CASE STUDY

Using pre-sessional resources to provide academic support and improve transition to university-level mathematics

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Abstract

This case study gives an overview of an initiative introduced at the University of Glasgow to ease the transition into university-level mathematics and promote student engagement. Beginning in the academic year 2023/24, this took the form of pre-arrival maths resources sent to incoming students which were designed to bridge the gap between Higher and Advanced Higher[1] entrants to first year. This included videos and practice questions to help them improve their skills and further introduced them to the maths support available during their studies. We will discuss the changes made since the introduction, as well as planned future changes based on informal feedback and lessons learned from this experience.

Keywords: Transition, pre-arrival, mathematics, engineering, maths support.

1. Introduction

It has been recognised for some time that students are entering university ill-equipped in terms of their mathematical skills despite having achieved good grades at Advanced Higher/A level. Dubbed the 'Mathematics Problem' by a 1995 report (LMS, 1995), this has been an ongoing challenge faced by mathematics educators and support staff, which is believed to have several contributing factors (Lawson et al, 2019, p.1227-1228). These include changes in the mathematical competencies of school leavers over time (Lawson, 2003 and Hodds et al, 2020) and much larger and more diverse student cohorts with varying prior qualifications.

The problems have become more apparent post-pandemic with studies showing that learning loss during the pandemic seemed to be greater for mathematics than for literacy (Ofqual, 2021). Students entering one UK university in 2021 performed significantly worse in entrance diagnostic tests than those the year before (Hodds, 2023), and there were disappointing maths exam results seen across several cohorts at the University of Glasgow in 2022/23. While some of this can be attributed directly to loss of learning time and changes in curricula (e.g. topics being removed from the Higher and Advanced Higher Maths curricula), other factors are thought to include the effects of the pandemic on student engagement more generally. There have been numerous news articles about the lack of

[1] Scottish Qualifications Authority (SQA) Highers and Advanced Highers are the standard qualifications for entry into higher education in Scotland. Highers are typically taken in the penultimate year (age 16-17) and Advanced Highers are taken in the final year (age 17-18) of secondary education.

attendance at university lectures since the pandemic (e.g. (Otte, 2024)), and an anecdotal lack of engagement has been noted amongst maths support practitioners.

Whatever the reasons, the cumulative nature of learning mathematics and the impact of self-efficacy on mathematical performance (see e.g. Cameron, 2024), mean that gaps in knowledge and a lack of confidence with fundamental skills will significantly hinder a student's progress. This motivated the creation of a resource that would allow students to ensure that the required underpinning knowledge is in place before they begin their studies, or at least as early as possible. This, along with the hope that engaging students early would lead to better engagement throughout their studies, led to the idea of the pre-arrival resources described in this case study, which are aimed at students on the two largest first-year maths modules at the University of Glasgow, namely Mathematics 1 and Engineering Mathematics 1.

In the remaining sections, we give a more detailed background of the modules we hoped to support, describe the pre-arrival resources produced and then discuss the outcomes of our work.

2. Mathematics 1 and Engineering Mathematics 1

2.1 Mathematics 1

The University of Glasgow has a College-entry system where students study three subjects in their first year. Mathematics 1 is the compulsory maths module for students on Mathematics, Statistics and Physics degree programmes. In addition, many other students take this module as an elective making it a very large cohort of up to 750 students.

University recruitment policy in Scotland means that, although most students taking Maths 1 will have at least a B grade in Advanced Higher Maths (or equivalent, such as A level), there are also a good number of students presenting with only Higher Maths - the maths course generally completed in the penultimate year of school in Scotland. Students with only Higher Maths will clearly have a gap in knowledge compared to those with an Advanced Higher qualification, e.g. Higher Maths students will not have seen complex numbers. To help bridge this gap, the School of Mathematics & Statistics introduced a 'Core Skills' component to the Maths 1 module when it was revised six years ago.

Core Skills covers five topics to reflect the differences between Higher and Advanced Higher Maths. These are: (1) Differentiation; (2) Integration; (3) Complex Numbers; (4) Binomial Theorem and Induction; (5) Matrices and Vectors. There is a test for each topic, and all students, including Advanced Higher entry students, are required to pass all five tests (pass mark 75%) before the end of the academic year. Students are given numerous opportunities to take the tests and can sit each test as many times as they need. A lecture is scheduled during semester 1 for each of these topics, which aligns with when the topic is needed for the main part of the Maths 1 module.

2.2 Engineering Mathematics

The Engineering students at the University of Glasgow follow a separate mathematics curriculum to other STEM students. They have two compulsory maths modules, Engineering Mathematics 1 and Engineering Mathematics 2, which are taken in first and second year respectively. Engineering Maths 1 covers topics such as functions, calculus, matrices, complex numbers and vectors, and has a significant overlap with Advanced Higher Mathematics. Engineering Maths 2 covers multivariable calculus, differential equations, Fourier series and Laplace transforms. Both are large classes, with approximately 400-500 students.

