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Research Article

Fostering interaction and engagement in remotely delivered mathematics tutorials in an Irish university

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ABSTRACT

With the initial COVID-19 lockdown of March 2020 in Ireland, many modules in university programmes that were designed to be delivered face-to-face were suddenly switched to remote delivery. The difficulty for both lecturers and students in replicating face-to-face interaction and the frequent lack of lecturers' visibility of students' work in such a setting created challenges for teachers and learners alike. In the current study, students' perspectives were sought on the format of remotely delivered tutorials for two first-year engineering mathematics modules. The format of the tutorials was designed to emulate face-to-face delivery as closely as possible and to promote student engagement, with an emphasis on real-time lecturer-student interaction as well as comprehensive visibility on student progress throughout each tutorial by combining an online mathematics assessment system Numbas with the video conferencing platform Zoom. Overall, students found the format to be a positive alternative to face-to-face tutorials and one that compared favourably with alternative delivery methods. It is hoped that the findings of this study would be of use to other practitioners engaged in remotely delivered mathematics tutorials.

Keywords: remotely delivered mathematics tutorials, lecturer-student interaction, student engagement

INTRODUCTION

There are many challenges inherent in delivering effective mathematics instruction online. The use of mathematical notation including formulae, symbols and subscripts means that communicating mathematics effectively online often requires the use of specific software (such as LaTeX) or hardware (such as a tablet) and is most effective for two-way communication if both student and lecturer are equipped with adequate information and communication technology (ICT) resources. Such technical challenges have been described in studies such as (Mullen et al., 2021; Ní Fhloinn & Fitzmaurice, 2021) and the resulting obstacles to effective communication have been felt by both students and lecturers in the transition to online education during the COVID-19 pandemic.

In several studies investigating students' perspectives on the impact of a shift to remote delivery during the COVID-19 pandemic, students have cited, among other things, the lack of real-time lecturer-student interaction as having a negative impact on learning and the learning experience across a variety of non-mathematical subjects (Means & Neisler, 2021; Shim & Lee, 2020) as well as for mathematics tutorials and mathematics support (Hyland & O'Shea, 2021; Lishchynska et al., 2021; Meehan & Howard, 2020; QQI, 2020). In particular, in the shift to remote learning during the first COVID-19 lockdown, 65.8% of students surveyed by Hyland and O'Shea (2021) indicated that their learning through tutorials was negatively impacted by the transition to remote delivery. Studies investigating lecturers' impressions of the impact of a move to online teaching offered similar views. In their study investigating mathematics lecturers' experiences of the remote delivery of mathematics in the early months of the pandemic, Ní Fhloinn and Fitzmaurice (2021) observed that lecturers surveyed found interaction with the class more difficult and felt that engagement levels were lower online than in person.

The importance of lecturer-student interaction is widely recognised (Heraty et al., 2021; Jaggars & Xu, 2016; Platt et al., 2014; Radmehr & Goodchild, 2023; Yang, 2021). Such interaction can improve students' feelings of connectedness and ability to focus (Yang, 2021). As against that, a lack of interaction with peers and lecturers was found to be the most significant challenge reported by students during the remote teaching period following the initial lockdown (Yang, 2021). This finding was also observed by Radmehr and Goodchild (2023) with lecturers, in particular, valuing lecturer-student interaction. In contrast, online learning experiences have been found to be positively associated with perceived levels of interactions in online classes. In a study of 289 students across multiple years in a university in the United States, in which the authors asked students to compare their experiences of online and face-to-face courses, Platt et al. (2014) found a strong positive correlation between how interactive the respondents perceived online courses to be compared to face-to-face courses and the comparative knowledge they felt they had acquired in online courses as against face-to-face courses ($r = .73$, $p < .01$). An analysis by Swan (2002) of responses from 1,108 students across 73 courses also revealed strong positive associations between perceived lecturer-student interaction and each of course satisfaction ($r = .761$, $p = .01$) and perceived learning ($r = .707$, $p = .01$). Heraty et al. (2021) also stress the importance of trying to reproduce, in an online setting, the two-way interaction that naturally occurs between students and tutors in a face-to-face setting. The challenge in achieving this interaction is discussed in a study on student and tutor perceptions of online tutorials by Lowe et al. (2016), who found that both students and tutors perceived online tutorials to be roughly as effective as face-to-face tutorials for learning, but that the former were significantly less effective for interaction than the latter.

Moreover, as with other subjects, in-person mathematical communication often involves non-verbal communication such as interpreting gestures, body language or facial expressions (Busto et al., 2021; Heraty et al., 2021; Jin, 2022; Mullen et al., 2021; Ní Fhloinn & Fitzmaurice, 2021). The absence of these non-verbal cues in a remote setting can present challenges for student comprehension and also for lecturers in gauging students' understanding. Both lecturers and students are acutely aware of these challenges, with some students reporting a need for more mathematics support online than in-person as a result (Mullen et al., 2021). Some research has been done on how to incorporate some aspects of non-verbal communication into online delivery. Jin (2022), for example, presents a study in which the instructor was visible alongside the material throughout parts of the lecture where it was felt that body language was important (such as pointing to relevant parts of an equation, making eye-contact, or directing the students where to look by following the instructor's gaze). The instructor was then absent from other parts of the lecture where it was felt that this could reduce distraction and improve engagement (where students were required to solve a problem that was presented, for example). A short survey on students' satisfaction with the method indicated that students found the lectures engaging and "felt more present in the lectures compared to other online teaching" (Jin, 2022, p. 309).

Busto et al. (2021) present an alternative option for preserving some of the communication aspects of traditional face-to-face mathematics lectures during the pandemic. Their blended approach involved a small number of students presenting for lectures and tutorials in person, while the remaining students attended (synchronously) online. This was similar in approach to a pre-pandemic study investigating the creation of a blended learning environment for masters' students in teacher training (Wang et al., 2018). Significant classroom upgrades and specialised staff training were undertaken as part of the former study to enable implementation. As such, while economically affordable, the logistical requirements and technical investment necessary for this strategy were considerable and may not be feasible for all institutions, in particular if required at scale. Moreover, such an approach would not be possible in the event of a full lockdown as was imposed in the initial stages of the COVID-19 pandemic.

The approaches described above provide opportunities for students to participate via chat, using microphone or by participating in polls and quizzes. Nonetheless, Trenholm and Peschke (2020) observe that even using methods such as these, the interaction between lecturer and students is predominantly one-sided. The opportunity for students to complement the lecturer-to-student interaction with a corresponding student-to-lecturer interaction and complete the two-way communication loop is often more difficult to realise.

The lack of visibility of students' work is one important facet of the communication component that inhibits the second half of this two-way communication. This aspect is of particular importance in tutorials – the focus of this study. Several studies have alluded to this difficulty (Heraty et al., 2021; Lishchynska et al., 2021), with many suggesting resourceful ways for how it may be overcome. Whiteboard sharing is a popular solution but requires the use of a stylus in order to be practicable. Equipping students with an inexpensive stylus for use on their smartphones (Heraty et al., 2021) may help, however there are limitations of space when drawing complex mathematical expressions, ideas or graphs on a smartphone screen. Asking students to upload photos of their workings for the lecturer to review in real time (Heraty et al., 2021) is another possibility. Others, such as asking students to hold their work in front of the camera can be a simple and effective means of sparking discussion or initiating the critique of a solution to a problem in a live class (Roicki, 2021). All of these options are, however, decidedly suboptimal in terms of efficiency and ease of communication compared to the lecturer simply walking around the classroom as students work on problems. Finding effective, practical means of alleviating any barriers to learning that result from decreased interactivity and reduced real-time visibility of students' workings that are characteristic of a fully remote setting are therefore important areas that still require further exploration.

This paper aims to address this problem by presenting the format of remotely delivered mathematics tutorials that were designed with lecturer-student interaction, student engagement and increased visibility of students' workings in mind and investigating students' perceptions of this delivery mode. Results of a survey disseminated to two groups of first-year engineering students in Munster Technological University in relation to the format of tutorial delivery are presented and considerations for the future design of online tutorials are set out. The findings of this study should be of interest to those interested in lecturer-student interaction and student engagement, in particular to those involved in delivering mathematics tutorials in an online setting.

