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A Survey of Research on the Impact of the COVID-19 Closures on the Teaching and Learning of Mathematics at University Level in Ireland

ANN O'SHEA

Abstract. In March 2020, Irish higher education institutions were forced to close their campuses because of the COVID-19 pandemic and all teaching activities moved online. We survey the research carried out on the effects of the COVID-19 university closures on the teaching and learning of mathematics in Ireland.

1. Introduction

On Thursday 12 March 2020 the Taoiseach announced that due to the COVID-19 pandemic all school and higher education institutions in Ireland would close the following day. At this time educators in Ireland, and indeed around the world, were faced with unprecedented challenges and were forced to completely change their teaching methods overnight. It is to their credit that with just a few days to prepare, most institutions moved their courses online by the start of the following week. To begin with, the closures were expected to last for a few weeks, but in the case of universities most classes did not return to campus until the start of the 2021/22 academic year. In this article I will outline how institutions responded, as well as surveying some research on the impact of the closures on the teaching and learning of mathematics at university level in Ireland.

In 2020 and 2021, research was carried out around the world into the impact of the COVID-19 closures on teaching and learning. Much of this work was at school level, for example Riemers [31] has information about the consequences of the pandemic for primary and secondary education systems in 11 countries. Organisations such as the OECD have issued wide-ranging reports on this topic [32]. In Ireland, the ESRI has published detailed reports on the implications of the pandemic for children [4] as well as highlighting the effects of school closures on widening inequality [5]. The importance of a numerate society in order to deal with issues affecting the health of a nation (such as a major pandemic) was discussed by O'Sullivan, O'Meara, Goos and Conway [29]. Amongst the studies conducted at school level in Ireland are those by Dempsey and Burke on the impact of educational closures on Irish teachers ([6]) and principals ([7]) at primary and secondary level. Of course one of the major consequences of the pandemic on second level education in Ireland was the cancellation of the Leaving Certificate in 2020; Doyle, Lysaght and O'Leary [8] report on how teachers navigated the calculated grades system.

The effects of such replacements of end-of-school state examinations on entry standards to university have been studied in the UK by Hodds ([11]). There have been many other studies of the effects of the closures on mathematics education at university

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level internationally; for example on lecturers and students in Norwegain universities [30], on graduate student programmes in the US ([15]), and on adapting courses for pre-service mathematics teachers in Australia [18]. Researchers have also written about the issue of assessment ([2], [14]). The situation in Ireland was studied extensively by various researchers in 2020. In this article, I will attempt to give an overview of their findings. I have grouped the relevant papers thematically into four categories: the lecturer perspective; the provision of mathematics support and tutorials; the student perspective; and assessment. I will give a brief overview of the research in each of these categories in the following sections.

2. The Lecturers' Perspective

Before we begin, let us acknowledge that third level institutions' response to the COVID-19 closures is very different from planned online delivery of courses. In fact educators coined the phrase *Emergency Remote Teaching* (ERT) to describe the rapid move online. Hodges, Moore, Lockee, Trust and Bond [12] define ERT as *a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances. It involves the use of fully remote teaching solutions for instruction or education that would otherwise be delivered face-to-face or as blended or hybrid courses and that will return to that format once the crisis or emergency has abated. The primary objective in these circumstances is not to re-create a robust educational ecosystem but rather to provide temporary access to instruction and instructional supports in a manner that is quick to set up and is reliably available during an emergency or crisis.* Thus they make a distinction between ERT and learning experiences that are carefully planned and designed to be online in advance.

Lishchynska and Palmer [16] describe the experience of mathematics lecturers across the country (and indeed the globe) of waking up one day in March 2020 to find that their job had changed completely overnight. They recall that after the initial shock the community realised that they had to move their teaching online, that they had very little time to do it, and that it probably would not be perfect. In the summer of 2020, Ní Fhloinn and Fitzmaurice conducted an online survey of mathematics lecturers to gather information on how they coped with this rapid change. They used various mailing lists to invite lecturers to take part in their study and received 257 responses from academics in 29 different countries. More than 30% of the responses came from mathematicians working in Ireland. The results of the analysis of the survey data have been published in [24], [25], [26] and [27].