As part of Engineering Maths 1, students sit a maths diagnostic test in their first week at university and are also required to pass five '100%' tests in the first semester, which take place online and are designed to focus on foundational skills. Support for these tests, as well as for the overall module, is provided by optional maths drop-ins run by Student Learning Development (where the centralised maths support service sits). However, there has been a stark difference in attendance at these drop-ins pre- and post-pandemic.

Anecdotal evidence from lecturers and support staff suggests that, despite the efforts made in Engineering Maths 1, there are numerous students in Engineering Maths 2 who are still struggling with their foundational skills – specifically with general algebraic manipulation, sketching graphs such as straight lines and parabolas, and basic differentiation and integration. Without being addressed, this can lead some students to underperform in Engineering Maths 2, also affecting their progression to third year.

3. Pre-arrival initiative

3.1 Undergraduate Mathematics Pre-enrolment Moodle

Once the semester is underway, the Core Skills tests can get forgotten by students amongst all their classes, labs and assignments. Since these skills are important for students to understand the content of their Maths 1 lectures, it was felt that it would be useful to engage students with Core Skills earlier and take advantage of freshers' enthusiasm. As such, a pre-arrival resource based on the Core Skills component of Maths 1 was planned and prepared. As students are not able to access the University VLE (Moodle) prior to registration and enrolment, the resource was hosted on the University of Glasgow's External Moodle, which anyone can create an account for. Students were sent out details on how to sign-up, including an enrolment key, in late August, giving them a few weeks before semester to look over the resource.

The pre-arrival course consists of:

- A welcome message to the School of Mathematics & Statistics alongside introductory information about Core Skills and a welcome video message from the member of staff responsible for Core Skills;
- A section dedicated to each Core Skills topic with links to external resources (mainly Khan Academy) as well as a forum for students to be able to post any topic-related questions;
- Information relating to maths support and other support services at the University including a welcome video by the Maths Adviser (from centralised support service) and the Hub Coordinator (in-house drop-in maths support);
- A small set of sample questions similar to those in the actual Core Skills tests (see Appendix).

The plan was to not just initiate the students into the Core Skills component but also to foster a sense of belonging by welcoming them to the university and giving them an opportunity to meet each other and as such, a forum was set up for this purpose.

We offered online drop-in sessions after the resource had been sent out in case students had questions relating to the material, and then in-person drop-ins during orientation week. We deliberately avoided giving answers to the sample questions, encouraging students to attend the support sessions if they had any doubts.

3.2 Mathematics Support & Advice for Year 1 Engineers Moodle

In the process of creating the pre-arrival Moodle for Mathematics 1, it was suggested that a similar resource would be beneficial for incoming Engineering students. Several of the goals remained the same; namely welcoming students to the university, building their confidence with foundational skills and encouraging them to engage with maths support right from the beginning of their studies. However, there were a couple of differences in the cohorts that we felt should be considered:

1. Engineering Maths 1 does not have the equivalent of the catch-up lectures offered as part of Core Skills, so it seemed important to provide asynchronous resources to help students act on the results of their maths diagnostic test;
2. Since the overlap between Advanced Higher Maths and Engineering Maths 1 is considerably greater than with Maths 1, we felt the content for Engineers should focus more on the foundational skills second year students were seen to be struggling with.

In addition, many Engineers are unaware quite how important maths will be to their studies (Harris et al., 2015), so we felt this was an excellent opportunity to highlight this early on.

In 2023, there was insufficient time to adapt the Moodle created for Maths 1, so only minor modifications were made. This included adding a new topic called ‘Maths Essentials’, which covered algebraic manipulation, trigonometry, straight lines and quadratics, and removing more advanced topics like proof by induction. Additionally, a set of practice questions and solutions was added to each topic, so that students could check their understanding of the video content (either while preparing for the diagnostic test, or when going back to review topics afterwards). Only numerical answers were given, as students were encouraged to attend the maths drop-ins if they had any queries. This was sent out to incoming students by the School of Engineering’s Teaching Office in early September, just a couple of weeks before orientation week.

For 2024, there was more time to make changes and to receive valuable input from staff within the School of Engineering. This led to the addition of a welcome video from the School’s Learning & Teaching Convener emphasising the importance of maths in Engineering, as well as a ‘Meet the Lecturers’ section where students could see videos from several of the lecturers they would meet on their course.

