Teaching Maths in the Time of COVID: The Good, the Bad and Missing Factors.

Maryna Lishchynska

Catherine Palmer

Munster Technological University, maryna.lishchynska@cit.ie

Abstract.

This paper looks at the (emergency) remote delivery (ERD) of mathematics versus a traditional face-to-face approach, in the context of the third level education ecosystem. We then describe the approach to the delivery we took and examine the students' response in terms of engagement, resource choices, experiences and preferences. The student cohorts considered were second year, fourth year and Master's students. Results of quantitative analysis using Canvas analytics and MS Forms, and qualitative analysis using an end-of-term feedback form, are presented. The work highlights how the course material lends itself well to remote delivery but it is the learning process that is most affected by the switch to ERD. Other deficiencies and positive aspects of emergency remote delivery, as well as potential strategies for improved lecturer-student and student-student interaction, are also discussed

Keywords: Emergency remote delivery; Mathematics; Teaching and learning.

"Teachers are expected to reach unattainable goals with inadequate tools. The miracle is that at times they accomplish this impossible task" (Haim Ginott, 1972).

1. Preamble.

Six years ago, one of us was invited to deliver a module online. The invitation was dismissed at the time by a complete non-believer in teaching mathematics remotely. The main arguments were:

- Mathematics as a discipline is all about understanding concepts and approaches. It is already challenging to achieve this understanding in a face-to-face class, let alone remotely.
- Teaching mathematics is meant to be interactive where a lecturer has instant feedback from the class and can adjust the teaching accordingly. The two-way communication is essential.
- Tutorials where students first apply new techniques and receive instant feedback from lecturers are a key part of the learning process in mathematics. Surely lecturers and students need to be in the same room for this level of interaction?

Fast forward to March 2020 when one day we woke up in a completely different job. There was little in our training and experience that prepared us for teaching remotely. After the initial shock, realisations came that (a) this had to be done, (b) one needed to act fast to set up a functioning process of online delivery that somehow met the needs of the students and (c) however intolerable, some deficiencies and sacrifices in quality had to be accepted as a temporary solution to an immediate problem.

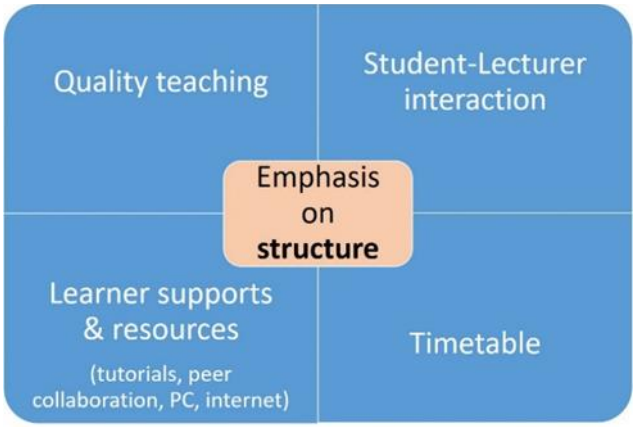
In this paper we look at the (emergency) remote delivery (ERD) of three mathematics modules at Cork Institute of Technology – CIT (now Munster Technological University, Ireland) versus a traditional face-to-face approach, in the context of the third level education ecosystem. We then describe the approach we took and examine the students' response in terms of engagement, use of learning materials, experiences and preferences. We note that the ERD discussed here is not the same as planned online learning and the aim of this paper is not to compare online learning with face-to-face but to reflect on the experience of ERD for lecturers and students. Doing so, we hope to identify deficiencies and positive aspects of ERD to inform future approaches.

2. Remote Maths Practice in the Context of the Education Ecosystem.

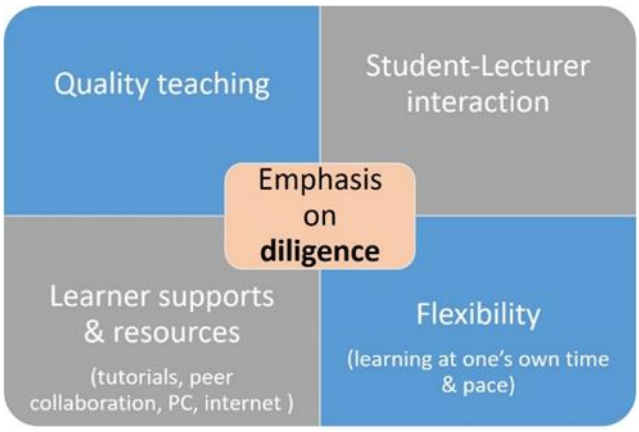
"Face-to-face education isn't successful because lecturing is good" (Hodges, 2020). In addition

to lecturing, the ecosystem of face-to-face education also comprises of student-lecturer interaction, various learner supports and institutional resources. A crucial factor tying these elements into a robust system is the overarching structured approach (Fig. 1-a). Having timetabled face-to-face classes enforces good time management and encourages engagement. Being in a physical classroom promotes concentration, an essential component for a discipline like mathematics.

