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Alternative Mathematics Assessment during University Closures due to Covid-19

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Summative and formative assessment are a core part of the teaching and learning process. A broad range of assessment methods is desirable to give a true measure of students' understanding and progress. However, research indicates that proctored, closed-book, summative assessments are traditionally favoured by university mathematics lecturers. In March 2020, assessment practices had to be abruptly reconsidered by the majority, midway through semester. An online survey of how mathematics lecturers adapted to emergency remote teaching was conducted in June 2020, with responses from 257 teaching staff in 29 countries. In this paper, the authors detail how assessment in mathematics was undertaken, remotely and virtually. We investigate how lecturers dealt with an enforced move away from traditional closed-book, highly-weighted, proctored, in-person examinations, and how satisfied they were with their eventual assessments. We also explore lecturers' perceptions of the impact the changes had on grade distribution during this unique teaching period. Finally, we report on whether their approaches to teaching the same modules in the future will change as a result of their experience of emergency remote teaching during the COVID-19 pandemic.

Keywords: Mathematics, Assessment, Summative, Remote Teaching

Research background and rationale

In March 2020, lecturers and students across the globe were forced to move to emergency remote teaching and assessment with immediate effect. For many, significant changes to teaching and assessment were warranted, with little time or notice to partake in relevant professional development. This paper explores the results of a survey which investigated how mathematics lecturers in higher education coped with this change, focusing specifically on how they approached assessment.

Assessment forms an integral part of teaching and learning, the purpose of which is to inform both teacher and student on the status of the learning that is

occurring (formative assessment) or has already occurred (summative assessment) (Kerka & Wonacott, 2000). Summative, closed-book assessments are typically easier and less time-consuming to set and mark, and make cheating less likely (Iannone & Simpson, 2011). These advantages make this form of assessment particularly attractive when teaching large groups, where regular assessments and feedback may not be possible, on top of an already heavy workload (Ní Fhloinn & Carr, 2017). One issue with summative assessments is that students typically do not see their answer book again after the examination, and remain uninformed about the areas in which they performed well/unwell, merely receiving an overall grade (Challis et al., 2003). Conversely, formative assessment embeds consistent feedback, sometimes with some small grade attached (Ní Fhloinn & Carr, 2017). Ideally, a blend of formative and summative assessments incorporated into one's teaching is recommended to assess a broader range of competencies (Buchholtz et al., 2018).

Closed-book assessments have long been the favoured mode of assessment in mathematics. Early this millennium, researchers began to cite the need for expansion into more modes of assessment in mathematics, as not all skills and concepts can be assessed effectively through such a medium e.g. problem-solving and the use of IT (Challis et al., 2003). There are arguments for and against the notion that mathematics is a domain whose nature lends itself to traditional forms of teaching and assessment, more than other subject areas (Ní Fhloinn & Carr, 2017). Regardless, Iannone and Simpson's (2011) study of UK universities state that proctored, closed-book assessments continue to dominate other forms of assessment in mathematics. Alternatives are more prevalent in modules of statistics, history of mathematics, mathematics education and final-year projects (Iannone & Simpson, 2011).

Modes of online assessment have grown exponentially in recent years. Greenhow (2015) demonstrated how the effective use of computer-aided assessments (CAA) can enhance examination performance. However, Kerka and Wonacott (2000) warn that assessing from a distance is not always a positive experience, with disadvantages including learner isolation and access to technology and resources.

Assessment, be it formative, summative, in-person or online takes time to create. The lecturers in this study were required to alter teaching and assessment strategies, and immediately adapt to emergency remote teaching. This study explores how they coped with this mandate, in relation to assessment.

Methodology and theoretical perspective

Design of instrument

We created a survey to investigate how mathematics lecturers were responding to the challenge of teaching remotely. We were interested in learning about technology used, modes of assessment, challenges faced and lessons learned. The questionnaire was piloted with experienced mathematics lecturers, and amended accordingly. The resulting survey had eight sections, including one on assessment. The anonymous survey was created in Google Forms and distributed via mailing lists in May 2020.