BACKGROUND

During the initial lockdown in March 2020, in-person tutorials for one of the engineering mathematics modules considered in the current study (MATH6006 – A first-year calculus module) were replaced with weekly Q&A sessions. These sessions were run through the 'conferences' (virtual call) feature on the university's virtual learning environment (VLE) Canvas, where students could join the call to ask specific questions on the module material or exercises from the tutorial sheets. The lecturer would then work through these problems or give further explanations using a virtual whiteboard. Student attendance at the Q&A sessions was typically very low, with active participation usually limited to only one or two students who were in attendance. The low attendance and participation in these sessions can perhaps be somewhat explained in the context of studies such as (Hyland & O'Shea, 2021). In that study, students were reported to have felt that in order to gain benefit from resources such as the Q&A sessions described above, they would already need to have somewhat of a grasp of the material in order to be able to ask questions.

With the continuation of remote delivery for the 2020/2021 academic year, rather than weekly Q&A sessions, in-person tutorials for both semester 1 and semester 2 engineering mathematics modules (MATH6005 – a first-year linear algebra module and MATH6006 – Calculus) were, instead, replaced with a revised tutorial format in an attempt to capture both the learning and interaction components of a traditional face-to-face tutorial. The format was as follows: tutorials were run via Zoom, with students attempting the weekly tutorial sheets on Numbas (an e-assessment tool for mathematics that was made available to the students through Canvas), while the lecturer was available in real time either using the microphone or Zoom chat for immediate feedback and to offer guidance or clarity as required. The lecturer had complete visibility on student progress in real time through the Numbas learning tools interoperability (LTI) and would therefore be aware if any student was either not submitting answers or was submitting incorrect answers. It would then be possible to engage with the student directly via Zoom chat to try to address potential difficulties. In addition, students were given the option of uploading photos of their workings for more detailed feedback and could request that the lecturer work through specific questions on a virtual whiteboard. The aim of this approach was to emulate the experience of an in-person tutorial as closely as possible by two means:

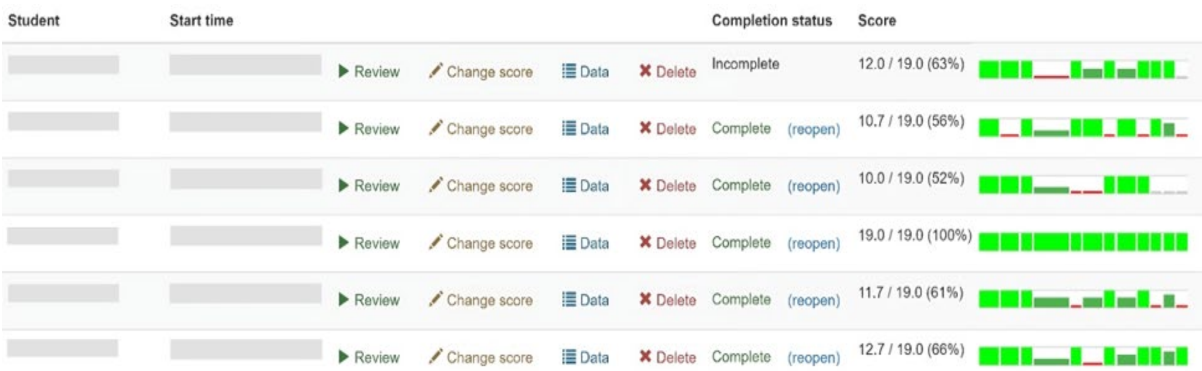

Figure 1. Lecturer's view of class progress on a tutorial sheet using Numbas LTI on Canvas. Different shades of green/red boxes in the bar on the right-hand side indicate the proportion of each question each student answered correctly/incorrectly. A blank box indicates that no answer was submitted by the student for that question.

(1) by encouraging active engagement from the students who were to work on the weekly problems individually during the tutorial hour and

(2) by promoting lecturer-student interaction.

While active engagement has long been recognised as an important component in achieving learning outcomes it has also been found to be an important factor in *perceived* learning (Rovai & Barnum, 2003), while the importance of lecturer-student interaction has been discussed above as well as in studies by (Bejerano, 2008; Horspool & Yang, 2010; Mohammad Zadeh et al., 2023).

The choice of platforms – Zoom and Numbas – was informed by the fact that the former was already integrated within the Canvas VLE and was the preferred platform across Munster Technological University for delivering synchronous content to students during the remote teaching period and by the author's familiarity with the latter as a useful tutorial and assessment system. Numbas has several features that make it a valuable tool for remote and independent learning. One such feature is the facility to incorporate tailored feedback that is to be provided in the event of a student entering a specific incorrect answer. In this way, it is possible to include targeted feedback to address common misconceptions and to correct common errors. A further strength is the capacity to incorporate a series of progressive hints into individual questions to allow students to access guidance at various points throughout the question. Furthermore, it is possible to randomise parameters within questions in Numbas, allowing for the creation of a bank of practice or exam questions that are superficially different but are of equivalent standard. Of particular benefit during the remote delivery period was the fact that the use of Numbas afforded the lecturer a comprehensive view of students' attempts at all questions. The progress of each student, as well as that of the wider class, was visible to the lecturer through the Numbas LTI, see **Figure 1**, allowing the lecturer to see how each student was progressing overall, as well as whether any particular question was causing difficulty for the class as a whole. The specific answer for each question submitted by a given student could be accessed by selecting the 'Review' option next to the student's name on the LTI and then selecting the relevant question from the list.

Figure 2 shows the lecturer's visibility of a student's submission for a particular question and also provides an example of targeted feedback built into a question while **Figure 3** illustrates the types of hints that might be included in questions to support student learning.

One frequently cited drawback of online mathematics lectures and tutorials is the challenge in assessing students' understanding in real time. In a remote setting, the ability to appraise whether or not students have grasped the material is stymied by a number of factors, including the lack of non-verbal cues such as facial expressions (Ní Fhloinn & Fitzmaurice, 2021) and the inability to see the individual workings of a student (Heraty et al., 2021; Lishchynska et al., 2021) unless the student chooses to upload their workings. Unfortunately, in this author's experience, few students chose to avail of this option. However, in a significant number of instances, an incorrect answer entered into Numbas by a student will often hint at the specific error(s) that the student may have made in arriving at that answer. When finding the inverse of a matrix M, for example, a student might inadvertently multiply the adjoint of M by the determinant of M rather than

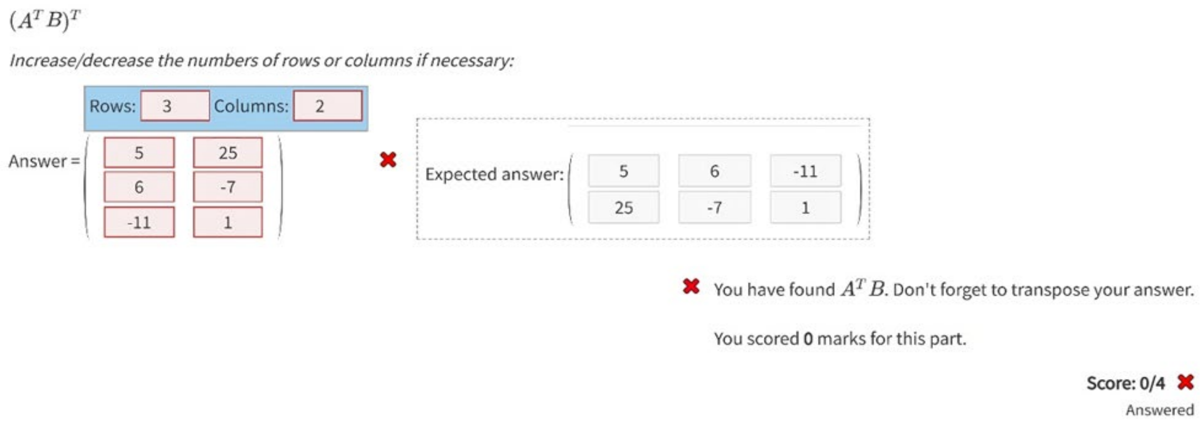

Figure 2. Lecturer's view of a student's answer for a specific question in the MATH6005 module, with the feedback the student received and the expected answer for the question