One of the first decisions facing lecturers in March 2020 was how to replace their face-to-face lectures in the online environment. Some chose to livestream their lectures using Teams or Zoom. Others made short videos or pre-recorded entire lectures. Three quarters of the respondents to Ní Fhloinn and Fitzmaurice's survey included some form of live online session in their teaching, more than 60% made recordings and over 40% had both [26]. Lecturers who chose to have live sessions said that they did so in order to facilitate students' questions and to try to keep the format as close to that of their regular classes as possible. They also emphasised the importance of giving structure to students' days by sticking to the lecture timetable. One reason given for not having live sessions was the worry that some students did not have access to fast broadband. Reasons for using recorded videos included the flexibility it offered to lecturers and students, and the fact that students could replay them as often as they wanted. Quality control was also cited as an advantage of making videos since the recording could be edited or redone if mistakes were made, however this was also seen as a disadvantage since this process could be very time-consuming. There was an increase in the use

of Virtual Learning Environments (VLEs) such as Moodle or Blackboard, with most lecturers uploading notes and examples.

Ní Fhloinn and Fitzmaurice [24] found that 90% of respondents had no previous experience of teaching online. It is no surprise then that the vast majority of them felt high levels of stress associated to the initial move online, although many of the lecturers reported that their stress levels decreased towards the end of the semester. Almost all of the participants found that teaching online was very time-consuming, and about two thirds of them said that they worked more hours than usual.

Apart from the stress and extra workload, lecturers encountered other challenges while conducting emergency remote teaching. Some of these were technical in nature; the main difficulty seemed to be the problem of replacing the ability to write mathematics on chalkboards or whiteboards during classes [24]. Ní Fhloinn and Fitzmaurice [26] found that the participants in their study were very resourceful in this regard, making use of tablets and stylus pens, visualisers, and even pen and paper recorded using their smartphones. Lecturers found it more difficult to translate other aspects of their teaching to the online setting however, with many reporting that conducting discussions or groupwork was problematic. Gauging student understanding during online classes was seen as a major challenge as lecturers missed being able to see their students' faces and reactions. They felt that communication with students was more difficult online not least because of the problems students faced when trying to type mathematical expressions when asking a question in an email or in a discussion forum [24]. More than a third of respondents to the Ní Fhloinn and Fitzmaurice survey were concerned about a lack of interaction in their classes along with problems with student engagement. Lishchynska and Palmer [16] noted that students were reluctant to take an active part in online discussions but that the majority of students did view these discussions. In contrast, some lecturers felt that the anonymity of tools such as online polling helped to increase student involvement over what might be expected in in-person lectures [24].

Lecturers also reported some advantages of online teaching [24]. Some liked the extra flexibility in their timetables and the fact that they did not have to spend time commuting to campus. Others felt that the resources created for online learning, such as short videos, allowed students to work at their own pace and they saw the fact that students had increased responsibility for their own learning as a benefit. In addition, some lecturers felt that the resources developed for emergency remote teaching could be incorporated in modules in future years. Ní Fhloinn and Fitzmaurice [25] summarise the practical advice of the lecturers in their study on issues of concern such as: technology options; specific online teaching approaches, ways of supporting students, and ways of reducing stress for teaching staff.

Lishchynska and Palmer [16] indicated that they saw a shift in emphasis for students from the familiar structure of on-campus classes and supports to the need to be a self-directed learner. They expressed the worry that students were expected to make this transition very quickly at the beginning of the COVID-19 closures. Many of their colleagues around the country had the same concerns and much work was done to provide supports to students. In the next section we will review some of the findings on these initiatives.