Figure 1: Authors' schematic representation of face-to face (a) and remote (b) education ecosystems.



(a)



(b)

The ecosystem of remote education combines a somewhat different set of features, with some important pillars like student-lecturer interaction and resources being de-emphasised or less reliable (e.g. access to a PC and high quality internet). Instead, the flexibility of learning anytime, anywhere, at any pace becomes a prominent aspect (Fig. 1-b). Such an approach hinges

significantly on the learner's diligence and self-discipline. The balance of greater flexibility with a significantly greater reliance on diligence is hard to strike, particularly for incoming students that are fresh from school and used to a rigid (timetabled) structure. It takes time to build a culture of diligence and independent learning in young individuals. In terms of in-service mathematics teaching, the absence of traditional (in-class) student-lecturer interaction and peer collaboration as well as over-reliance on diligence, poses risks such as non-engagement, lower standard of learning and losing some students due to an inability to study independently (unsupported).

In light of the above, our immediate concerns were about rolling out a functioning teaching process while maintaining student engagement.

3. Emergency Remote Delivery.

The student cohorts we focus on are second year (n=89) and fourth (final) year (n=27) students taking mathematics modules and Master's students (n=39) taking a statistics module. The three cohorts are further referred to as Year 2, Year 4 and MSc correspondingly.

3.1 Learning materials and communication.

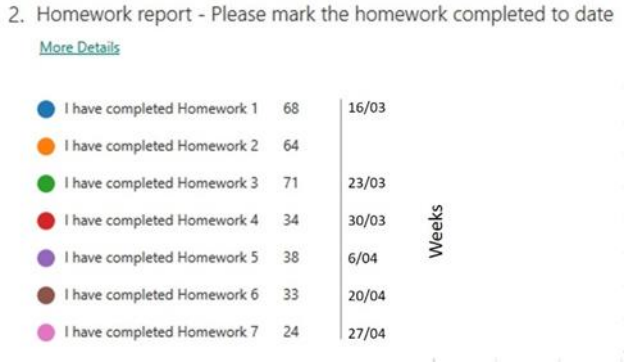
The virtual learning environment Canvas was already in use at CIT. In addition to facilitating the dissemination of learning materials, Canvas was also used for communication. Videos of narrated notes, explaining some theory and worked examples, were created using a screen casting software Screencast-O-Matic. Guidelines on the use of software and training videos were provided by the department of Technology Enhanced Learning at CIT. Though it felt strange talking to oneself while narrating the videos, a simple but effective piece of advice "*to not worry too much about getting the recording 100% perfect as it is a conversation of sorts*" saved the authors from getting stuck in a 'this can be done better' loop. The students had access to both lecture videos and static notes. The reasoning behind this decision was that it might suit some students to work through videos, pausing and taking notes down, then resuming, but also to facilitate those who might prefer to watch the entire video and then open the static notes and work through in silence. Each set of learning materials included exercise sheets and/or lab notes normally used within the module. New material was released on a weekly basis and students were provided with a weekly work schedule.

3.2 Student engagement.

So much subtle effort goes into fostering a working relationship and good rapport with a class that the sudden disconnect and the prospect of losing that illusive connection was a serious concern from the start. Canvas offers several analytics tools for gauging students' engagement, mainly through their accessing various learning materials (see Fig. 2-a for example). In addition to that, Year 2 and Year 4 students were asked to report when they have completed a particular homework by checking in a MS Form (Fig. 2-b). The students had to input their names in the report form hence some sense of accountability was attached to it. Together with Canvas Analytics, the report painted a richer picture of the engagement. Figures 2-a and 2-b show how the on class group engaged in a module. As the students got busier with exams and project deadlines towards the end of semester their 'enthusiasm' for self-reporting tapered off. Canvas Analytics continued to show increase in activity towards the assessment dates with 87% of students accessing materials necessary to complete the last assessment. This pattern of increased activity on Canvas before assessment dates was also observed for the Year 4 and MSc students.

Figure 2a: Students' activity on Canvas.