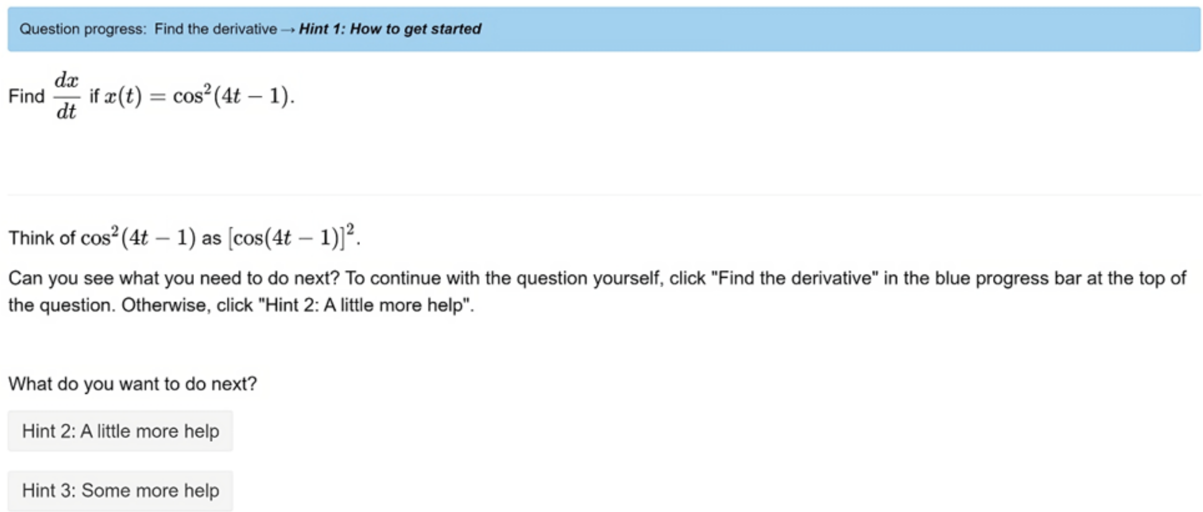

Figure 3. Progressive hints built into a Numbas question from the MATH6006 module

dividing by the determinant, or when finding the magnitude of a vector with some negative components such as $u = \langle 1, -2, -5 \rangle$, a student may make errors when squaring such components in their calculator (typing $\sqrt{1^2 + -2^2 + -5^2}$ instead of $\sqrt{1^2 + (-2)^2 + (-5)^2}$, for instance). On such occasions, it was possible for the lecturer, having viewed a student's answer in Numbas, to send a message to the student via the Zoom chat to highlight the area(s) for the student to review and to guide them to the correct answer. **Table 1** gives some sample interactions between the lecturer and students.

The tutorial format described above applied to both the first semester MATH6005 module and the second semester MATH6006 module in the 2020/2021 academic year. For context, most of the lectures for both modules were delivered asynchronously via short videos produced using Screencast-O-Matic software, with one live lecture every two weeks and one additional (optional) Q&A session each week to address any general questions. To maintain a sense of structure for the module and to help students to pace their learning, the videos for each class were uploaded in advance (at most one day ahead) of the timetabled hour for that class, along with suggested exercises to try after each video. Students were polled after four weeks to determine whether a change in lecture delivery mode was preferred but the majority voted in favour of continuing with the above delivery mode.

A move towards more on-campus delivery began in the first semester of the 2021/2022 academic year, with in-person tutorials resuming for the MATH6005 module. However, in order to adhere to social distancing protocols, instead of the lecturer walking around the class, the Numbas LTI was still used to monitor students' progress and the Zoom chat was once more employed to address possible errors in students' workings. All lectures for semester 1 were delivered remotely, in line with the description above. Full on-campus activity

Table 1. Sample interactions between the lecturer and students via Zoom chat during tutorials

Conversation	
Lecturer to student 1	Hi ****. You're very close in Q2 – it's just in the decimal part. Just double check the calculations again.
Student 1 to lecturer	Do you take the angle as 67.29 degrees?
Lecturer to student 1	No – that might be, where the rounding issue is coming from. Rather than converting it to degrees, make sure your calculator is set to radians and use the 1.1745 radians [given in the question] in the calculation.
Student 1 to lecturer	Oh okay perfect thanks.
Student 1 to lecturer	For when it's to the power of -2 ([question] 7 c) do you square first and then divide by (-2+3i) or how do you do it?
Lecturer to student 1	Because of the negative power, think of it as 1 / (-2+3i)^2. So you will need to square out the denominator first and then once that's tidied up, do your usual division of complex numbers.
Student 1 to lecturer	Perfect I get it now thanks.
Lecturer to student 3	Hi ****. To multiply two matrices you don't just multiply individual elements. You need to multiply entire rows by entire columns. Take a look at the example that's on the board.
Lecturer to student 5	Hi ****. It's just the entry in row 1, col 2 you need to check – the rest are perfect.
Student 5 to lecturer	Perfect, thank you.

was resumed in semester 2, 2021/2022 with a return to pre-pandemic tutorial format and so the second semester module (MATH6006) is not included in this study for the academic year 2021/2022.

RESEARCH METHODOLOGY

Two first-year engineering cohorts (Structural Engineering and Common Entry Engineering) with combined delivery were selected to participate in this study for each of the academic years 2020/2021 (Cohort 1) and 2021/2022 (Cohort 2). Cohort 1 comprised 112 students and Cohort 2 108. Non-probability convenience sampling was used to select participants for the study and all students aged 18 and over from each cohort were invited to complete a short, anonymous survey created using MS Forms. The survey was purpose-designed, as it pertained to a very particular tutorial format adopted during the pandemic and consequently no suitable surveys were available at that time. Design of the survey was informed by the author's experience in the area and was fine-tuned based on discussions with colleagues, in line with approaches taken in (Lishchynska et al., 2023; Mac an Bhaird et al., 2021). The survey comprised a number of closed questions with Likert-scale, ranking and multiple-choice type responses as well as two open-ended questions where students could make suggestions for improvement or other general comments in relation to the tutorials. A copy of the survey is included in **Table A1** in **Appendix A**. In addition to the survey, informed consent was sought from students to include data related to Zoom calls attended, Zoom chat conversations and data generated through the students' use of Numbas.

Ethical approval for the study was received from Munster Technological University's Research Ethics Committee on 3 November 2021 (week 6 of semester 1), after which the survey was distributed to Cohort 1. Cohort 2 were provided with the survey in week 10 of the semester in order to ensure sufficient exposure to the tutorial format to make informed comments. A total of 28 responses were received from Cohort 1 and 30 from Cohort 2, giving response rates of 25% and 28% respectively. Students from Cohort 1 who failed either module in 2020/2021 and were repeating the module(s) in 2021/2022 were only invited to participate in the survey distributed to Cohort 1 and so there was no overlap of participants across the cohorts.

Given the low response rates, the author acknowledges the potential for non-response bias. Comparing respondents to non-respondents for similarity was not possible due to the anonymous nature of the survey and the resulting lack of knowledge as to which students had responded and which had not. On the one hand, the students in each cohort would have been similar in age to all other students in the same cohort, Cohort 1 being second-year students and Cohort 2 first-year students at the time of the survey. However, differences between respondents and non-respondents within a given cohort may persist in relation to factors such as gender, socioeconomic background or accessibility to reliable hardware and software. Such factors might enhance or inhibit a given student's experience of the tutorial delivery, thereby potentially resulting in significantly different responses to the survey questions. Caution is therefore advised in relation to any generalisation of the findings of this study.