3. Provision of Online Support

Tutorials have traditionally been one of the main supports offered to mathematics students at university as they offer students the opportunity to learn in a small group setting. Lishchynska, Palmer and Cregan [17] outline the benefits of this teaching method, for example students can ask for help and get instant feedback on their work, in addition to interacting meaningfully with their peers. Lecturers and tutors also benefit

since they get good information on the difficulties that students are experiencing and can identify problematic topics and misconceptions in real-time. Lishchynska et al. [17] report on how a range of alternatives to in-person tutorials were put in place in MTU during the COVID-19 closures, and on the views of students and academics on these alternatives. Staff at MTU replaced the traditional in-person problem-solving tutorial sessions in six modules with combinations of: live tutorials delivered through Zoom, group-work conducted in Zoom breakout rooms, discussion fora, automated formative feedback on online quizzes, and written individual feedback on students' submitted homework. For the latter, lecturers encouraged students to submit their solutions to a set of exercises and also allowed them to indicate if they had problems with questions so that the lecturer could offer advice. The authors were the lecturers of the modules in question [17]. They reflected on the positive and negative aspects of the various alternatives from their own point of view. They noted that the live tutorials (on Zoom) were similar in some respects to in-person tutorials in that interaction with students was possible, however they found it difficult to see students' written work and to interpret silences. Lishchynska et al. note that the silences could mean that students have no questions or that they do not feel comfortable asking questions. They had similar issues with the groupwork tutorials via Zoom breakout rooms; although students could help each other and share their screens, good interaction was not guaranteed and progress could be slow. Lishchynska et al. [17] note that the discussion fora were popular with students however very few of them were willing to ask questions and most students only accessed the forum to see replies to others' inquiries. The authors valued the online quizzes and associated formative feedback but found that both the creation of good quiz questions and the creation of constructive feedback was very time-consuming. Similarly, giving written feedback on students' assignments was a heavy burden, however this process gave the lecturers insight into student thinking, allowed them to give targeted assistance, and enabled them to foster a connection with students. Lishchynska et al. conclude that no one tutorial alternative was found to match the learning experience of in-person tutorials but they suggest that a combination of such approaches may be beneficial. In particular they saw that the formative feedback initiatives (either in written or automatically-generated form) helped to engage students and inform lecturers.

Lishchynska et al. [17] surveyed the 264 students who experienced the range of tutorial alternatives to gather their views on the supports. Of these, 139 students responded. The students were very positive about the live tutorials saying that they liked having access to the lecturer, and having their questions answered. They made similar comments about the groupwork tutorials. Some students enjoyed working with their peers but others found this difficult and felt that they would benefit from more time with the tutor. The students who had the opportunity to get written feedback on assignments said that this initiative helped them build understanding as well as confidence in their work. In addition, they liked having a regular schedule of exercises to work on. Similar comments were made about the online quizzes and students appreciated the opportunity to practice and to receive instant feedback. Students were also asked whether they used other supports; nearly half of respondents said that they did not seek further help while 39% sought help from their peers and 13% used MLS or private tuition. The majority of students who interacted with other students did so through messaging apps with a minority using video conferencing facilities. When asked to rank potential future supports the majority chose live tutorials and homework with feedback, however nearly 40% felt that in-person tutorials were more beneficial than any form of online support.

Prior to March 2020, mathematics learning support (MLS) was common in most higher education institutions in Ireland [3] but the provision of online supports was

limited [19]. Thus the COVID-19 closures necessitated a drastic change in the provision of mathematics support. Many of the Mathematics Learning Support centres aimed to replicate their in-person drop-in services using web conferencing platforms such as Zoom, Teams, or their VLE [1], [20], [23]. This was the case in UCD where Mullen and Cronin ([22], [23]) conducted a study with colleagues Pettigrew, Rylands, and Shearman from Western Sydney University (WSU). In this project they investigated student and tutor views on online MLS in Ireland and Australia. Six tutors and six students from UCD were interviewed, along with seven students and four tutors from WSU. Mullen et al. categorised the comments of the participants into five themes: usage of mathematics and statistics support, pedagogical changes, social interaction, 'Maths is different', and the future of online mathematics and statistics support. In both institutions, the tutors described changes to their usual pedagogy because of the move online; in particular they tended to spend more time giving detailed answers instead of using their usual techniques such as guided questioning. They found it more difficult to interact with students and especially to diagnose difficulties. This was in part because of the lack of non-verbal cues (exacerbated when students did not turn on their cameras), and not being able to see students' work. Students also commented on the lack of interaction and the subsequent loss of rapport with their tutors, as well as the difficulty of showing their work. The participants expressed the view that this was a particular problem in Mathematics. Tutors usually had access to tablets and stylus pens and so were able to write mathematics in real-time and share their screens with students, but most students did not have access to this technology. Students also found it difficult to type questions involving mathematical notation in chat facilities. However online support did offer certain advantages, and both groups mentioned positive aspects of online MLS; for example some tutors reported that students seemed to be better prepared for the online sessions than they might have been in the past, while some students said that they felt more confident asking questions in an online environment than they would in person. Students and tutors appreciated the increased flexibility and accessibility of online MLS.

