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Large-scale Delivery of Mathematics to Mixed-ability, Multidisciplinary Scientists in a Lockdown

ADAM J. WOOTTON and JEFF T. NEAT
Keele University

Foundations of Numerical and Quantitative Methods for Scientists/Health are two modules that, between them, deliver foundational Mathematics to over 200 students in the Science and Health Foundation Years. With the onset of the Covid-19 lockdown, a technological solution was needed in order to build up both skills and confidence for students whose last experience of Mathematics may have been a C grade at GCSE level. The cornerstone of the approach was Learning Pool, initially used as part of a project to integrate assessments with original and pre-existing materials relevant to a Mathematics and Computer Science module on logic and cryptography. In this case, the Learning Pool platform was used as a one-stop repository for course content, exercises and external resources. Every topic in the module was broken down into subtopics, for which students accessed videos and example problems. These resources are then supported by formative progress checks, which the students self-assess and review in tutorial sessions. Additional in-situ support classes were arranged for those students who felt that they required extra help. The online MS Teams tutorial sessions employed home-made visualisers or graphics tablets alongside MS Whiteboard to annotate work and explore topics, providing an experience similar to an in-situ class.

Introduction

The traditional model of university education was almost entirely reset with the onset of the Covid-19 pandemic. This was particularly true for Foundations of Numerical and Quantitative Methods for Scientists/Health (FNQMS), two Semester One modules from the Keele University Foundation Year. The importance of specialist mathematical provision at foundation year level has been previously reported (Craven & Sharp, 2018) and so, with a few notable exceptions, such as those students progressing on to study Mathematics or Physics, these modules are taken by all Science or Health Foundation Year students and provide a baseline level of Mathematics required to study a scientific discipline at university. A typical cohort would have around 200 students, ranging from those whose last experience of Mathematics was a GCSE grade C two or more years prior to entry to those with a relatively accomplished mathematical background.

Even then, there are longstanding concerns over the extent to which the school mathematics curriculum prepares students for scientific study (Anon, 1995). A lack of confidence amongst students – so called 'maths anxiety' – has been identified as a problem in a range of disciplines at university level (Khasawneh *et al*., 2021; Gyuris *et al*., 2012; Mji & Mwambakana, 2008; Marshall *et al*., 2017). Thus, the main challenge of the module is to provide close, confidence-building support to the weaker students while also pushing on those who are more capable, and catering for the many students in between. In the 2020-21 academic year, this needed to be achieved in an entirely online setting.

Overview of pre-Covid FNQMS

The original plan for FNQMS was conventional for a large module. There would be one lecture on a different mathematical topic each week. The cohort would be split into three smaller groups of 60 – 70 for these lectures, allowing for slightly more interaction. This was the main mode of content delivery for the module. This was to be supported with one problem class per week, where students would apply the knowledge gained from the lectures to problem exercises. The students were to be split into groups of around 20, which would give staff more time to support individuals while also allowing for peer support. These problem classes were critical to the success of the module: they allowed staff to monitor student progress and to identify areas for troubleshooting. For those students who lack confidence, this was a key time for accessing staff support. The monitoring allowed for interventions, with any students who continued to struggle invited to attend a weekly optional tutorial session. These were for up to five students to receive more targeted support. This approach is one that has been shown to develop skill efficiency (McNaught & Grouws, 2007), while the drop-in tutorials have been shown to enhance confidence and ability in mathematics amongst nurses (Byatt, 2014).

The Covid-19 restrictions and subsequent prohibition of in-situ teaching meant that there was no possibility of any part of this plan being carried out. This presented a significant problem, as many of the traditional methods of monitoring and intervention were no longer practical, such as circulating around the room, observing how students approach problems and demonstrating work to a group via the whiteboard. The biggest loss was the face-to-face contact with students: building a relationship with a student proved to be one of the most effective ways of overcoming confidence issues (Furner & Duffy, 2002; Clute, 1984).

Primary challenges

The main questions raised by transitioning to online-only learning were as follows:

- What was the most effective way to deliver content to students?
- How could student engagement with materials be monitored?
- What could be done to ensure that students who need support, get support?
- How can student progress be monitored?
- How can a large number of students be managed online

An Online-only Model for Large-scale Delivery of Mathematics

Providing the same level of learning support to students in an online setting required a complete rethink of the way in which the modules were delivered. This included changing the way that the course was delivered and structured, as detailed below.

Synchronous and Asynchronous Content

Pre-existing teaching methodologies provided a solid base to build the online-only modules around. The flipped classroom approach (Baker, 2000), where students work through course materials in advance and live taught sessions are used to consolidate gained knowledge through application, has seen some success when applied in university-level Mathematics (Fernandez-Martin *et al*., 2020), which suggested that it could be an appropriate method of delivering FNQMS.