Pooling the data from both cohorts was considered, however the experiences of the two groups were considered sufficiently different to justify treating the cohorts as separate populations (Cohort 1 attended tutorials remotely while Cohort 2 attended in person. Furthermore, at the time of the survey, Cohort 2 were first-year students with less experience of remotely delivered third level education than the second-year students of Cohort 1).

Statistical analyses were performed using SPSS 28.0 for Windows. Student responses were summarised using descriptive statistics, numerically as frequencies and percentages and graphically using bar charts and pie charts. Chi-squared tests were used to test all results for significance at a 5% level. Following this, Binomial tests were carried out to compare responses pairwise, using the Bonferroni correction method to correct for multiple comparisons of responses to the same question. For more informative reporting purposes, when carrying out the Binomial tests, 'very unhelpful' and 'somewhat unhelpful' were combined into a single response category, with 'very helpful' and 'somewhat helpful' combined into a second response category, and 'neither helpful nor unhelpful' kept as a separate category. Qualitative data were analysed using general inductive analysis (Thomas, 2006). The responses to the open-ended questions were studied, following which several categories were identified for each of the questions, along with sub-categories in some cases. Details of the themes that emerged are discussed in the next section.

RESULTS

The survey was designed to capture students' perceptions of

(1) the efficacy of Numbas as a remote learning tool,

(2) the use of Zoom chat to facilitate guided learning,

(3) the value in uploading workings for lecturer feedback, and

(4) the combination of all three components as an overall remote tutorial format.

In this section, the results pertaining to each of the above components are presented, following which summary statistics relating to all questions are presented in **Table 2**.

The section closes with details of students' responses to the open-ended questions.

Perceptions of Numbas as a Remote Learning Tool

Students were asked to rate Numbas as a remote learning tool for practising mathematics. The results were consistent across both cohorts, with a very high proportion regarding it as a beneficial resource. A total of 25 students from Cohort 1 (89%) and 28 students from Cohort 2 (93%) rated Numbas as either 'somewhat helpful' or 'very helpful' ($p < .001$) (**Figure 4**).

Feedback for common errors or misconceptions was included in a number of questions throughout the tutorial sheets. Students were asked to state whether or not they had noticed this feedback and, if so, to rate the feedback they received. Once again, the responses were consistent across both cohorts. The majority of respondents (26 students [93%] from Cohort 1 and 25 students [83%] from Cohort 2) noticed where feedback for common errors was included. Of those, 23 students from Cohort 1 (88%) and 23 students from Cohort 2 (92%) rated the feedback as either 'somewhat helpful' or 'very helpful' ($p < .001$) (**Figure 5**). It should be noted that, for the students who reported that they did not notice feedback, it is possible that they simply did not see the feedback or that they did not make the common errors in those questions for which feedback was provided. Moreover, the students who rated the feedback provided as either 'somewhat helpful' or 'neither helpful nor unhelpful' did not correspond to the students who rated Numbas as either somewhat or very unhelpful (**Figure 4**).

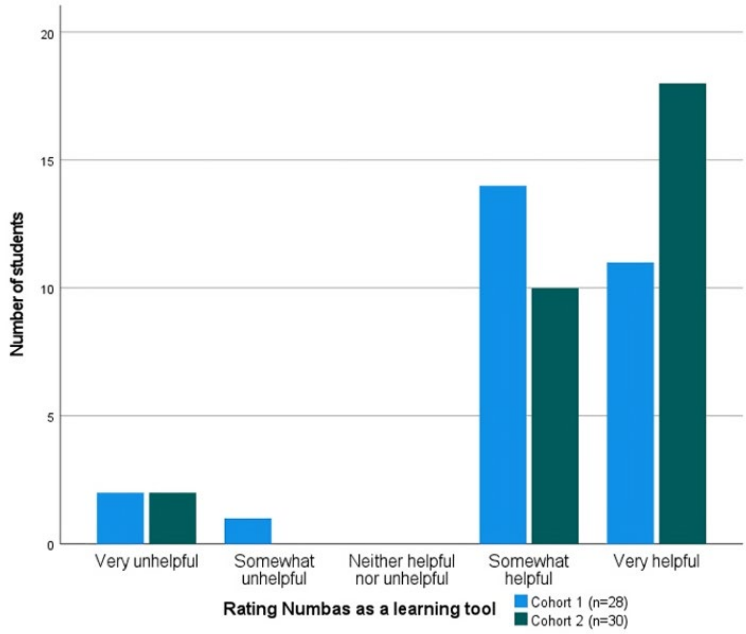

Figure 4. Perceptions of Numbas as a remote learning tool for practising mathematics questions

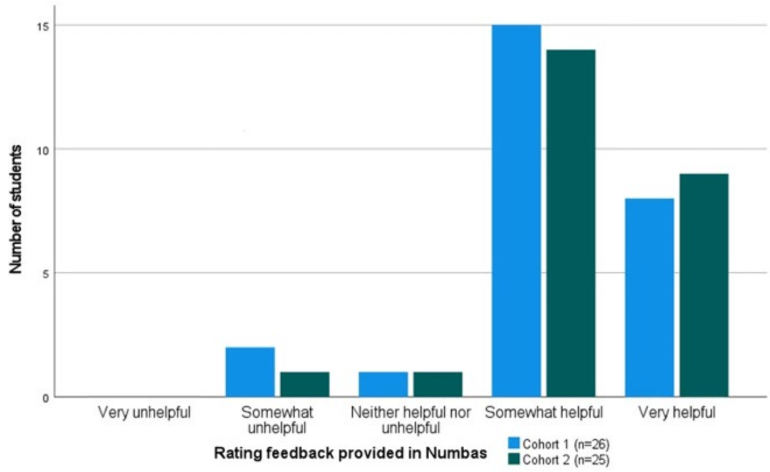

Figure 5. Students' views of feedback incorporated into Numbas questions

Perceptions of Zoom as a Learning Tool

Students were invited to share their views on the effectiveness of receiving feedback via Zoom chat as a means of helping them in

(a) completing individual questions (Q5 of the survey) and

(b) their overall understanding of the material (Q6 of the survey).

Although there were statistical differences between the responses of both cohorts, it was still the case that a statistically significant majority of each cohort perceived Zoom chat as having high utility. As a mechanism for providing feedback in tutorials, Zoom chat was rated as either 'somewhat helpful' or 'very helpful' for completing individual questions by 24 students (89%) from Cohort 1 ($p < .001$) and 28 students (97%) from Cohort 2 ($p < .001$). As a means of facilitating overall understanding of the module material in tutorials, it was rated as one of 'somewhat helpful' or 'very helpful' by 21 students (78%) from Cohort 1 ($p = .003$) and 29 students (100%) from Cohort 2 ($p < .001$). One student from Cohort 2 selected 'very helpful' for Q5 and 'I did not receive feedback on individual questions via Zoom chat' for Q6 and so was excluded from the analysis for these two questions. Figure 6 shows the responses from both cohorts. The three students from Cohort 1 who rated Zoom chat as either 'Somewhat unhelpful' or 'Neither helpful nor unhelpful' as an aid to understanding