It was notable that in both universities involved in the Mullen et al. study that the numbers of students availing of MLS decreased significantly during the COVID-19 closures ([22], [23]). A similar drop in attendance was seen in the Mathematics Support Centre in Maynooth University [20]. Mac an Bhaird, McGlinchey, Mulligan, O'Malley, and O'Neill reported on the introduction of online study groups at the beginning of the 2020/21 academic year as a means of encouraging students to engage with online MLS [20]. More than 700 students registered to take part in the initiative. They were assigned to groups of four or five students who were studying the same material. These groups met once per week on Teams and had access to a tutor during their meeting time. About 60% of the registered students eventually participated in the study groups with 220 students attending at least half of the sessions. In December 2020, Mac an Bhaird et al. [20] surveyed students who were registered for mathematics modules at Maynooth University. The survey had 114 responses of which 88 were from students who had availed of online MLS. Seventy one of the respondents had been involved in the study group initiative. The majority of these students felt that the study groups helped them to increase their understanding of and engagement with their mathematics modules. They appreciated the help from tutors, the opportunity to work with their peers in a small group setting, and that the process was student-led. Some expressed disappointment that attendance in their group was often low and that the group did not work well as a result. Other students said that it was sometimes difficult to interact with their groups online. The students suggested that the group size should be increased, and that efforts should be made to help group-members get to know each other at

the outset. Some students also wanted more tutor involvement in the sessions. The students who had not taken part in the study group initiative gave a variety of reasons for not engaging with it. Some did not know about the scheme, others said that they had no time, did not need the extra help, or preferred to work alone. Mullen et al. [22] reported that tutors in WSU encouraged group work in their online sessions but sometimes found it difficult to get students to engage. Some students said that it was easier to avoid contributing to discussions online than it would be in-person. However students in WSU valued the groupwork sessions because they offered a chance to interact with their peers, and some noted that they did not realise how important these kinds of interactions were for their learning until they were gone.

Mac an Bhaird et al. [20] also asked students about their experience of online drop-in mathematics support. About one-third of the respondents to their survey had availed of this; they commented positively about the flexibility of the service and in particular about the help received from tutors. The reasons given for not attending drop-in sessions were similar to those cited above. In addition, some students felt that they had enough support within their module and did not need the drop-in service, while others reported that timetable clashes meant that they could not attend. Nearly one-third of respondents said that they did not have access to good broadband, which had implications for their engagement.

Students in the Mac an Bhaird et al. [20] study were divided on whether in-person MLS was preferable to online MLS. The students who prefered in-person support said that they found it easier to ask questions in-person and that they missed working in the atmosphere of the Mathematics Support Centre. Mullen et al. [23] noted that the future of MLS is likely to include in-person and online elements. The tutors in their study were keen to return to campus but felt that the online resources developed during the pandemic should be re-used. Students missed face-to-face interactions, however some wanted to keep elements of online MLS as it is useful for when they cannot make it to campus [23].

As well as synchronous support most institutions around the country also offered asynchronous support in the form of notes, videos, practice questions etc. O'Sullivan, Casey and Crowley [28] describe a project undertaken at MTU which aimed to use learning analytics to study students' engagement with online asynchronous support. The authors focused on a set of resources called *Maths Online* which was offered through their institution's VLE. The resources were organised by topic and by degree programme. They consisted of notes, auto-corrected quiz questions, software (MAPLE, SPSS and Minitab), links to other websites, a discussion area, and a facility to book online MLS consultations. Solutions to previous examination papers relating to one module were available through *Maths Online*. O'Sullivan et al. [28] used student interaction data gathered by the VLE to study how students engaged with these resources. They found that engagement was high, with nearly three-quarters of students enrolled in mathematics and statistics modules accessing the *Maths Online* course. However less than a third of these students accessed content on three or more days, and more than four-fifths used *Maths Online* for a total of 30 minutes or less. The most popular features were the software downloads and the examination solutions. The discussion forum was also viewed by a high percentage of students even though they seemed reluctant to actively participate in discussions. The quizzes were used by a minority of students. O'Sullivan, Casey and Crowley [28] comment that students' first impression of an online resource is crucial to their continued engagement with it and thus the design and presentation of online learning objects are vitally important. They advise that a home page for a resource such as *Maths Online* needs to catch the attention of students as well as being clear and informative.