Based on this idea, it was decided that the previously planned lectures would be delivered asynchronously. Each lecture topic would be broken down into smaller sub-topics, each with its own 5 – 15 minute video, following the best pre-and-post-pandemic practice reported elsewhere (Barr *et al*., 2020; Hughes, 2009; Ozan & Ozarslan, 2016; Rickley & Kemp, 2021). The students therefore watched these videos in lieu of attending a live lecture. One advantage of this was that it gave students control of their teaching schedule; they could choose the time that was best for them for viewing lectures and rewatch them as many times as they needed.

The problem classes were nominally retained in the new structure, but the emphasis was different. Since any online platform would make it difficult to observe a student's working methods, using live classes to allow students to work through mathematical problems was considered a poor use of time. Instead, the students would be given the problems in advance with the expectation that they would be completed by the scheduled problem class. During the problem class, they would be given model solutions and asked to mark their own work. Allowing students to self-assess formative work in this manner has been shown to promote achievement in both university-level Mathematics (Beumann & Wegner, 2018) and Higher Education in general (Andrade & Valtcheva, 2009). As students developed an understanding of their strengths and weaknesses in a topic while marking their work, a staff member was on hand to work through any problems that arose. These classes were conducted using MS Teams (see below).

The tutorials were an unfortunate casualty of the pandemic and there was no way to provide a similarly effective support class in the online domain. However, students who were identified as finding the modules particularly challenging were offered one-to-one online support and, in the brief period when pandemic restrictions permitted it, in-situ tutorial classes were again offered.

Learning Pool and MS Teams

This entire approach hinged on two pieces of technology: Learning Pool's Adapt Builder[1] and MS Teams. Learning Pool predominantly dealt with the asynchronous delivery of the module, and Teams was used for synchronous delivery. While Teams has been widely used during the pandemic (see Baker & Spencely, 2020; Misut & Misutova, 2021; Krasna & Pesek, 2020; Hai-Jew, 2020) for examples), Learning Pool has not been used for asynchronous learning in Higher Education beyond its use for continuing professional development courses for staff.

Learning Pool's Adapt Builder is an elearning package that allows for the creation of interactive online courses that can be stored as SCORM files. This meant that they could easily be embedded within Keele's existing learning platform, the KLE, which is based on Blackboard. The chief advantage of using Learning Pool is that it easily allows for the creation of a simple, responsive and organised 'one stop' repository of content, exercises and external resources. It also includes an engagement monitoring system that can be used by both students and staff to monitor progress. Each individual lecture would have its own folder on the KLE, which would

[1] https://learningpool.com/adapt-builder-a-huge-step-forward-for-gamification/

contain a link to a SCORM file developed in the Adapt Builder. This SCORM file would show all of the sub-topics for that week in a grid, along with links to the module handbook, a table of the mathematical skills required by each scientific discipline and some external resources. When a student clicked on a sub-topic, they would be taken to a page that had a brief summary of the learning outcomes for that sub-topic and the 5 – 15 minute lecture video. Each SCORM file would also include a special page of exercises and practice questions with model solutions. This also included the progress check, a selection of exercises which the students were expected to complete in time for their problem class. This repository gave students the impression of a course that was purpose-built for online learning, which is a significant factor in maintaining student engagement (Cole *et al*., 2021; Short & Martin, 2011).

MS Teams was the chosen platform for online problem classes, based on the University's decision to recommend Teams as the preferred platform for synchronous delivery. A Teams team was set up for the module and a channel created for each problem class group. A meeting would then be held in that channel at the timetabled time every week. One advantage of this approach was that the progress check solutions could be uploaded to the files section for each individual channel, meaning that it only became accessible for students during their scheduled class. The students would then mark their own work and add messages to the 'conversation' section of the meeting to indicate their progress. Staff developed their own methods for working through student questions according to what they considered the best use of the technology. For example, one staff member combined the Whiteboard feature in Teams with a graphics tablet to work through handwritten solutions in real time, while another used a webcam as a makeshift visualiser in order to work through the solutions with pencil and paper. When students had completed their marking, they had the opportunity to ask any questions and were then required to submit their marked work to the KLE as evidence of completion.

Cycle of Work for Students

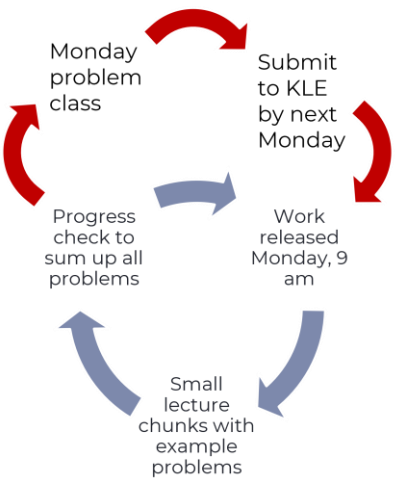

Figure 1: The student work cycle for FNQMS. The overall process took place in three weeks of the academic year: one week to digest the materials and attempt the progress check, one week for self-assessment following the problem class and then submission by the Monday of the following week.