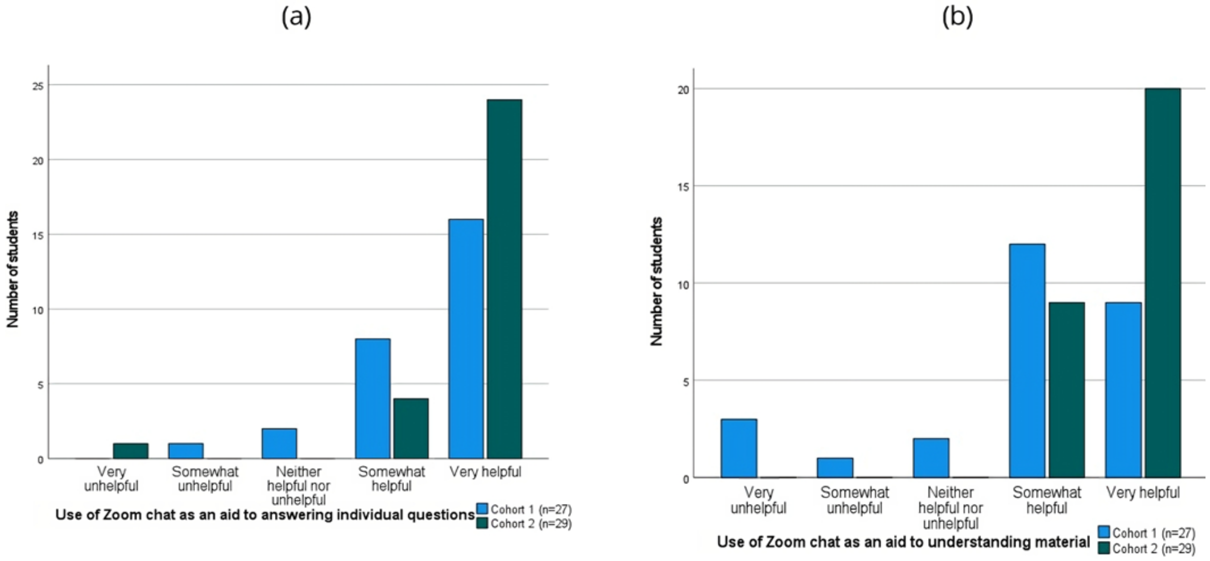

Figure 6. How students from each cohort viewed the use of Zoom chat (a) as an aid to completing individual questions and (b) as an aid to overall understanding of module material

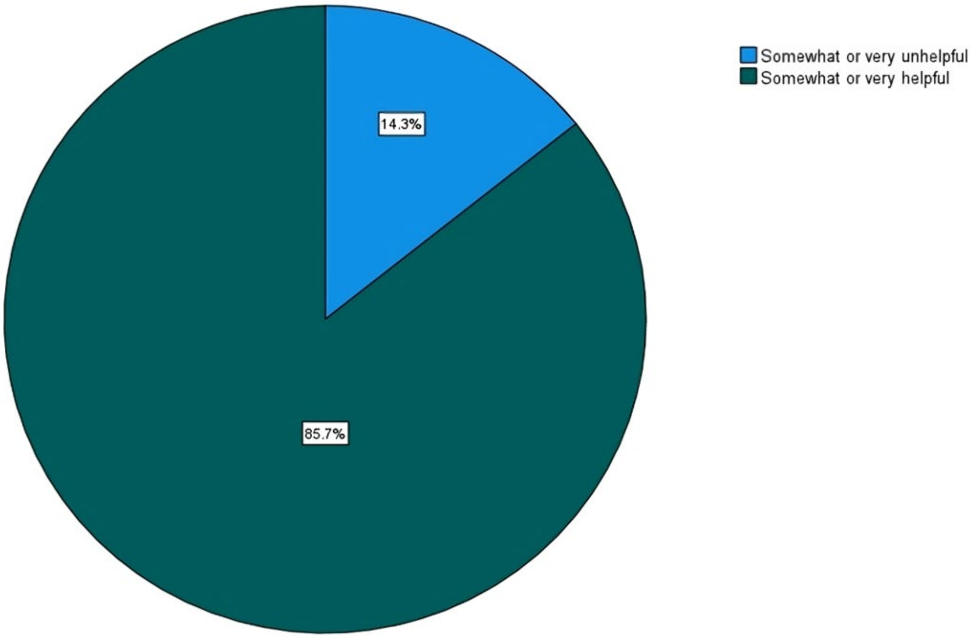

Figure 7. Students' views on feedback from workings uploaded during tutorials (Cohort 1, n = 14)

individual questions (Q5) also rated it neutrally or negatively (either as 'very unhelpful' or 'neither helpful nor unhelpful') as an aid to overall understanding of the material (Q6).

Uploading Workings

As tutorials for Cohort 1 were delivered remotely, students from that cohort had the option of uploading photos of their workings during the tutorial. The option of uploading workings for feedback was also available to Cohort 2 but was only availed of outside of the tutorial hour. As the study related to the running of the tutorials only, Cohort 2 were therefore not asked for their feedback in relation to uploading workings. A total of 14 respondents (50%) from Cohort 1 availed of the option of uploading workings during tutorial hours. Of those, 12 students (86%) found the feedback received on their workings to be either 'somewhat helpful' or 'very helpful' ($p = .013$). None of the students reported the feedback as 'neither helpful nor unhelpful' (**Figure 7**).

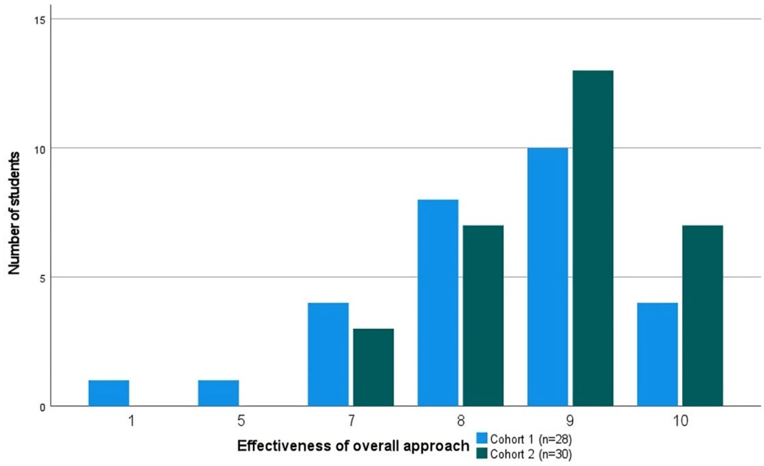

Figure 8. Overall rating of tutorial format on a scale of 1-10

Table 2. Summary of students' responses for each cohort

Variable	Cohort	Min, Q1, Median, Q3, & Max
Numbas as a learning tool	1	1, 4, 4, 5, 5
	2	1, 4, 5, 5, 5
Feedback within Numbas questions	1	2, 4, 4, 5, 5
	2	2, 4, 4, 5, 5
Zoom chat as an aid to answering individual questions	1	2, 4, 5, 5, 5
	2	1, 5, 5, 5, 5
Zoom chat as an aid to understanding overall material	1	1, 4, 4, 5, 5
	2	4, 4, 5, 5, 5
Feedback on uploaded workings*	1	1, 4, 5, 5, 5
Overall rating of tutorial approach	1	1, 7, 8, 9, 10
	2	6, 8, 9, 9.25, 10

* Feedback on uploaded workings applied to Cohort 1 only

Perceptions of Overall Approach

Students were asked to rate the overall approach taken in the delivery of tutorials for the MATH6005 and/or MATH6006 modules on a scale of 1 to 10 with 1 being 'not at all effective' and 10 being 'extremely effective'. The median scores for Cohort 1 and Cohort 2, respectively were 8 (IQR 7-9) and 9 (IQR 8-9.25). A total of 23 students from Cohort 1 (82%) and 28 students from Cohort 2 (93%) rated the approach as 7 or more with the remaining 5 students from Cohort 1 (18%) and 2 students from Cohort 2 (7%) rating the approach as 6 or less ($p = .001$, $p < .001$ respectively). Just two students (both from Cohort 1) rated the approach as 5 or less. The results are shown in **Figure 8**.

For each question, the distribution of responses was tested for normality using the Shapiro-Wilk test. In each case the responses were found to follow a non-normal distribution. **Table 2** gives the minimum, Q1, median, Q3 and maximum values for all variables. Values for the overall rating of tutorial approach are as above, with values for all other variables ranging from 1–'very unhelpful' to 5–'very helpful'.

Open-Ended Questions

To gain a richer insight into the students' perceptions and experiences, two open-ended questions were included in the survey. In the first of these, students were invited to suggest areas for improvement in the overall approach taken for the two modules (for both lectures and tutorials). There were five responses to this question, all from Cohort 1. Three main categories emerged from the analysis of the responses: *synchronous delivery* (4 respondents), *difficulties with Numbas* (1 respondent), and *overall format* (1 respondent).