4. The Student Perspective

Although we have seen some of the views of students on the provision of online support during the COVID-19 closures, we have concentrated up to now on the views of lecturers and tutors. In this section we will summarise the findings of three studies that surveyed mathematics undergraduate students during the summer of 2020.

The first is a study carried out by Meehan and Howard which investigated the perceptions of mathematics students in UCD of online teaching and learning during the initial lockdown period [21]. They emailed a survey to 900 students in May 2020 and received 156 responses. One of the aims of this project was to elicit students' views on the aspects of online lecture and tutorial formats that were beneficial for their learning. Meehan and Howard [21] gathered students' comments into three categories relating to: the online environment in general; the online environment for learning; the online delivery of lectures and tutorials. Each of these categories contained both positive and negative experiences. For example students liked the fact that the move online meant that they did not have to spend long hours commuting to university, but some students found working at home difficult either because of a lack of a quiet place to work or because of poor internet connections. This created problems for students when downloading large video files, when trying to participate in a live lecture, and most particularly when taking an online examination. Students liked having the ability to watch and re-watch recordings of lectures and shorter videos. They mentioned that they used these resources to review material and liked the flexibility involved as well as being able to work at their own pace. However the move online meant that they lost the structure of their usual timetable and some of them had difficulty scheduling their work. Some felt that it was easy to fall behind in this learning environment and mentioned that having a regular schedule of short quizzes helped to keep them on-track and to allow them to gauge their own understanding. Many students missed interaction with their peers, lecturers and tutors and the consequent loss of learning opportunities. Some said that it was more difficult to carry out group work and ask questions online, although for some it was easier to do this. The students liked discussion boards and especially the possibility of seeing others' questions. Some asked for more anonymity when asking questions in this format, and also that questions be answered promptly. In regards to the delivery of lectures online, some felt that the live lectures provided a structure for their days and allowed students to ask questions. Some students wanted more opportunities for interaction in lectures while others felt that this was not useful and was distracting. When lectures were recorded and delivered asynchronously, students preferred having a sequence of short videos rather than one long one. This was partly due to the problems of downloading a large video but also because students felt that shorter videos aided concentration and motivation, and were easier to navigate to find material. In some modules, the lecturers did not provide recordings or live lectures and the students in these modules were adamant that providing notes alone was not enough. Students said that they liked live interactive tutorials although they had difficulties sharing their work and writing mathematics online. They also liked when solutions to assignments were provided.

Meehan and Howard [21] asked students about their ideal blended learning experience. Many students responded by saying that they hoped that they would be fully back on-campus in the future. Others stressed the need for more interaction in the online environment. Some students described something similar to a flipped-classroom model where students would be provided with pre-recorded videos, notes and exercises in advance of small-group problem-solving sessions with lecturers and tutors. Based on their analysis, Meehan and Howard [21] make some recommendations at the end of their report. They advocate for maintaining some elements of the flexibility afforded

by the online environment, especially in an effort to avoid long commutes for students. They also highlight the need to plan for better interactions between peers and between students and teaching staff. They advise that each module should have clear weekly schedules and that carefully organised and labelled recordings be made available to students.