Profile of respondents

We received 257 responses (52.3% male) from across 29 (mainly European) countries. Over 45% of respondents had 20+ years of mathematics teaching experience in higher education, with a further 38% having 5+ years. 57% of respondents were teaching students who were mathematics majors, and 51.8% were teaching service mathematics, taught in degree programmes where mathematics is not the primary subject e.g. science

or engineering.59.4% of respondents were teaching small groups (up to 30 students), 50.4% had medium sized classes (30 – 100 students) and 22.7% were teaching large groups (over 100 students).

Theoretical perspective

'The term "assessment" in Mathematics refers to the identification and appraisal of students' knowledge, insight, understanding, skills, achievement, performance, and capability in mathematics' (Niss 1998, p263). Traditional mathematics assessments are silent, timed, written tests, where communication with others is forbidden. The main issue with this is that they only assess a narrow range of skills due to time constraints (Iannone and Simpson, 2011; Niss, 1998). Assessment in mathematics often focuses on learners' ability to recite skills and concepts on demand (Pegg, 2002). Pegg, Gutierrez, and Huerta (1998) proposed a continuum of assessment practices with two opposing paradigms on either end: on one end, the traditional written assessment, assessing a narrow range of skills and promoting rote learning; and on the other end, what they call "qualitative" forms of assessment, which provide non-numeric feedback. They state that 'as one moves from one end to the other, features of both can be identified in varying proportions' (Pegg, Gutierrez, and Huerta, 1998, p277). The aim in this investigation was to see where on this continuum mathematics lecturers moved to, during the transition to remote teaching.

Findings and results

There were 12 questions (six closed, six open) in the assessment section of our survey. The results are presented in this section.

Initially, we wanted to establish if lecturers gave any online assessments during this semester and, if so, whether they were formative, summative or both. The breakdown of responses is outlined in Figure 1.

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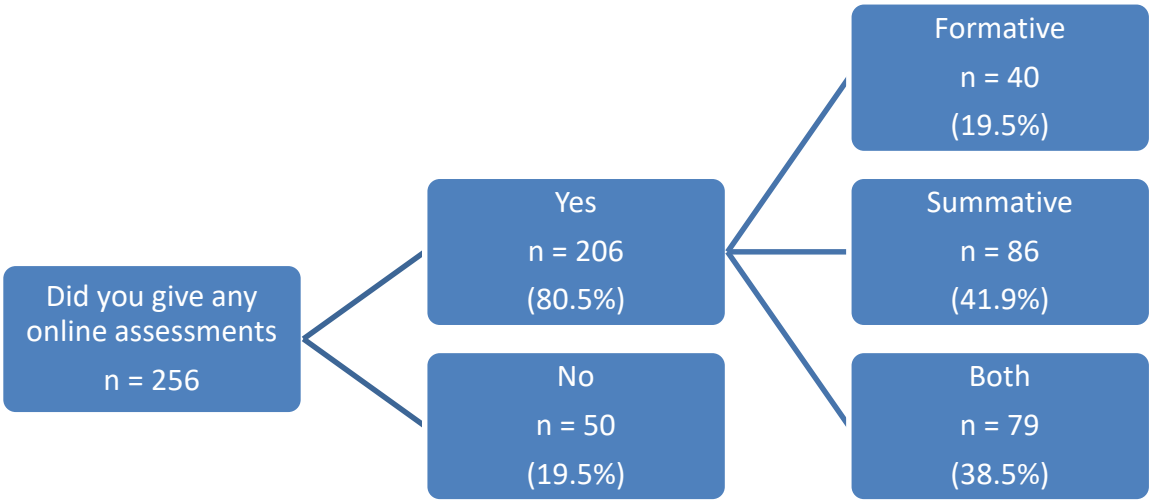

Figure 1. Responses to the question "Did you give any online assessments?"

Almost one fifth of respondents stated that they did not give online assessments. Of those that did, more than twice as many gave summative only (n = 86), compared to those that gave formative assessments only (n = 40), with 37.2% (n = 79) giving a blend of both.

Those who gave formative assessments were asked what format these took, and the breakdown is displayed in Figure 2. These comprised mainly assignments and online assessments. The 'Other' category included assessment items such as learning journals and discussion boards.

