet speed and lack of the preferred model of pocket calculator. Some students also highlighted concerns related to exam timing and a lack of quiet space for taking the exam (**Figure 4**).

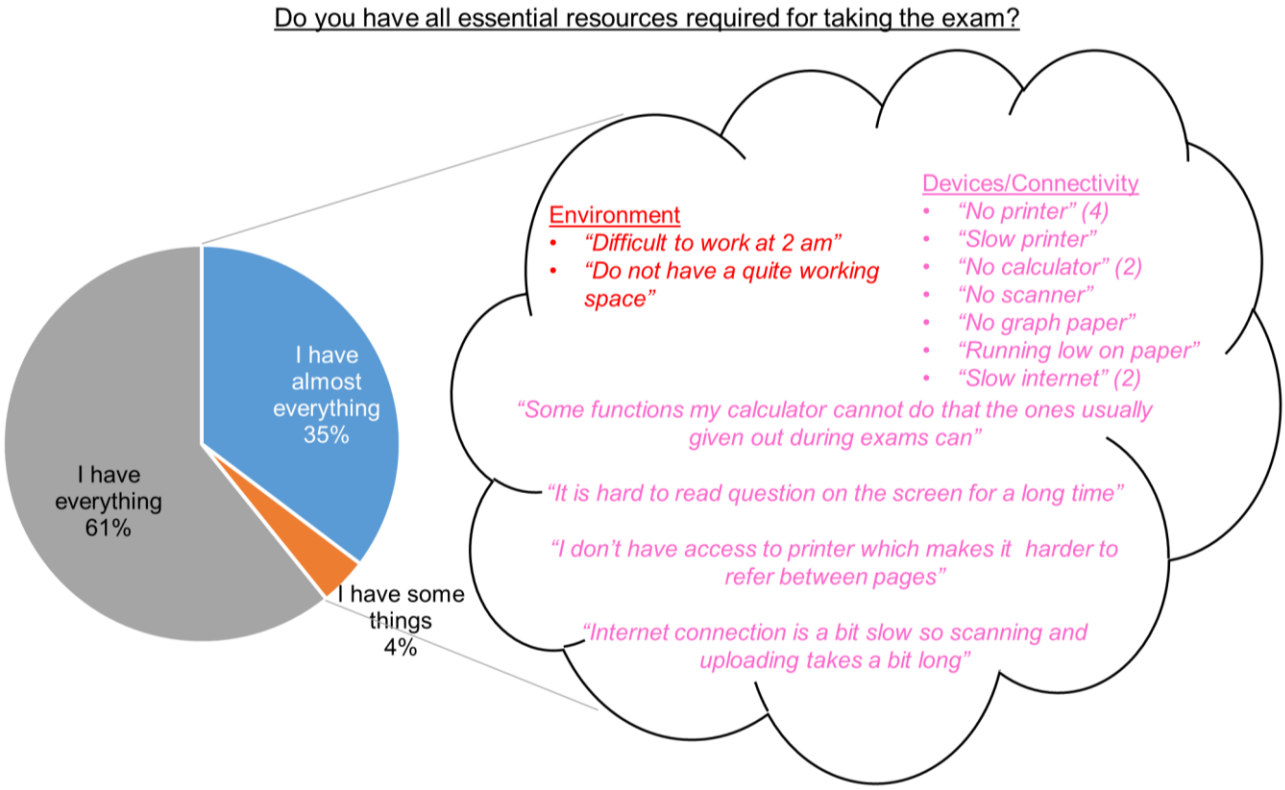


Figure 4: Student response on availability of resources.

Since students would have to scan and send the scripts, the mock exam was used to determine whether students had to change the way they write their exams. While a plurality of students (~40%) did not have to adapt their writing style for the remote examinations, as shown in **Figure 5a**, many students reported various ways in which they had to adapt due to the change in setting. Some common changes were writing larger and with extra clarity than usual, which incidentally was very much welcomed by markers later. The majority of students was comfortable with the submission (**Figure 5b**) process.