In a similar project, Hyland and O'Shea [13] carried out a national survey of mathematics undergraduates in the summer of 2020. The survey consisted of questions in three broad areas: teaching and learning, assessment, and personal experience. The aim was to get information on the impact of the COVID-19 closures on students' learning experiences as well as students' view on the future provision of teaching and assessment. In all, there were 263 responses from students in six universities. To begin with, students were asked about their access to equipment and infrastructure; almost all participants said that they had a laptop or PC, three quarters of them had a quiet place to work, but more than one third of them had poor internet access [13]. The survey asked students how their lectures were delivered during the university closures. The answers to this question highlighted the range of resources that lecturers around the country put in place for their classes. About 90% of respondents said that they were provided with recorded lectures or short videos, about half of them had live lectures online, while four fifths of them had access to lecture notes. In addition the majority of students said that their lecturers created practice quizzes for them and gave them solutions to assignments or past examination papers. Even with these resources at hand, nearly 60% of students said that the COVID-19 closures had a negative impact on their capacity to learn mathematics. Many of the students said that they missed in-person classes especially tutorials. More than three quarters of the students had some form of tutorial support during the initial closures. The majority of these students said that they had live tutorials facilitated through Teams or Zoom, while some of their modules had discussion boards manned by tutors who were able to answer mathematical questions. The students seem to prefer online live tutorials to the discussion board format as they said that they found it difficult to ask questions and were sometimes embarrassed because everyone could see their query. This may be one of the reasons for the findings we saw in the O'Sullivan et al. [28], Lishchynska et al. [17], and Meehan and Howard [21] studies that showed that students often viewed discussion boards but were reluctant to participate themselves. The students in the Hyland and O'Shea [13] study also missed the usual interactions with tutors and students in in-person tutorials and the resulting learning opportunities that these interactions afford.

It was notable that very few students complained about the quality of teaching during this period with most of them citing the loss of interaction and communication with their lecturers, tutors and especially their peers as reasons for their difficulties [13]. This lack of interaction may be the reason why more than half of the respondents in the Hyland and O'Shea study said that they felt more isolated than usual. The university closures seemed to have a large impact on students' well-being and mental health as about two thirds of students said that they felt more anxious and found it more difficult to motivate themselves during that time. In addition, the participants echoed the views of their peers in the Meehan and Howard [21] study that it was difficult to pace their learning without the help of a set timetable and structure.

Students also found positives in their experience of learning during the initial COVID-19 closures [13]. Some of them liked the flexibility of being able to study at home (without a commute) and whenever was convenient. Some students liked working at their own pace and were proud of their new study skills. Others mentioned that the extra resources that were put in place for them were very helpful. Students expressed mixed views when asked what kind of learning experience they would like in the future.

Some wanted all teaching to be back on-campus but asked that resources be made available to students who could not attend. Others recognised that large-group lectures were unlikely to take place on campus in Autumn 2020 but asked that small-group tutorials return to in-person delivery.

Lishchynska and Palmer [16] used engagement data from their VLE and end of module feedback forms to gather information on students' preferences for learning resources in three modules in MTU. These were a second-year module, a fourth-year module and an MSc module. They found that overall 63% of students used both notes and videos when studying however a much higher proportion of MSc students did this in comparison with the undergraduates. The postgraduate students also found remote learning more difficult than the other students in this study. The vast majority of students surveyed said that they preferred asynchronous to synchronous learning resources, When asked about their preferences for future course delivery nearly 90% did not want a fully online experience but over half of them said that they would like a mix of in-person and remote learning. The students were asked to describe the advantages and disadvantages of learning online during the university closures and their opinions were strikingly similar to those that we have seen in the two studies above. They liked having the flexibility to study at their own pace and in their own time but some missed the structure of their usual timetable. They also found it harder to motivate themselves to work and some had no access to a quiet place to study. They liked the recordings that were available to them and having the ability to pause and re-watch segments. However they missed having the opportunity to ask questions in classes and to interact with their peers. Some of the students in this study felt that although they had learned how to use methods during the COVID-19 closures, they worried that they did not fully understand the reasoning behind the methods. How to assess student understanding in an online environment was a difficult problem for lecturers; we will consider this issue in the next section.