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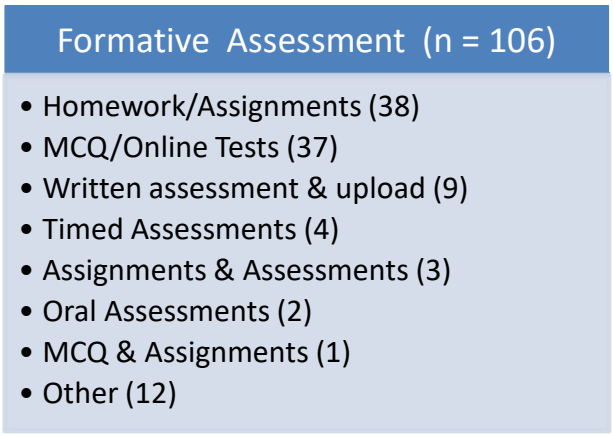

Figure 2: Format of Formative Assessment undertaken

Those who gave summative assessments were also asked to provide further information on the type of assessments. The breakdown is outlined in Figure 3. Open-book assessments (timed or untimed) were the most common (*n*=58). The 'Other' category included assessments such as reports, interactive virtual labs, and presentations.

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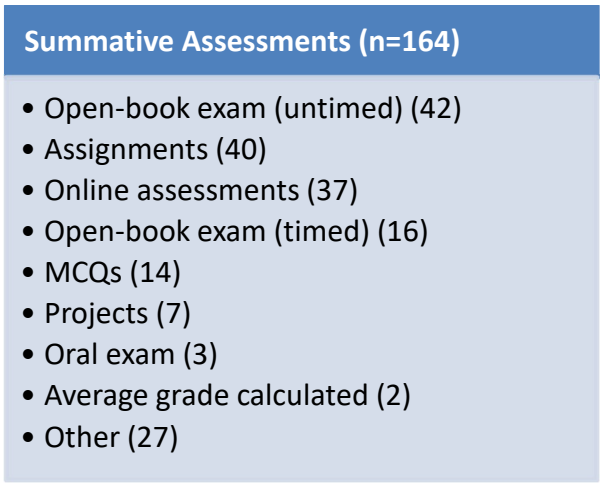

Figure 3: Format of Summative Assessment undertaken

Respondents were then asked if they had given a final examination online, and of the 249 responses, 62% (n = 154) stated that they did. 133 of these respondents commented further, 73.7% (n = 98) of whom had given a final open-book assessment. Of these, 54% specifically stated that they gave a timed assessment (5 hours or less) with extra

time included for students to scan and upload their documents. The remaining open-book assessments ranged from 24 hours to 7 days. 16.5% of responses (n = 22) were related to online assessments (e.g. Mobius or Moodle), 8% (n = 11) gave oral assessments, and two stated that coursework formed the basis of their final examination. Across these responses, 9% (n = 12) stated that they created different assessments for students to reduce the likelihood of cheating.

38 of those who did not give a final online examination commented on what they did instead. Of these, 13 said that final exams had not yet occurred but would be held during the summer. For seven lecturers, the final exam was replaced with coursework; 11 replaced it with smaller/continuous assessments and four said they were cancelled, with grades of previous assessments used to calculate a final grade. The final three responses were mixed: instead of a final exam, they had a take-home exam, a modelling project and online presentations.

Next, respondents were asked if there was a difference in grade distribution compared to previous years. This Likert-scale question had respondents pick a value between 1 (no difference) and 5 (a big difference). The results are displayed in Figure 4.