Figure 2b: Student progress report (n=89



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As another form of engagement and for efficiency, the students were encouraged to use Discussions on Canvas to post queries on new material and exercise sheets (with an option to attach images of work). Given how often the same question is asked multiple times in tutorials, having a public forum for such questions and answers minimised repetition and hopefully helped the students who otherwise might have been shy to ask a question of the lecturer.

To encourage peer interaction and help several high performing students from each cohort were invited to post responses to the queries on par with the lecturer. Overall, a moderate level of interaction took place. In one module for example, Discussions section had 8 active participants but was accessed by 72 out of 89 students with a total of 678 page views. It was good to see the majority of students reading the forum, and hopefully benefiting from it, but in future we will aim for more active participants. To achieve that it may be beneficial to prepopulate Discussions with some topics and create threads to encourage higher participation.

Outside Discussions, some students still preferred to use the traditional ‘email the lecturer’ route. Depending on a query some of these students were prompted to post their question in Discussions which they did. Student shyness to participate in such public forums could be a potential barrier to engagement, and it is not an easy one to dismantle.

Overall, the above tools have given the lecturers a much needed and important sense of feedback as well as comfort in knowing that their efforts were reaching the end user and the students were engaging with the material.

3.3 Assessments.

For a face-to-face delivery, grades were mostly determined using invigilated in-class assessments and final exams. Remote assessments were run online as timed exams facilitated through Canvas where students had, for example, 45 minutes to work and write out solutions with an extra 15 minutes to upload their work. Students entitled to extra 10 minutes per hour in an in-class exam availed of the same in online assessments. A small proportion of students had issues with submitting on time due to poor internet connectivity. Such late submissions had to be accompanied by timestamps showing that the images of the work were taken within the timeframe of the exam. The MSc class also had individual projects to complete over a four-week period.

The challenges posed by online assessments require us to rethink our current approach to assessment; while projects allow for deeper engagement with the course material, which makes them more suitable for open-book examination than timed online assessments, there is no guarantee of academic integrity for either method. For smaller classes and suitable module material, assessed group work, presentations and oral assessments could be included in future assessment breakdowns.

4. Students' Resource Choices, Learning Experiences and Preferences.

Upon completing the module, the students were invited to participate in the study by giving anonymous feedback on their experience of learning mathematics remotely. This work was carried out in line with the research ethics policy of CIT and ethical approval was granted by the institute. The feedback was collected using the end-of-term feedback form (see the Appendix), set up and administered in MS Forms. Out of 155 students, 82 (53%) responded. We were interested to see how students used the learning materials, what they thought about remote learning and assessment and what modes of delivery and communication they preferred now, after having been exposed to the remote practice.

With regard to the use of learning materials, 63% of all respondents used both videos and static notes as opposed to videos or lecture notes alone. Figure 3a shows an interesting correlation between the level of a module and choice of resources: the more advanced a module taken (Year 2→Year 4→MSc) the higher the proportion of students (53%→67%→84%) using both video and text resources.

The difference in the level of the module also manifests in how the students found the remote learning experience compared to face-to-face. Whereas 94% of Year 2 students found remote learning similar or easier, 52% of MSc students found it harder (Fig. 3a). It is possible that the complexity of the concepts presented in higher-level modules makes remote learning harder or perhaps, the level of educational experience affects the perception of remote learning. Both possibilities should be considered when planning a remote delivery. Interestingly, when it comes to assessments the trend changes to the highest proportion of students finding the online exam a harder experience (34%) being in Year 2 (Fig. -b). This could be explained by the experience, maturity and greater focus of the final year and postgraduate cohorts. Overall, 74% of the

students found remote assessments similar to or easier than in-class tests.

Figure 3-a. Module difficulty and remote learning.

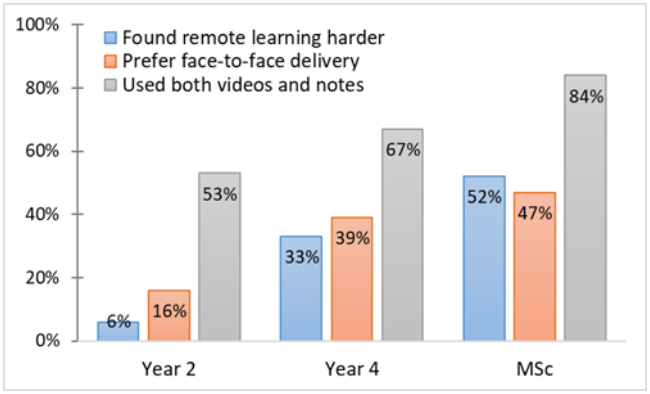
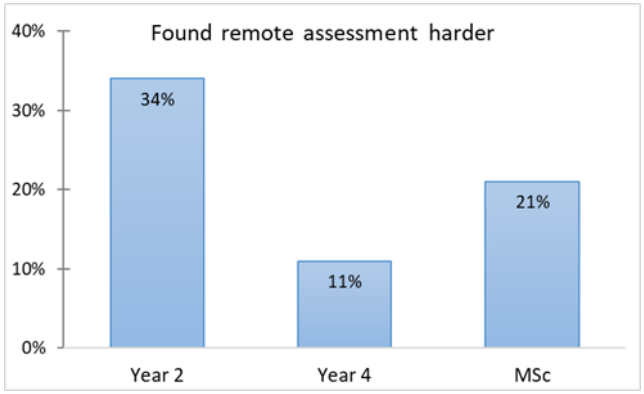