Two sub-categories were identified in the *synchronous delivery* category: a desire for *on-campus delivery* (3 respondents), with one student saying they felt that "on campus hours are necessary", and a desire for more *synchronous delivery online* (1 respondent), where the student stated that they "personally find live lectures to be more beneficial than prerecorded videos". Two distinct sub-categories also emerged from the *difficulties with Numbas* category: the *time taken* to input answers and *format restrictions* in different questions. In this instance, the student found that "sometimes the Numbas tutorial sheets took long to fill out the answer. Also if the format of the answer was wrong according to Numbas although the answer was correct, it was mark [*sic*] wrong." In the final category, *overall format*, although the student had commented that "an in-person tutorial sounds like the best option", they also noted that "the approach was extremely helpful. It was most likely the best approach given the online [*sic*]."

In the second open-ended question, students were asked to provide further general comments on the approach. There were ten responses to this question, five from each cohort. The three main categories that were identified during the analysis of responses to this question were *on-campus delivery* (2 respondents), *overall format* (6 respondents), and *communication* (2 respondents).

Both students whose comments related to the *on-campus delivery* theme expressed a desire for in-person delivery, with one student acknowledging that it was not possible at the time: "Of course more in person but understandably that is not possible". Only one of the students gave a reason for their preference, citing the widely recognised difficulty in providing effective and timely feedback in an online setting: "A good approach considering the circumstances obviously it would be more beneficial to be in a classroom where you can receive instant feedback".

There were six sub-categories identified under the *overall format* category. The most common sub-category was that the overall approach was *helpful*, with six students referencing this. Two students felt that the module *supported independent learning* while providing a platform for one-to-one support, with one student observing: "The fact that the delivery was very structured and the material was uploaded in advance of the tutorials allowed me to go through the material and find areas I didn't fully understand or maybe wanted further explanation on and ask question on those areas in the live tutorial lectures" while the other student commented that "it was a very effective approach that allowed me to practise the material independently while availing of one to one supports." One student's comments related to the sub-category *recordings are more streamlined* than live sessions, expressing the view that "recorded lectures are generally more polished and less time is wasted". The remaining three sub-categories each accounted for one student comment. One student found the approach to be *structured* (see quote above), the same student remarked that they found the *flexibility* of the approach assisted them in staying on top of the material: "the fact that we could watch the prerecorded lectures when every we wanted and weren't tied down to a fixed schedule meant you could watch the lectures before the recommended time which really helped with staying on top of the content and not falling behind." One student felt that the approach *reduced stress*, commenting that the mode of delivery was a way of helping to "make the already stressful lives of students that bit less stressful".

There were four sub-categories identified under the *communication* category. One student observed that they found the *anonymity* afforded by the use of Zoom chat in tutorials beneficial, "as sometimes you might not want to ask a particular question in front of the whole group". They also felt that the *lecturer's view of Numbas* was useful for pinpointing and addressing problematic areas: "I like as well how you can see which question I'm stuck on and give me individual feedback based off that question as you can see what data i inputted." There was one comment in relation to *feedback* received, with the student stating: "It also provides good feedback and lets you know when you're wrong", although it is unclear as to whether the student was referring to the feedback built into Numbas questions or the feedback that was received from the lecturer over Zoom chat. Finally, one student expressed a difficulty with communicating *mathematical notation* online, stating that they found it "difficult to use the format for typing in answers".

DISCUSSION

This study explored students' perceptions of an online mathematics tutorial delivery format that involved integrating the e-assessment system Numbas with the video conferencing platform Zoom. Descriptive statistics detailing student responses to each question were presented, and there were four main findings from the survey:

1. Numbas was found to be valued highly as a remote learning tool and the built-in feedback was seen as effective.

2. Zoom was seen as having high utility both as an aid to completing tutorial questions and in assisting overall understanding of the module material.
3. The option of uploading workings had a low uptake but was valued highly by those who engaged with the resource.
4. The overall combination of Numbas, Zoom and the facility to upload workings for feedback was seen as an effective online tutorial delivery method.

Each of the findings above will now be discussed in the context of previous research.

Numbas as a Remote Learning Tool

Of the students who responded to the survey, the vast majority considered the use of Numbas as a remote learning tool for mathematics as either somewhat or very helpful. The extent to which all students' attempts were visible to the lecturer via the Numbas LTI is arguably the predominant factor in how the tutorial format presented here differs from other online approaches where students' work is entirely inaccessible to the lecturer unless the student very deliberately presents their work (for example, by screen sharing or uploading an image of their workings). This visibility, as well as built-in feedback based on common student errors allowed for the provision of targeted feedback to individual students through Numbas itself and via Zoom chat, which was noted as constructive in respondents' comments – "I like as well how you can see which question I'm stuck on and give me individual feedback based off that question as you can see what data i inputted". When discussing the use of e-assessment systems in online mathematics teaching and learning, Trenholm (2023) stresses the importance of maximising human interaction and suggests that new technologies should be used to achieve this aim as opposed to simply being used for their own sake. This viewpoint is supported by (Ran et al., 2022) whose meta-analysis on the impact of technology on mathematics learning indicates that the efficacy of technology is at its highest where it is used to facilitate such interaction and whom Trenholm cites in his work. The combination of Numbas and Zoom presented in this study aims to utilise technology in this way, so that communication and synchronous interaction between the lecturer and students are enhanced.

One notable feature within Numbas is the capacity to include customised feedback that is to be provided in the event of a student entering a specific incorrect answer. Rather than simply receiving information as to whether an answer is correct or incorrect, common misconceptions or errors that led to the particular answer can be highlighted and the student can be guided as to what corrective action to take. Such feedback was incorporated into several questions throughout the weekly tutorial sheets. The high proportion of respondents who noticed and subsequently rated this feedback as somewhat or very useful is encouraging and, although time-consuming to build into questions, the extent to which the feedback was visible, together with the evaluation from the students would seem to justify some time being invested in the provision of feedback for very common errors at least.

The above findings replicate the outcomes of previous studies (Sarmiento, 2017; Zerr, 2007), where students taking mathematics modules across a range of domains (accounting and finance, mathematics, science and engineering) expressed positive attitudes towards their experiences with online mathematics homework systems. In particular, detailed feedback provided in the case of incorrect answers in (Zerr, 2007) was regarded as extremely valuable by students, and is consistent with the views of students in the current study.

Zoom as a Remote Learning Tool

The use of Zoom chat in tutorials was viewed by a very high proportion of students who responded as somewhat or very helpful, both as an aid to answering the questions and in facilitating understanding of the content overall. Students' appreciation of the relative anonymity afforded by the use of Zoom chat being of benefit to those who might hesitate to ask questions in a more open setting also reflects the findings of other studies relating to both the online provision of mathematics support (Gilbert et al., 2021; Lishchynska et al., 2021; Radmehr & Goodchild, 2023) and to students' experiences of the move to emergency remote teaching (Ní Fhloinn & Fitzmaurice, 2021; Shim & Lee, 2020). Although not highlighted in the current study, students in

(Wang et al., 2018) also reflected on how more introverted students could use the chat to present a query privately to another classmate. If desired, the question could then be raised more openly with the lecturer.