This led to a new cycle of work for students, based on the timescales required for all of it to take place. This cycle of work can be seen in Figure 1 and uses the idea of continually revisiting topics, based on the Ebbinghaus forgetting curve (Murre & Dros, 2015). The process started at 9.00am on each Monday, when the materials for a new topic would be added to the KLE. In previous years, the lecture would take place in the first half of the week and the problem class for that topic later in the week. Here, the problem class took place a full week later, giving students the opportunity to digest and revisit the lecture materials and progress check at their own pace. The following Monday or Tuesday, the students then had a problem class on the previous week's topic. At the same time, the materials for a new topic would be released. The students would self-assess their work during the problem class and then make any corrections over the course of the following week, with the deadline for submission of marked work set to the following Monday. Having the students working on multiple topics simultaneously meant that there was more of a spiral curriculum (Bruner, 1996) and this reduced the risk of students completing a topic and only revisiting it at the time of final assessment, by which time they may have forgotten large parts.

Outcomes

In many ways, the Covid-19 restrictions that necessitated the changes outlined in this paper also made it very difficult to quantitatively assess their impact. For example, an increase in average marks and first-time completion rates may be in part due to the new structure and online delivery, but it could also be caused by changes to the assessment. It has previously been suggested that there are no significant differences between in-situ and open-book exams (Durning *et al*. 2016) and that open book exams actually have some advantages over their in-situ counterparts in high-stakes assessment (Samsa, 2021). However, it is difficult to argue that, given the depth of materials available to students, a 48-hour open book exam was not significantly easier than a two-hour in-situ exam. A change in coursework from a graph analysis exercise to a more authentic statistical exercise may also have contributed to changes. Thus, the successes of the online-only module are best assessed not through changes to student achievement, but how the re-allocation of staff time changed the way in which the module was supported.

The reduction in time spent delivering content meant that staff had more flexibility to focus on student engagement and progress. The requirement to submit marked work produced a longitudinal record of how students' engagement with the module changed over time and also gave a record of students' understanding of a topic. Both of these factors made it easier to identify students who would benefit from a targeted intervention. In some cases, this meant getting in touch with a student to remind them of their responsibilities and the importance of promptly completing the work. For other students, this meant spending time working more closely with them and recommending tutorial sessions.

The use of Learning Pool also gave advantages in terms of engagement monitoring. As previously mentioned, Learning Pool gave students the ability to monitor their own progress through a topic by giving them a progress bar and ticking off any elements that had been viewed. However, a more sophisticated breakdown of student engagement was available for staff. The embedding of resources within the SCORM package meant that any time that a student spent working through resources was time spent on the KLE. This meant that Blackboard's engagement monitoring reports could be used to compare the amount of time that different students spent on the work. This breakdown could be provided for the entire cohort or individual problem class groups, making it easier for tutors to provide more bespoke help to their students. In one case, it became apparent that a student who was struggling with the content had spent almost no time looking through the resources, making it straightforward to identify the root causes of the problem.

In short, the move to asynchronous delivery gave staff more time to focus on those students that they saw in live sessions and to better analyse their engagement and progress through the use of monitoring tools.

Summary and Concluding Remarks

This paper presented the transition to online-only delivery for two Mathematics modules delivered to a large, diverse cohort of students. A three-week-per-topic working model was developed and delivered through a blend of synchronous and asynchronous learning. Asynchronous lectures and resources were provided through the integration of Learning Pool SCORM packages and the KLE, while synchronous problem classes were delivered via MS Teams.

The three-week cycle enabled students to continue to revisit past topics while studying new ones, helping to crystalise their knowledge and understanding, as did the emphasis on the self-assessment of their formative progress checks. A reduction in the time spent delivering content freed up stuff to undertake a more thorough analysis of student engagement and progress, allowing for more targeted interventions and support.

As Higher Education hopefully moves into a post-Covid (or at least post-Covid-restriction) world, FNQMS will cease to be an online-only module, raising questions about how a hybrid delivery, large-scale Mathematics module would best be constructed. It is the view of the authors that the move towards asynchronous delivery of core content has been a positive one, both pedagogically and in terms of better use of staff time. As such, FNQMS will continue to use the Learning Pool SCORM packages in the future. However, while the MS Teams classes adequately allowed staff to provide support for students, they were ultimately a poor substitute for in-situ teaching. A return to the classroom for problem classes and tutorials will be very welcome, although scheduling only problem classes for more able students merits consideration.

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About the Authors

Adam Wootton is the Director of Education and a lecturer in Mathematics, Computing and Physics for the Keele University Foundation Year. He has a particular interest in innovation through technology in the Foundation Year. He can be contacted at a.j.wootton@keele.ac.uk

Jeff Neat is the Head of Foundation Year Mathematics and Computing at Keele University and has vast experience of both Further and Higher Education, having been at Keele for the last six years and Stoke-on-Trent Sixth Form College for the 26 years prior. He is a strong believer in the role and benefit a foundation year can offer in supporting students to fully achieve their potential.