5. Assessment

One of the most significant implications of the COVID-19 closures in 2020 was that traditional on-campus examinations were impossible forcing universities to react swiftly to modify their assessment methods. Ní Fhloinn and Fitzmaurice [27] report on how the mathematics lecturers in their study tackled this issue. They found that four fifths of them gave some form of online assessment while the remainder did not. Some of the people who did not use online assessment said that their examinations had not yet happened, others replaced examinations by coursework, and for some the examinations were canceled completely. Of the lecturers who did use online assessment, one fifth gave formative assessment only (such as written assignments or online quizzes which did not contribute to grades), two fifths gave summative assessments only (such as open-book exams or multiple choice quizzes which did contribute to grades), and the remainder used a combination of both. The participants were asked whether they saw a difference in grade profiles compared to previous years. About one quarter saw no difference and the remainder observed some differences ranging from small to large, however less than 10% reported very large differences. The lecturers reported grade increases in some modules and decreases in others. When asked for possible reasons for these differences, some said that the stress of doing examinations online could have led to decreases in overall grades, while others thought that increases may have been due to having open book assessments, having more time allotted to each examination, or changes in marking guidelines. A small number attributed increases to cheating on the part of the students with some lecturers worried that it was difficult to vouch for the legitimacy of grades in an unproctored setting. Others highlighted the (sometimes

physical) challenge of grading written examinations online [24]. Despite these issues, most of the lecturers were satisfied with their assessment regime.

Some of the studies that we saw earlier give information on the students' views of changes to traditional assessment methods. Meehan and Howard [21] found that students in UCD liked having open-book examinations and that having examinations at home was less stressful for most students. However when students did not have a quiet place to work or had poor internet connections, having the examination on campus was preferable. Hyland and O'Shea [13] also found that students seemed to like the open-book examinations and thought that they were fair. However the initial uncertainty in March 2020 about the format of assessment was disconcerting for students and some mentioned that they had technical problems during exams or when submitting their work which caused them much stress.

6. Conclusion

In this article, we have seen many themes recurring. In particular, we have seen that lecturers, tutors, and students value the connections that are fostered in in-person classes. These interactions give teaching staff valuable insights into student thinking, and give students opportunities to ask questions and receive feedback. This is particularly true in the tutorial and MLS settings, but also holds in the case of lectures. This may come as a surprise to those who view traditional mathematics lectures as very static. In any case, when designing any online teaching experiences, care should be taken to incorporate design features which enable meaningful communication between teaching staff and students, and between peers.

We have seen that students' difficulty in writing mathematics and sharing their work in an online environment was one of the reasons for the lack of interaction. It seems that access to specific types of technology can really help here. Heraty et al. [10] outline various different methods that tutors in Maynooth University used to communicate mathematics effectively to their students. It is vital that students also have access to appropriate technology. Many of the studies above found that although students usually had laptops or PCs, they may not have tablets and stylus pens and a large proportion of them do not have access to reliable broadband. These facts must be taken into consideration when designing future provisions.

There seems to be little appetite from lecturers or students for fully online courses, however both groups saw benefits from aspects of the teaching and learning experience over the last two years. In particular, many resources have now been created and can be profitably re-used. Staff and students both liked the element of flexibility that the move online facilitated, however the lack of a timetable was problematic for some students. A major concern is the heavy workload that lecturers had to bear during ERT. It is clear that creating good resources is very time-consuming and this must be included in any planning.

Apart from an increased workload, staff often found ERT stressful. This was the case for students too, many of whom felt more isolated and more anxious than usual. This highlights the importance of paying attention to the mental health of staff and students.

The studies that we have reviewed above have shown the effects of the COVID-19 closures on teaching staff and on students. They share many common threads, but perhaps the main message conveyed is that, despite the best efforts of all concerned, it remains difficult to recreate the atmosphere of in-person mathematical learning opportunities in an online setting. Engelbrecht, Linares and Borba ([9]) expressed the view that the international COVID-19 university closures have hastened the advent of online and blended learning becoming more prevalent. If they are correct, it would be

prudent to use the experience that we have gained from ERT over the last two years when designing any future online courses or resources.

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Ann O'Shea studied at UCC and the University of Notre Dame. She is a professor in the Department of Mathematics and Statistics at Maynooth University. Her research interests lie in Mathematics Education.

Department of Mathematics and Statistics, Maynooth University
E-mail address: `ann.oshea@mu.ie`