Uploading Workings

A lower than desirable proportion of students availed of the option of uploading workings for feedback, either during or outside of timetabled tutorial hours. Although students were frequently reminded of and encouraged to engage with this resource, feedback was provided promptly and 86% of respondents who used the resource rated the feedback as either somewhat or very helpful, the low uptake suggests that it is not a preferred resource for students. It is however worth noting that those who did engage with the process tended to engage on multiple occasions. The low uptake on this resource is consistent with studies such as (Lishchynska et al., 2021), where each week between 9% and 66% of a class group submitted weekly assigned homework for a remotely delivered mathematics module. Students' attitudes towards the value in submitting workings or homework has been found in other studies to depend on whether or not the submission contributes to their overall grade. Drumm and Jong (2020) present one student's perceptions of the impact of COVID-19 on academic life who reported that regular graded tasks acted as an incentive to engage with the material. Doorn et al. (2010) found that 85.4% of students surveyed viewed graded homework as beneficial for learning, compared to less than 1% who viewed it as useless, with the remaining students perceiving it to be of no greater benefit than ungraded homework or studying worked examples. It therefore appears that submitting homework for which a mark is assigned is seen by many students as more worthwhile than simply uploading workings if feedback is specifically sought. This suggests that perhaps selecting a particular subset of questions from the weekly tutorial sheets for students to complete and upload as homework for which a mark is assigned might encourage more students to engage for future deliveries. Questions that are observed to be most problematic during the tutorial hours might be good candidates for these homework questions. In addition to providing the lecturer with a clearer view on students' developing understanding of the content, low-stakes weekly assessments have been found by some students to both motivate them to stay up to date with the material and to gauge their own understanding (Meehan & Howard, 2020), and so may contribute to improved learning outcomes. For large class sizes however, lecturer workload needs to be considered. Ní Fhloinn and Fitzmaurice (2021) noted that almost 64% of respondents (lecturers) reported feeling an increased administrative burden as a result of the switch to remote delivery. Consequently, any tasks that may result in a significant increase in workload require careful consideration. While using an e-assessment tool such as Numbas would save time on marking, it is not feasible to construct Numbas questions that will provide feedback for all possible errors. Therefore, it is important to consider the purpose of any homework questions – to encourage students to engage further with questions outside of tutorial hours (in which case Numbas may provide feedback in sufficiently many cases) or to provide detailed feedback to students on their written workings (in which case the lecturer would need to mark submissions manually and workload then comes into consideration).

Overall Delivery Mode

The overall delivery mode of the two modules considered in this study was viewed positively by the students. There was a feeling that the format was beneficial given the restrictions in place due to the pandemic. The asynchronous delivery of most of the module lectures with optional Q&A offered a flexibility that many students found advantageous. This was reflected in the comments received in the survey – "the fact that we could watch the prerecorded lectures when every we wanted and weren't tied down to a fixed schedule … really helped with staying on top of the content and not falling behind" – as well as in the proportion of students who expressed a preference to continue with a predominantly asynchronous delivery when polled after four weeks of delivery. This preference supports the findings of other studies such as (Harris et al., 2021) where 64.9% of participants (psychology students) indicated a preference for asynchronous lectures with live Q&A support over the alternative options of entirely synchronous or entirely asynchronous lectures (without Q&A support), with flexibility of viewing times and the ability to pause and re-watch videos cited as some of the reasons for this preference. These same advantages (flexibility and options to pause and rewind) were also perceived by students in (Lishchynska & Palmer, 2021; Meehan & Howard, 2020) as highly valuable aspects of the online learning environment. Mohammad Zadeh et al. (2023) likewise reported findings of perceived flexibility associated with asynchronous aspects of the delivery of three undergraduate engineering modules, with 73.8% of respondents citing time management as an advantage.

On analysing the qualitative data, it emerged that there were more negative responses associated with Cohort 1 than Cohort 2. Some of these comments were in relation to a desire to have some on-campus delivery, in line with responses observed in (Meehan & Howard, 2020), which was not feasible at that point in the COVID-19 pandemic. However, it is worth observing that many of the comments related to either a difficulty in adapting to the new Numbas software or a frustration that numerically correct answers were marked as incorrect if the format of the answer entered by the student was not what was required for that question. The fact that these frustrations were particular to Cohort 1 might point towards insufficient assistance for students who were attempting to navigate a new technology in a remote setting. In a fully online environment, there is less opportunity than in an in-person setting for a student to request incidental guidance on the subtleties of syntax that are inevitably required when inputting mathematical expressions into a mathematical software package. This guidance would have been more readily available to the students in Cohort 2 who attended on-campus tutorials. The challenge of trying to adapt to new technologies aligns with the findings of other research, where for example, students exhibit a preference for formats and tools that closely resemble those with which they are already familiar in a face-to-face setting (Dinu et al., 2022). For future deliveries in a fully online setting, therefore, it would be crucial to ensure that sufficient time is allocated at the beginning of the semester (and throughout as required) to assist students in transitioning to alternative technologies such as Numbas and to make it very clear if a specific answer format is required. The latter could be achieved verbally – by the lecturer highlighting the relevant question numbers at the beginning of the tutorial – as well as within the questions themselves (both through very clear wording of the question and through the feedback generated if an incorrect format is entered).

This study has placed an emphasis on the importance of improving real-time lecturer-student interaction to enhance the online teaching and learning experience. Any increase in real-time lecturer-student and/or student-student interaction online underscores the importance of a reliable internet connection and the availability of appropriate hardware. Several studies have referenced the inequalities that can arise when there is a cross section of students without access to adequate equipment or internet connectivity. In a study investigating students' experiences of emergency remote teaching of mathematics in disadvantaged second level schools in South Africa during the COVID-19 pandemic, 85% of respondents cited the cost of internet data as a barrier to remote learning, with 74% noting poor internet connectivity as an obstacle to learning (Chirinda et al., 2022). Murat and Bonancini (2020) also report a significant correlation between the lack of suitable ICT resources and cognitive losses (equivalent to the impact of a student's absence from school) in second-level students across France, Germany, Italy, Spain and the United Kingdom. The unavailability of an internet connection at home, for example, was found to be correlated with "cognitive losses corresponding to two school years in the United Kingdom, more than one year in Germany, and less than one year in Spain and Italy" (Murat & Bonancini, 2020, p. 13). These studies emphasise the important role that educational institutions and governments have in ensuring students with insufficient resources are not disadvantaged. In their case study presenting a considered approach to blended mathematics teaching, for instance, Busto et al. (2021) took particular care to ensure lectures were broadcast using high-quality, low-bandwidth streaming to mitigate problems of slow internet connection, showing one way in which practitioners can attempt to facilitate students with poor quality internet.

Trenholm and Peschke (2020) present an interesting opposing viewpoint regarding the immediacy of real-time interaction (the assumed importance of which is the basis of much of the approach in the current study). In that work, the authors propose that the time afforded by asynchronous interactions (for example, a student uploading a solution for feedback to be provided by peers or the lecturer at a later time) may facilitate "analysis, reflection, cognitive assimilation and reassembly" (Trenholm & Peschke, 2020, p. 14), thereby enabling deeper learning. Such a viewpoint may therefore support the argument for a combination of immediate and delayed feedback (incorporating some delayed feedback provided by peers) to deliver the optimal learning environment for mathematical subjects online.

CONCLUSIONS AND RECOMMENDATIONS

This paper presents the format of remotely delivered mathematics tutorials that were designed to emulate face-to-face tutorials as closely as possible and explores students' perceptions of this delivery format. The aim was to improve students' online learning experiences by promoting student engagement and real-time lecturer-student interaction, facilitated by extensive visibility of students' progress. Below is a summary of the author's recommendations for the design of remotely delivered mathematics tutorials, along with some suggestions for how these might be implemented and some potential limitations to be considered. Note that the recommendations below refer to Numbas, but an alternative e-assessment tool could also be used.

Recommendation 1: Ensure sufficient support is available to students in the transition to any new technologies such as Numbas. A small number of students in this study expressed a difficulty in adapting to the software and it is possible that others felt a similar challenge but did not express it.

Implementation: The first tutorial could be used as an introduction on how to use the software, with a short demonstration by the lecturer followed by a short worksheet for the students to practise how to input simple commands/the types of expressions they will need during the semester. A list of useful commands could also be provided to the students, highlighting common pitfalls (such as forgetting multiplication signs, omitting brackets etc.). Regular instruction should be given by the lecturer as the weeks progress, in relation to newer or more complex inputs that emerge. Clear direction should also be given in relation to the format expected for particular answers, verbally during the tutorial and/or within the Numbas question itself.

Limitations: Using the first tutorial for this purpose means that this time is no longer focused on addressing student queries on material. However, only a modest amount of material will typically have been covered in the introductory week ahead of the first tutorial and so it is felt that this should only be a minor drawback.