Figure 3-b. Remote assessment experience.



As far as the mode of delivery, 56% of all respondents prefer a blended (mix of face-to-face and remote) delivery. Again, the module level appears to be a factor at play influencing a preference for a face-to-face mode of learning (Figure 3-a). This suggests the desire to be in a physical class to understand material that is more complex. Moreover, 61% of students voting for face-to-face delivery found remote learning harder. An overwhelming majority of respondents (>89%) were found not in favour of 'remote only' practice.

Table 1. Exposure to 'live' online classes and preferred mode of communication for remote delivery

Cohort	Experienced 'live' online classes	Preferred mode of communication	
		Synchronous	Asynchronous
Year 2	No	7%	93%
Year 4	Yes	22%	78%
MSc	Yes	35%	65%

In terms of the preferred communication mode for remote delivery, synchronous (scheduled live online classes) versus asynchronous (pre-recorded) remote delivery, the picture is rather uniform with 83% of all respondents preferring the asynchronous mode. The students seem to value the flexibility of studying at their own time and pace. The pace and rhythm of a traditional lecture doesn't suit all and asynchronous delivery addresses this issue. The possibility to re-watch a video or part of it was highlighted by many students as a positive factor. Some variation in numbers was observed which can be explained by students' exposure to 'live' online classes. Groups that did experience 'live' online classes (within other modules) expressed higher interest in synchronous delivery (Table 1). The preference for asynchronous delivery resonates with the research by (Howard, 2017) where in normal (pre-Covid) times first year undergraduate students taking a Maths module had an opportunity to attend live in-person lectures or watch videos, or avail of both. The study found a large proportion of respondents (60%) using videos as the only resource.

The end-of-term feedback form used to gather students' views did not explore in detail why students preferred asynchronous delivery, however, an institution wide survey of students at CIT found that 37% of respondents lacked a suitable study space, 36% of respondents had issues with unstable or unreliable internet connectivity and 22% of respondents lacked suitable equipment (e.g. computer). These technical barriers may explain students' preferences for asynchronous delivery and should be considered when lecturers plan their remote teaching strategy.

The students also had an opportunity to leave general comments on their experiences of emergency remote Maths teaching and learning. This general feedback is collated in Table 2.

Table 2. Summary of students' feedback on emergency remote practice.

Advantages	Deficiencies
Learning experience	
• Flexibility of learning at own pace and time • More concise and concentrated material • Possibility to replay videos • More time to understand the content instead of rushing to write things down	• Lack of structure • Difficulty with motivation and time management • No opportunity to ask questions on the spot and get immediate feedback • Missing peer interaction • Distractions at home e.g. lack of study space
Assessments	
• Shorter exams • More relaxed atmosphere at home	• Time constraints and reliance on poor internet when submitting online • Distractions at home

An interesting and insightful group of comments related to the lower standard of 'home learned' maths versus 'class learned' and having learned how to do the questions but not understanding the reasoning behind it. This shows that the students have considered the potential long-term impact of emergency remote learning. Coming from learners this only reinforces the finding that mathematics is a discipline where understanding of concepts counts most yet is not easy to achieve remotely (Trenholm, et al., 2019). A further study examining the use of recorded lecture videos in combination with live lectures for undergraduate mathematics students found that students who depended more on recorded video lectures engaged with the material using what is described as a 'surface' approach (e.g. rote learning), which does not lead to a conceptual understanding of the material (Trenholm, et al., 2018).

5. Final Remarks.

The suddenness of the situation and the speed with which lecturers had to scramble to set up a functioning process for their students was unprecedented, stressful and not to be experienced again. Both, lecturers and students, were asked to take extraordinary steps in teaching and learning. It was truly survival mode rather than the well-planned, resourced and coordinated process that education is meant to be.