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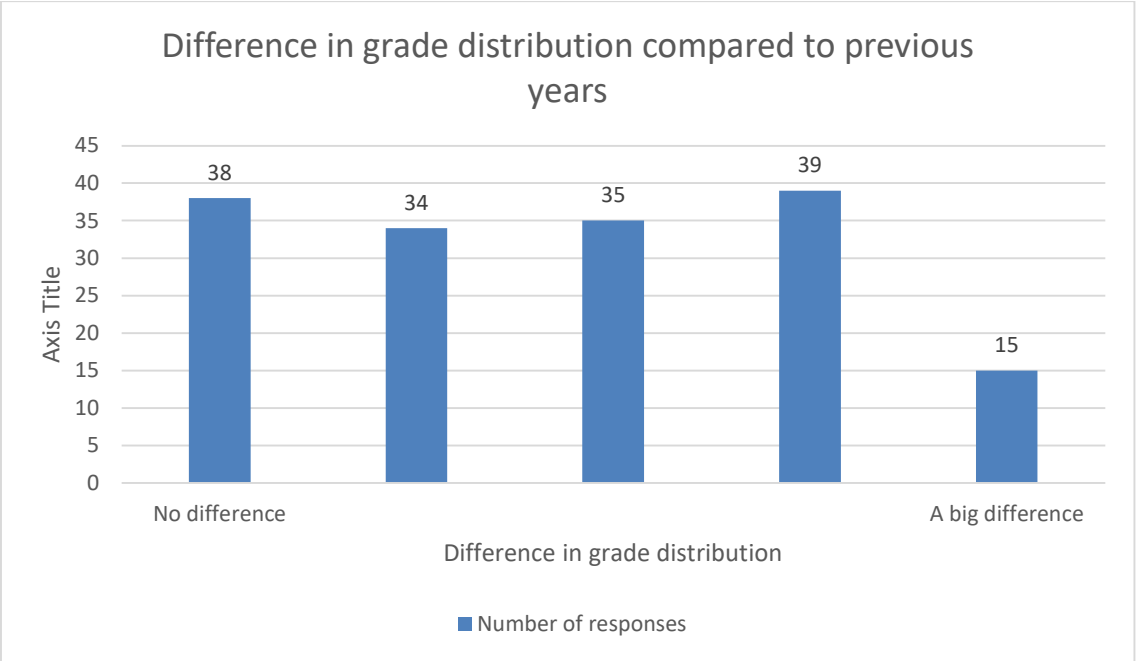

Figure 4: Grade distribution in comparison to previous years (*n*=161)

Of the 161 responses, almost one quarter said there was no difference, while 9.3% found a big difference. The remaining responses were relatively evenly dispersed between the other three options.

When we asked why lecturers thought there might be a difference, 40 respondents were awaiting results and did not yet know. The remaining responses fell into 8 categories. Five said that the online exam format was tougher, and two stated that stress contributed to lower grades. As to why students did better generally, reasons given were: cheating (*n* = 13); easier marking (*n* = 6); easier assessments (*n* = 8); more time than normal to complete (*n* = 8); and unsupervised open-book assessments (*n* = 19).

In terms of whether formal support was offered to help them redesign their assessments for online purposes, of the 239 responses, 20.5% (n = 49) said yes, and 69% (n = 165) no.

We asked lecturers to rate their satisfaction levels with their assessments on a scale of 1 (not at all satisfied) to 5 (very satisfied). Only 6.1% (n = 13) stated that they were very dissatisfied and the majority (74.7%) gave a rating of 3 or 4. The breakdown of responses is displayed in Figure 5.

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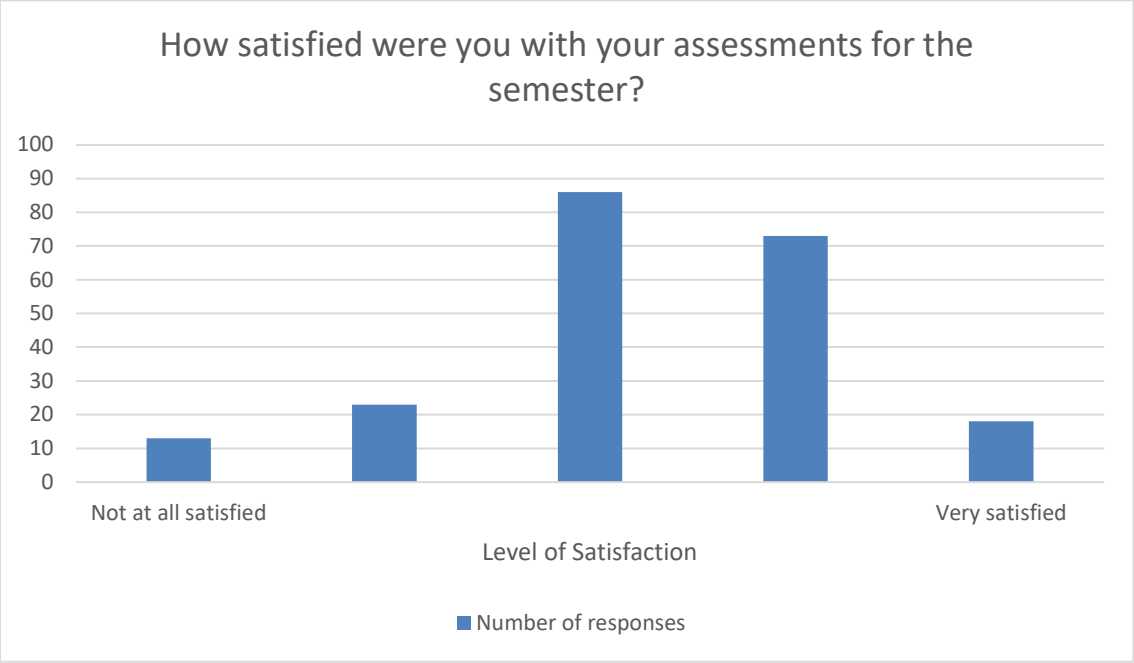