Discussion with the module lecturers also led to a decision to further restrict the content on the Moodle to the fundamental skills; for example, removing the topic on complex numbers (which they have a whole block on during the module) and instead expanding other topics such as sketching graphs. We added a short (5 questions) interactive quiz to each section, so that we could assess engagement more easily and, more importantly, students could quickly assess whether they should spend time looking at that topic. Students did not receive answers to the questions they got wrong in these quizzes, just directions on which videos to watch or a suggestion to attend the maths drop-in sessions. We additionally expanded the range of videos (still curated rather than created due to time constraints) and practice questions (see Appendix), with each practice question also mapped to the relevant video(s). Finally, we ensured that some of the questions had an engineering focus to them, as students sometimes cite the perceived lack of relevance of the maths they are learning as a barrier (Harris et al., 2015).

4. Outcomes and Discussion

4.1 Dissemination

In an ideal world, we would like incoming students to have access to the relevant Moodle early in the summer, so that they have plenty of time to work through the resource if they choose to. However, the nature of university admissions makes this impossible since offers are not confirmed until after the students receive their exam results. For A level students, this is not until mid-August which means that the resource cannot be sent out until after then.

The other challenge we face is identifying all the relevant students who should receive access to the Maths 1 pre-arrival Moodle. Although we had a list of all the students who have Maths 1 as a compulsory module (i.e. Mathematics, Statistics and Physics students), many other students take Maths 1 as an elective. These students will not make this choice until after they are enrolled, which may not happen until orientation week, or sometimes even later. We took the approach of sending it to students on degree programmes from which students often choose maths as an elective (e.g. computer science, economics and chemistry) hoping that this would reach most students. This was not an issue for the Engineering Maths 1 Moodle, as it is only Engineering students who take this module.

For 2023/24, the sign-up information for the Moodle resource was sent to students multiple times via email, but despite this, over half the students who later gave feedback about the resources stated that they did not know it existed. The same approach received a similar response the following year, but other options for reaching students before term begins are limited. However, for 2024/25, we additionally displayed a QR code for the Engineering Maths Moodle at the students' induction session in orientation week. While this no longer counted as 'pre-arrival', it was highly successful in getting students to sign-up and ensured that they had the resource to prepare for, and more importantly review, the diagnostic test the following week.

4.2 Engagement

For the academic year 2023/24, we had approximately 160 students sign up to the pre-arrival Moodle for Maths 1, and approximately 220 for the Engineering version. For 2024/25, the numbers increased to approximately 200 and 360 respectively, with the significant increase in Engineering numbers due solely to displaying the QR code at their induction event.

In September 2023, attendance at the online drop-in session for students enrolled on the Maths 1 pre-arrival Moodle was very low, and the few questions asked were concerned more with enrolment and registration than the mathematical content of the sample test. Attendance at the in-person session in orientation week was good and students were keen to get their work checked and ask any questions relating to the sample problems. For this reason, it was decided to remove the online support session in September 2024 and run two in-person drop-in sessions instead.

In addition, a board games session was organised to take place in the same classroom at the end of the second drop-in session, and the Maclaurin Society (the students' Maths Society) were invited to attend as well. The inclusion of a fun social event proved popular and twice the number of students were in attendance compared to the session that took place earlier in the week.

A small number of students posted a short message on the 'general' forum on the Maths Moodle, introducing themselves and adding which course they were planning to pursue at Glasgow. It would

be good to have more students participating in informal chat on this forum, so students will in future be encouraged in their email invitations to post an introduction message.

For the Engineering students, attendance at the first-year maths drop-ins that take place throughout the year has remained low in both 2023/24 and 2024/25. However, we have seen an improvement in attendance at Engineering Maths 2 drop-ins in 2024/25, which corresponds to the students who received the first pre-arrival Moodle. We have yet to establish the cause of their change in engagement between first and second year, but we feel that it warrants further investigation.

Adding interactive quizzes to the Engineering Moodle this academic year has made it easier to track engagement, and we hope to be able to use this information in the future to establish whether there is any correlation between early (or continued) engagement with the pre-arrival resource, and final results in Engineering Maths 1 and 2.

4.3 Core Skills Results

Despite student numbers staying relatively constant, the total number of tests passed (score greater than or equal to 75%) by December 2024 is 3297 which is a dramatic increase compared to the number of passes at same time over the last two years: 1776 and 1643 tests passed in December 2023 and December 2022 respectively. Reminder emails are sent to students, but the frequency and timings of these have remained unchanged.

4.4 Informal Feedback and Future Plans

On the Maths Moodle, the most popular topics were ‘Complex Numbers’ and ‘Vectors & Matrices’, which is perhaps not surprising given these were the topics that were given less time, or left out of the syllabus entirely, during the Covid period (Price et al, 2022). Interestingly, ‘Differentiation’ was also one of the more commonly revised sections.