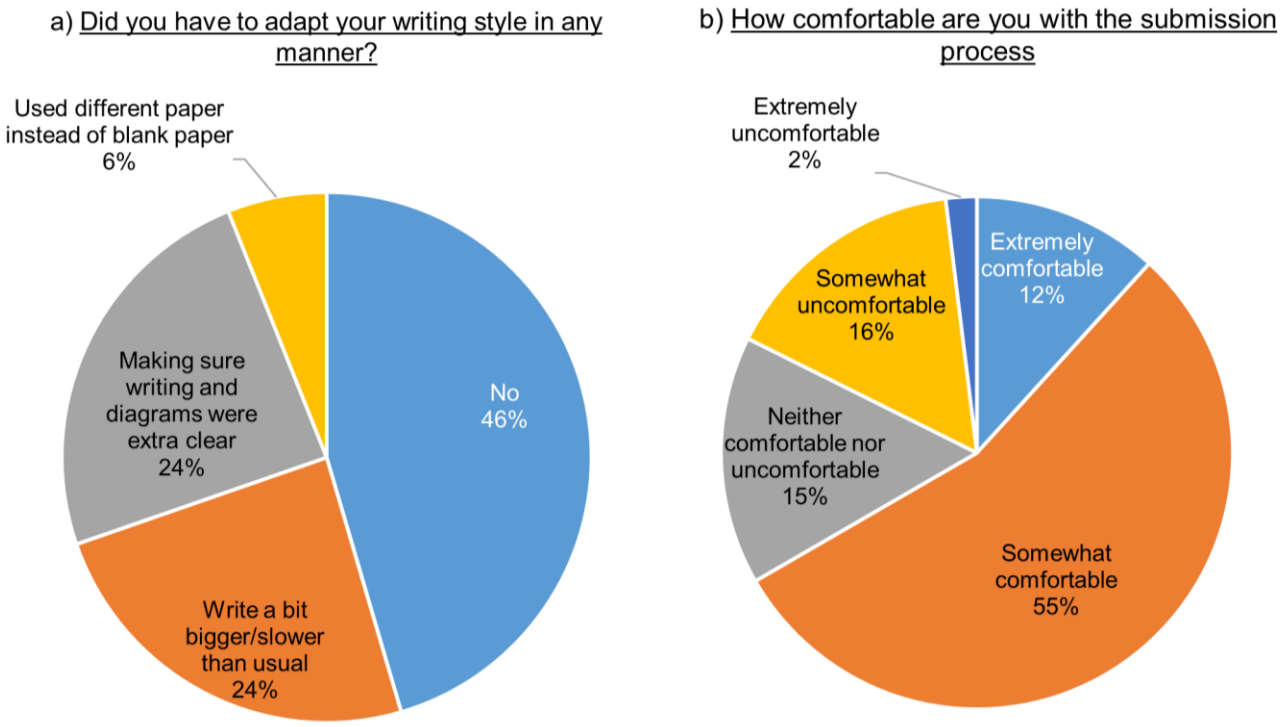


Figure 5: Student response related to adapting to writing style and submission process. a) Student were asked to provide details if they adapted their writing style. Their responses were coded to specific categories. b) Pie chart representing students' perception of the whole submission process.

Students were asked to express their experience during the mock exam in free text fields. The generated word cloud shows some comments that back up the main findings of the survey (**Figure 6**). Comments such as "instructions were fairly comprehensive" and "straightforward process" show that the preparations and efforts made by the department worked in practice. However, the word cloud shows several entries of "slow internet" and "submission processes took time". Since the submission relies on internet speed, larger file sizes can compound the issue which was indeed observed during exams.

Figure 6: Word cloud of free text comments from students.

The submitted mock exam papers were used by staff to trial remote marking. Two options were tested: either by using Blackboard directly or by electronically annotating downloaded PDF scripts using Microsoft Edge. In combination with a tablet computer and a stylus, the second option provided as close an approximation to marking on paper as possible, which many markers preferred over handling the traditional paper copies. Both options were trialed by Team 1 and a step-by-step guide was provided to staff, with positive response.

Execution of COVID-19 Impacted Assessments

Despite a successful mock examination, many students struggled with the submission in their first real exam. In the DCO's own, ironically hyperbolic words, "The first exam for every year group was a mild disaster". The DCO believes these issues were due to students not practicing the process enough

– or at all. With more time, additional training opportunities would have been made available "until all students get it right". Consistent with this, we observed the percentage of weekly late submissions in the first week was 4.85% (**Figure 7**). The average percentage late submissions in the following weeks was 2.54% (95% confidence interval: [1.85%-3.22%]). This is supporting evidence that students planned and acted responsibly after the first week of exams.