Figure 5: Lecturers' satisfaction levels with their assessments (*n*=213)

Finally, we investigated the impact of the experience of teaching remotely on future teaching of their modules. They were asked to rate on a scale from 1 (not at all) – 5 (A lot) how much they would change their approach in future, and then invited to elaborate. Figure 6 shows the breakdown of responses. Over 50% of respondents (*n* = 127) answered in the upper categories of 4 and 5, suggesting that there were a lot of positives to be learned and practices to sustain for future teaching.

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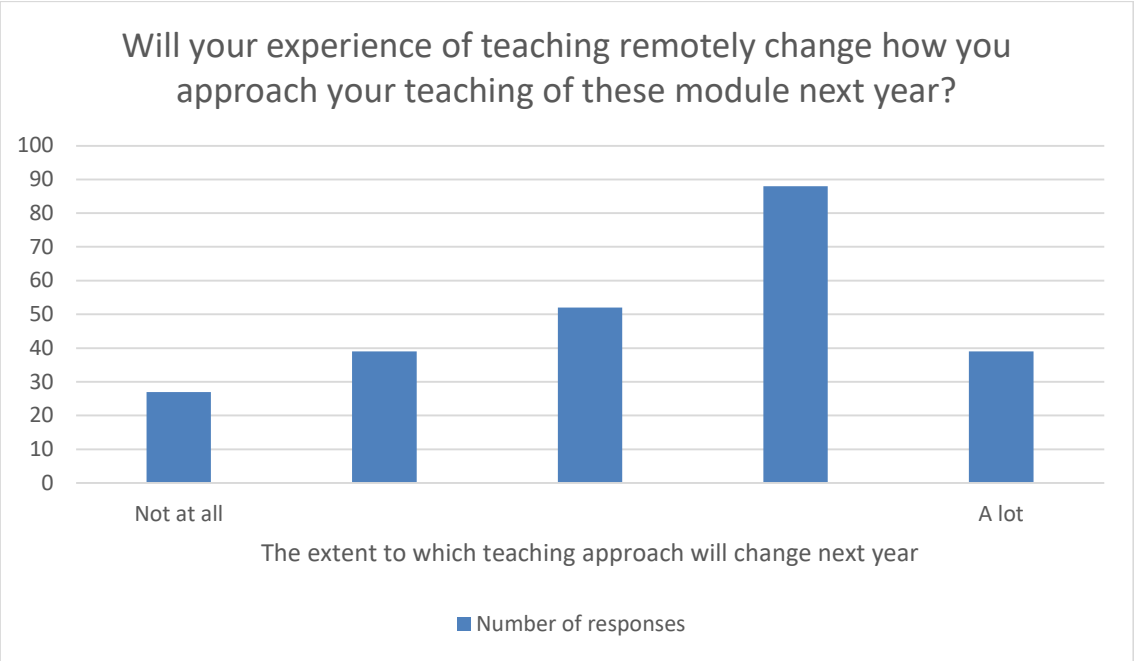

Figure 6: Lecturers' thoughts on impact of remote teaching on future teaching (*n*=245)