On the Engineering Moodle, the most popular topics were ‘Algebra’ and ‘Vectors’. Again, seeing ‘Vectors’ amongst the popular topics is not surprising, but it was interesting to see ‘Algebra’ (which included rearranging equations, functions, quadratics and inequalities) there too – this could simply be that it was the first topic listed on the page, or it could indicate that students are already aware this is something that they need to work on.

Generally, the students who enrolled on either Moodle reported finding the resource very helpful, with a consensus that it was nice to know what was expected of them, and that they would recommend the resource to others. For 2023/24, the most commonly requested change was for there to be more practice questions and worked examples available. While this theme remained in the feedback for the Maths Moodle in 2024/25, the addition of more questions and interactive quizzes to the Engineering Moodle resulted in these now most commonly being cited as something they liked about the Moodle. We hope to expand on this for future years, adding more interactive quizzes, and perhaps also linking to the Helping Engineers Learn Mathematics workbooks (HELM Project, 2015), so that they are aware of this excellent resource early in their studies.

Some of the comments we received indicated that students were confusing the pre-arrival Moodle resource with the one currently in use for Maths 1. For this reason, feedback was sought earlier this academic year, but the confusion seems to have persisted. Other students reported the disconnect between the pre-arrival Moodle and their current Moodle pages (namely, that they have to login to a separate place to find the pre-arrival resource) is something they would like changed. This is not possible given the nature of the External Moodle, but we will consider making a copy of the

Engineering Moodle available on the internal Moodle, so it is easier to access once teaching begins. This is not necessary for the Maths Moodle, since there is already a Core Skills Moodle in place.

Finally, we are keen to address the fact that there are still many students on both modules who did not enrol on the relevant pre-arrival Moodle. As discussed above, the most cited reason for this was that they simply didn't know about the Moodle. However, it was also common for students to say they had not enrolled because they were already confident in their maths ability. Despite making an effort to remove any language indicating this was a remedial resource, this theme persisted the following academic year. It would be interesting in future to investigate whether there is any evidence to show future likeminded students that they could still benefit from engaging in the resource.

5. Acknowledgements

The authors would like to thank Dr Andy Wand, Head of Core Skills, School of Mathematics & Statistics and Mr Greg Burgess, School Retention & Success Lead, College of Science & Engineering, who were part of the team that made this project possible.

6. Appendix

6.1 Practice questions from Mathematics 1 Pre-enrolment Moodle

1. Consider the following function:

$$f(x) = 2\ln(x-3)$$

   (a) Sketch the graph of f.

   (b) What are the domain and range of f ?

   (c) What is the x-intercept of the graph of f ?

2. Write the complex number $-9+9i$ in form $r(\cos\theta + i\sin x)$ where r is a non-negative real number and $0 \leq \theta < 2\pi$.

3. Let a, b, and d be integers. The following statement:

   If the product ab is divisible by d, then at least one of a and b are divisible by d.

   is false. Provide a counterexample of integer values for a, b and d to prove this.

4. Find

$$\int_0^{10} f(x)dx$$

   where

$$f(x) = \begin{cases} 8 & \text{if } x < 8 \\ x & \text{if } x \geq 8 \end{cases}$$

   (In other words, f is the function which returns the constant value 8 for all x less than 8, and returns x for all x greater than or equal to 8).

6.2 Example of Topic Questions Engineering Maths 1 Pre-enrolment Moodle

Quadratics

University of Glasgow

If you get stuck with any of the following questions, try taking a look at the corresponding video on the Moodle page - the relevant video(s) are indicated in brackets after the question number.

You may find it helpful to start by watching **Video A** to get used to the terminology surrounding parabolas.

1. **(Video B)** Expand the brackets in the following:

a. $(x+3)(x+2)$

b. $(x+4)(x-4)$

c. $(x+4)^2$

d. $(2x+4)(x-1)$

e. $(4x-5)(3x+12)$

f. $(x+1)(x+2)(x+3)$ (actually a cubic instead of a quadratic)

5. **(Video G)** Complete the square, i.e express each quadratic as $y = \alpha(x-\beta)^2 + \gamma$:

a. $y = x^2 - 4x + 2$

b. $y = x^2 - 4x - 4$

c. $y = x^2 + 6x + 4$

d. $y = x^2 - x - 1$

e. $y = x^2 + 3x + 4$

f. $y = 4x^2 - 16x - 16$

6. **(Videos E and A)** An object is thrown from the top of an 88.2m building (approximately the height of the Gilbert Scott Building at the University of Glasgow), at a speed of 14.7 metres per second. The height from the ground t seconds after being thrown is given by the quadratic equation

$$y = -4.9t^2 + 14.7t + 88.2.$$

After how many seconds will the object hit the ground? And what is the maximum height it will reach?

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