Recommendation 2: If possible, upload the tutorial sheets in advance of the tutorial. Being able to attempt the material in advance of the tutorial was reported in this study as facilitating the identification of specific areas of difficulty ahead of the tutorial, which could then be targeted in the tutorial hour.

Implementation: Each tutorial sheet could be uploaded by, for example, the Friday of the week preceding the relevant tutorial, to allow students to access the exercises during the weekend prior to the tutorial.

Limitations: If tutorial sheets are being created from scratch, this can be time-consuming for lecturers who are still adapting to the Numbas software/online delivery themselves. However, there is an active Numbas-users community online with resources shared widely and so it is possible that relevant questions can be found online and adapted by the lecturer to suit their specific needs.

Recommendation 3: Where possible, include feedback for common errors. A large number of students in this study noticed the feedback in Numbas and the majority of these found it to be a valuable aid to learning.

Implementation: Feedback can be built into the questions as they are being created in Numbas. Any portion of the marks (from 0% to 100%), along with tailored feedback, can be assigned for each individual error.

Limitations: This is a time consuming process; it is not possible to catch all errors; if a non-zero percentage is assigned to the student's answer, a grey tick (green if the answer is fully correct) appears next to the answer and so there is the possibility that the student would interpret this as a correct answer and would fail to read the feedback. Assigning 0% for any error, regardless of how minor, can help to mitigate this but can be discouraging for the students.

Recommendation 4: Consider assigning a low-stakes grade to a small number of homework questions each week. Very few students in this study uploaded workings during the tutorial hour for the purposes of feedback. However, in studies such as (Doorn et al., 2010; Drumm & Jong, 2020; Meehan & Howard, 2020), students perceived *graded* homework/quizzes to be beneficial for engagement and learning.

Implementation: Select a small number of questions (between 1 and 3) from the weekly tutorial sheets that were problematic during the week and ask students to complete and upload their workings for feedback. Assign a small percentage of the module mark for these questions.

Limitations: For large class sizes, this can lead to an excessive amount of work for the lecturer and so works best for small class sizes.

Recommendation 5: Incorporate some aspect of peer-to-peer interaction. Although not mentioned by students in the current study, peer-to-peer interaction can help to create a sense of community and belonging and several studies have found that students considered peer-to-peer interaction to be a valuable aspect of the learning experience that was lost in the transition from face-to-face to remote delivery (Dinu et al., 2022; Means & Neisler, 2021; Meehan & Howard, 2020; QQI, 2020; Shim & Lee, 2020).

Implementation: This might be done by assigning problems that emerged as problematic during the tutorials (as highlighted in the lecturer's view of class progress on the Numbas LTI) to small groups of students in breakout rooms during the weekly Q&A sessions or dedicating some of the tutorial time to a discussion of these problems. The lecturer could join individual breakout rooms to facilitate discussion of these problems and guide students on how to approach the solutions. This might also serve to address the issue of students feeling unsure of where to begin or what questions to ask in the Q&A sessions as discussed earlier.

Limitations: Can be time-consuming – may not be feasible to use each week; some students can be reluctant to participate; requires good internet connection; works best when students can share their work, however not all students will have a stylus/tablet to facilitate the use of a shared whiteboard or similar.

Recommendation 6: When uploading tutorial sheets, if the class is split into several smaller groups for individual tutorials, assigning each tutorial sheet to the individual groups can make observation of the group's progress easier for the lecturer.

Implementation: When uploading the tutorial sheets on Canvas, set up individual assignments (with the same tutorial sheets) for each of the different groups of students.

Limitations: Can be time-consuming for larger classes with many groups, however this approach makes viewing the progress of the students assigned to a particular tutorial hour (via LTI) significantly easier as a result, as the lecturer is only viewing the attempts of students in that particular group.

Limitations of the Study

There are a number of limitations of the current study. No account was taken of individual student circumstances that may present challenges or affect students' experiences of synchronous versus asynchronous tutorials – for example, availability of a quiet study space, access to appropriate technology such as computer/laptop/tablet and a steady internet connection or caring or other responsibilities in the home. Furthermore, the survey did not investigate the basis for students' answers to the Likert-scale or ranking questions. The study would be strengthened by conducting focus groups to explore the specific aspects of Numbas and Zoom the students found particularly useful. This would provide a deeper insight into the students' experiences and would aid in the design of future online tutorials. In addition, this study looked only at first-year engineering students taking one linear algebra and one calculus module in a single university and this, together with the low response rate means that the results cannot be generalised to a wider population. However, given that the findings of this work support the results of other studies pertaining to student perceptions of online learning – students' support for modes of delivery that promote interaction and engagement – and that the study presents a way in which students' progress can be readily observed throughout online tutorials, it is hoped that this work may provide a useful example of how a mathematics assessment system such as Numbas can be combined with Zoom in order to foster lecturer-student interaction and student engagement in a remote setting.

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APPENDIX A

Table A1. Survey questions

Consent and age requirement	
Q1	Your consent is required in order to process your data. Please select "Yes" or "No" below to indicate whether or not you agree with the following statement: I have read the information provided on the research study "Combining Numbas and Zoom as a remote learning tool", or it has been read and explained to me, and I consent to the results of my anonymised responses to this survey being used as part of this research project. o Yes (*survey proceeds to Q2*) o No (*survey closes*)
Q2	What age are you? o Under 18 (*survey closes*) o 18-22 (*survey proceeds to Q3*) o 23 or older (*survey proceeds to Q3*)
General questions	
Q3	How would you rate Numbas as a remote learning tool for practising maths questions? o Very unhelpful o Somewhat unhelpful o Neither helpful nor unhelpful o Somewhat helpful o Very helpful
Q4	How often would you say you used Zoom chat for feedback in MATH6005 and MATH6006 tutorials last year? This includes reading and acting on messages sent to you by your lecturer as well as you sending messages to your lecturer. o Never o 1 or 2 times o 3-5 times o 6-9 times o 10-14 times o 15 times or more
Q5	How would you rate the process of receiving feedback on individual questions via Zoom chat in tutorials **in helping to complete the individual question(s)**? o Very unhelpful o Somewhat unhelpful o Neither helpful nor unhelpful o Somewhat helpful o Very helpful o I did not receive feedback on individual questions via Zoom chat
Q6	How would you rate the process of receiving feedback on individual questions via Zoom chat in tutorials **in helping to improve your overall understanding of the material**? o Very unhelpful o Somewhat unhelpful o Neither helpful nor unhelpful o Somewhat helpful o Very helpful o I did not receive feedback on individual questions via Zoom chat
Q7	Some of the Numbas questions in the tutorial sheets were programmed to provide automatic feedback if one of a number of common errors was made. Did you notice this feedback in any of the questions? o Yes o No
Q8	If 'Yes', how helpful did you find the feedback? o Very unhelpful o Somewhat unhelpful o Neither helpful nor unhelpful o Somewhat helpful o Very helpful
Q9*	Did you make use of the option of uploading images of your workings for feedback during the tutorials? o Yes o No

Table A1 (Continued).

Q10*	If 'Yes', how helpful did you find the feedback you received on your workings? o Very unhelpful o Somewhat unhelpful o Neither helpful nor unhelpful o Somewhat helpful o Very helpful
Q11	Overall, how would you rate the effectiveness of the approach taken for the MATH6005 and MATH6006 tutorials (combining Numbas with Zoom chat for feedback, with the option of uploading images of your workings for feedback)? Please rate the effectiveness on a scale of 1 to 10 with 1 being "Not at all effective" and 10 being "Extremely effective". o 1 o 2 o 3 o 4 o 5 o 6 o 7 o 8 o 9 o 10
Q12	Overall, reflecting on your experience of the tutorials for MATH6005 and MATH6006, would you suggest any particular areas for improvement? o Yes o No
Q13	If 'Yes', please give details. (Free text box included).
Q14	Are there any other comments you would like to make in relation to the approach taken for the MATH6005 and MATH6006 tutorials? (Free text box included).

Note. Questions marked with an asterisk (*) were asked to Cohort 1 only