22 respondents who answered "not at all" left comments to explain their reasoning. Over half (*n* = 14) stated that face-to-face is a superior mode of delivery to teaching online. Other reasons given were that online teaching relies on personal commitment to studies from students which was not always present. Four respondents commented that emergency remote teaching meant they had neither the time nor support from their institutions to prepare sufficiently for effective online teaching. 30 of those who answered option 2 left comments. 15 stated that, if they return to face-to-face teaching, they will teach as they did before. Others stated that they hope to use some of the material created during remote teaching e.g. recorded classes, online quizzes, and pencasts. For those who answered at the upper end of the scale, 67 who selected option 4 and 30 who selected option 5 left comments. 20 said that it will change their future teaching but only because they anticipate being in the same circumstances next semester in relation to the pandemic. 25 stated that they plan to change their teaching approach by blending the most effective features of face-to-face and remote teaching to maximise

engagement e.g. creating a flipped classroom by assigning pre-recorded lectures and activities prior to discussion face-to-face. Five of these respondents specifically mentioned that technology would continue to play a role in their future teaching. Some commented that online teaching is more beneficial when teaching large groups. Seventeen said that they had amassed a range of resources, mostly recorded videos, that they planned to use in future to supplement face-to-face teaching. Eight said they gained knowledge, skills and confidence throughout this period of remote teaching that they believe will bolster future teaching. Eleven said their experience would affect how they think about assessment in future. For some, this meant the inclusion of more formative assessments and online MCQs; others felt that remote assessments did not have the same integrity so traditional assessments needed to be revisited.

Discussion and Conclusion

Prior research tells us that mathematics lecturers favour closed-book, timed, proctored assessments to evaluate student learning, although these only assess a narrow range of skills (Iannone and Simpson, 2011). With this option suddenly unavailable during initial university closures due to Covid-19, it is clear from our findings that a broader range of formative and summative assessment methods were embraced by the mathematics teaching community, moving the community further along the assessment continuum of Pegg, Gutierrez, and Huerta (1998) described previously. This is a positive outcome of the move to remote teaching as alternative assessment strategies assess a broader range of learning (Pegg, 2002). A one-size-fits-all assessment is neither possible, nor recommended. Seeley (2005) recommends designing assessments by "incorporating problem solving, open-ended items, and problems that assess understanding as well as skills", making assessment an integral part of teaching and learning. Niss (1998) states that assessment of a broader range of skills can be attained

through report writing, projects, investigations, and/or oral examinations, regardless of the level at which a student is studying mathematics, and many of these were introduced by respondents in our study. Suurtamm et al. (2016) say that implementing a range of assessment approaches allows students multiple opportunities to utilise feedback and demonstrate their learning.

The assessment that aligns nearest with a final, closed-book, supervised (in-person) examination is an open-book, timed examination and this option did prove popular in this study. Relaxing timing restrictions on traditional examinations is necessary if a broader range of skills, knowledge and understanding are to be assessed (Niss, 1998). Take-home assessments is one way of removing timed restrictions but the issue of students collaborating cannot be fully prevented. It can however be countered if an oral assessment is embedded into the assessment structure (Niss, 1998).

Greenhow (2019; 2015) recommends the use of CAA to complement rather than replace traditional modes of mathematics assessment. CAA was used by majority of respondents in this study in this way. Among its many advantages are that it provides immediate feedback to students, removes the tedium of marking for lecturers, and is a better platform for students with specific learning needs (Greenhow, 2015). Question creation can be an issue, as those assessed via ICT methods are different to those marked by hand (Greenhow, 2015). MCQs proved popular with respondents in this survey. Sangwin (2013) warns that MCQs have the potential to bias against students with varying learning styles and confidence levels. Greenhow (2015) and Nagasaka (2020) recommend MCQs when assessment is formative and low stakes in nature, which appear to be how they were used by the majority in this study.

Regarding grade distribution, most respondents felt that there was a difference this year in comparison with other years, as discussed above. However, the majority

stated that they were moderately to very satisfied with their assessments and many welcomed the changes that technology brought to their teaching, and hope to blend the most effective components of face-to-face and remote teaching for their classes in future. Most stated that support and training for adjusting their assessments appropriately was not available to them in this time-frame: if mathematics lecturers in higher education are to make significant moves towards alternative forms of assessment on a longer-term basis, subject-specific professional development opportunities must be provided to practitioners to upskill them in the appropriate design and setting of mathematical assessment in line with best practice (Suurtamm et al. 2016; Pegg, 2002).

Ethical considerations

Ethical approval to proceed with the study was granted from the ethics committee in one of the authors' university.

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