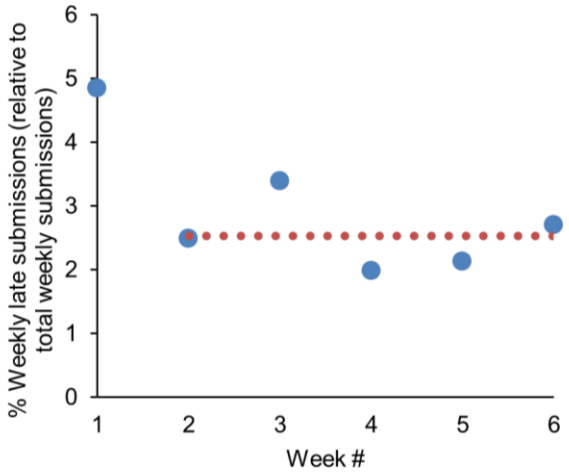


Figure 7: Percentage weekly late submissions per week. The dotted line represents average of the % late submissions for weeks 2 to 6.

Analysis of exam results is currently in progress and their comparison with historical exam performance will be the subject of further study.

Impact of Changing Assessments on Staff

While the impact on markers was minimal, the change in assessment type had a large impact on the administrative side of assessment delivery. In traditional examinations, the core team for the delivery of exams includes the DCO, two members of administrative staff and a wider team of invigilators and academic staff. The process of printing, handing out and collecting the papers as well as answering student queries is spread across a wide team. Invigilators also record the attendance of students and ensure they have the correct exam paper as well as collect their answer sheets at the end.

For remote delivery, there could be only one point of contact through a dedicated email address which had to be monitored by the core team for every exam. This team ensured that every student was

sent the exam at the correct time, and that all submissions were accounted for. While this was not necessarily more work in comparison to traditional exams, it had to be done by fewer people and it had to be absolutely correct at first attempt. This put a lot of pressure on staff: “During the start of the exam, and then again when it comes to submission time, we have to monitor the exam mail inbox. That is where all the students will email with problems. They come in very densely at around 15 minutes before the submission time and also around 10 minutes of the exam start time.”

Finally, after the exams, another round of checks is needed to ensure submissions are complete and valid. Despite these difficulties, there is one significant advantage to administering remote assessments: “We only have electronic files now. Usually we would have to do printing and photocopying. That is [a monetary] saving, … but it also helps [with time] because you can edit a paper literally in [up to] five minutes before [the exam].”

CONCLUSIONS

The decision to hold year end exams in a remote setting in a short amount of time has certainly pushed the limits of departmental capability to deliver it. Original plans had to be changed at short notice and a reliable system was created from scratch in 45 days by a small number of staff.

The mock exam was a key step which allowed students to stress-test the process individually and staff the whole system collectively. Key lessons learned were that having good internet connectivity is an absolute must, as is for the students to create a suitable exam environment for themselves. While the department would have never embarked on such a course of action without being forced into it by the pandemic, now it is being recognized that remote exams offer serious benefits as well, for example independence from exam rooms: exams could be scheduled at any appropriate time around the year, not just when rooms are available.

Perceived insurmountable obstacles to electronic exams could be overcome with reasonably basic tools of the modern world, essentially internet, a smartphone and a tablet or computer. Going forward, the department plans to use online assessment platforms such as WeBWork for delivering the exams to overcome the challenges associated with upload speed. This will be first trialed in assessment of few courses including Physical Chemistry, Thermodynamics, and Mathematics during the Autumn term in the AY2020-21. The process of modifying the question format and coding the questions has already

begun using the WeBWork platform. This will also reduce the marking related issues and improve the turnaround times. We believe electronic exams will have the potential for regular application, even in a non-pandemic scenario.

AUTHOR INFORMATION

Corresponding Author

*Dr. Vijesh J. Bhute, Email: v.bhute@imperial.ac.uk or vijeshbhute@gmail.com, and Dr. Clemens Brechtelsbauer, Email: c.brechtelsbauer@imperial.ac.uk

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