In conclusion, yes mathematics can be delivered remotely. We are certainly better prepared for it now. The experience of these past months has equipped the lecturers with some confidence in remote practice as well as skills that can be utilised in normal times to provide extra materials

outside scheduled classes or replace cancelled lectures. The factors we will consider when planning for remote delivery in the future are:

- provision of both videos and static notes on lecture material;
- weekly schedule for structure and time management;
- alternative forms of support to facilitate questions and feedback (in lieu of traditional tutorials).

Despite our initial concerns, the students rose to the challenge and engaged with the material with over 98% of students completing their module. The question is whether remotely delivered mathematics is received properly at the other end? Is it effective in terms of long-term knowledge retention? These questions go far beyond the scope of our reflections on ERD, however, we can highlight aspects that transferred well to remote delivery and those that did not (see Table 3).

Table 3. Aspects of maths teaching and their suitability for remote delivery

Aspects that **transfer well** to remote delivery	Aspects that **do not transfer well** to remote delivery
• background material • concepts (to some degree) • worked examples	*Lecturer-student interaction*: • lecturer prompting students to think and 'discover' some mathematical ideas and connections by themselves • immediate feedback on students' questions • adjusting teaching on the spot • picking up on misconceptions • tutorial work, especially when a student doesn't know where to start or is stuck halfway through a question *Peer collaboration*: • helping each other in class • explaining material to each other • spotting each other's mistakes
↑ **Material**	↑ **Teaching/learning process**

It was relatively straightforward to disseminate the course material via short-videos and notes. The videos offered high-quality material delivered in a flexible manner that allowed students to learn at their own pace. As highlighted in Table 3, it was the *learning process* itself that was most affected by the switch to ERD. The absence of in-class lecturer-student and peer interactions meant the student took a more passive role in the learning process, which has undoubtedly affected learning. This absence was noted in the student feedback; the lack of opportunity to ask questions in class was the most frequent comment submitted on the feedback form. Both lecturer-student and peer interactions have been shown to increase undergraduate students' learning (Mazur, 1997; Smith, et al., 2009; Smith, et al., 2011). Addressing this absence in ERD should be a priority for future deliveries.

Strategies to support the lecturer-student interaction remotely and encourage student participation include: timetabled live online Q&A sessions for small groups, pre-booked one-to-one online consultations and online quizzes that provide instant feedback through Canvas or the e-assessment tool *Numbas*. Solutions to facilitate peer interactions include: greater use of Discussions boards enlisting the help of student volunteers, use of interactive white boards such as Google *Jamboards*, peer instruction using concept questions and online polling (Mazur, 1997) which can be administrated through break-our rooms during live lectures, the use of the online learning platform *PeerWise* where students create and discuss course related questions and the use of group work for assessing course material. As well as encouraging peer interactions, the use of group work for assessments has the benefit of engaging students with richer, more complex material that is suited to open-book assessments.

We finish with a personal reflection that, for the authors, the energy and magic of the teaching/learning process taking place in a face-to-face class was missing. However, the challenge posed by ERD has forced us to rethink and reflect on our teaching approaches, to try new strategies and learn new skills that will be incorporated into future teaching whether online, face-to-face or a blended delivery.

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7. Appendix. End-of-term feedback form.

1. Which online learning materials did you use in this module?
   - o Lecture videos
   - o Lectures in static slides
   - o Both, videos and slides

2. How does your experience of remote learning compare to face-to-face maths classes?
   - o I found remote learning experience SIMILAR to face-to-face classes
   - o I found remote learning EASIER than face-to-face classes
   - o I found remote learning HARDER than face-to-face classes

3. If applies, please describe what aspects of remote learning maths made it easier or harder for you.

4. Assuming you have a choice, please rank the following approaches to remote teaching maths in order of preference where 1 is most preferable and 3 is least preferable.
   - o Line online lectures (lecturer talking over slides at a scheduled time)
   - o Pre-recorded videos of narrated slides
   - o Pre-recorded videos of the lecturer writing on a whiteboard

5. Any other comment you would like to make about your experience of remote learning in this module?

6. How did you find taking online assessments in this module?
   - o Similar to in-class assessments
   - o Easier than in-class assessments
   - o Harder than in-class assessments

7. If applies, please describe why you found online assessments easier or harder.

8. Any other comment you would like to make about the online assessments?

9. If you had a choice, which mode of learning maths would you choose?
   - o Face-to-face
   - o Remote
   - o A mix of face-to-face and remote delivery
   - o I don't mind.