RESEARCH ARTICLE

Supporting Students at the Transition to University with a Self-Paced, Online Mathematics Induction Course

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Abstract

In this article we report on the design, development, and delivery of an online, self-paced, Mathematics Induction Course given to all incoming students in the Faculty of Science & Engineering at the University of Wolverhampton. We outline the background to the project, and we report on some preliminary findings which will be used to inform the future delivery of this course.

Keywords: Mathematics, Mathematics Education, Numeracy, Blended Learning.

1. Introduction & Background

Concerns regarding the mathematical preparedness of students entering UK Higher Education (HE) are certainly not new. As far back as June 2000, the Engineering Council recommended that all students embarking on mathematics-based degree courses should have a diagnostic test on entrance to University (Engineering Council, 2000). There have been many reports since then highlighting the need for mathematics support for students entering HE. In 2003, the LTSN MathsTEAM project carried out a survey on diagnostic provision at the time and produced a series of case studies on practices across UK HE institutions (LTSN MathsTEAM, 2003). The case studies included the delivery of paper-based diagnostic tests and computer-based diagnostic tests. Using funding provided by the Higher Education Funding Council for England (HEFCE), the Sigma Network (sigma-network.ac.uk) was created in 2005 as a collaborative Centre for Excellence in Teaching and Learning (CETL) in the provision of mathematics and statistics support. This led to the development of mathematics support centres in many UK Universities over the following fifteen or so years. See (Sigma, 2022b) for more information and see (The National HE STEM Programme, 2012) for details of the provision of mathematics learning support in UK HE institutions at the time.

In a parallel movement during the years 2000 to 2020, widening participation was becoming a priority for HE (Cox and Bidgood, 2002). This led to the development of many new routes into HE and the increasing popularity of these new routes created a very diverse cohort of students entering HE each year. In 2003, Lawson wrote (LTSN MathsTEAM, 2003)

> No longer do the overwhelming majority of mathematics undergraduates have double maths and physics A-Levels or the majority of engineers have maths, physics and chemistry A-Levels. Indeed, on engineering degrees in some universities, students having A-Levels in any subject have become a minority as the numbers with vocational qualifications have steadily increased. Add to these, mature students returning to education through university foundation years, or a variety of Further Education

> (FE) based access courses, not to mention a growing number of overseas students, and it becomes clear that university intakes have lost all semblance of homogeneity.

This statement is more relevant today than ever and it certainly rings true at the University of Wolverhampton. As the University of Opportunity, it "*aims to provide students, whatever their background or circumstance, the opportunity to fulfil their potential and realise their career ambitions in partnership with a supportive community*" (University of Wolverhampton, 2022).

For many years, at the University of Wolverhampton, there was a fragmented approach to diagnostic testing. Many subject areas did utilise a diagnostic tool of sorts, but these tended to be paper based and there was limited scope to follow up on findings afterwards. The adoption of the Canvas learning management system/virtual learning environment (www.instructure.com/en-gb) in 2017 provided an opportunity for a modern coordinated approach. A decision was taken to develop a cross faculty approach to be taken by all new incoming students to the Faculty of Science & Engineering (FSE) each year (approximately 900 students). The Mathematics Induction Course (MIC) was developed during summer 2017 and is now delivered to all new incoming students each year.

The Faculty of Science and Engineering offers more than 250 undergraduate programmes with minimum mathematics entry requirements of General Certificate Secondary Education (GCSE) Grade C/4 for level four students. Approximately 65% of incoming students will not have studied any mathematics post GCSE. About 25% of new students will have studied mathematics to AS-level or A-level while a further 10% of students will have other mathematics qualifications equivalent to GCSE. For this reason, it was decided that the MIC would presume a level of prior mathematics equivalent to GCSE grade 4. All incoming level four students in the faculty are automatically enrolled on the MIC on Canvas at the start of the academic year. Participation is mandatory and completion of the MIC is a compulsory element of the student Individual Learning Profile (ILP) at level four. The ILP is administered in conjunction with an academic skills coach.

This article includes analysis and insight gained from the submissions of 505 students who consented for their data to be used as part of this study.

2. The Maths Induction Course

The Maths Induction Course is an online, self-paced course aligned to a subset of the topics from the GCSE mathematics syllabus which assesses student competency in the areas shown in table 1.

The aim of the course is to encourage students to identify any of the above areas within which they may need some extra assistance and to overcome any difficulties at the outset of their studies. These content areas have been chosen based on feedback collected from staff across the faculty.

The MIC is live for the duration of the first semester, during which time students are required to complete all modules in the course. It was decided to make the course available throughout the entire semester so that students would not only have sufficient time to complete the course, but to also have the opportunity to interact with the extensive supporting materials that are available and, if required, receive any additional support.

Each module consists of a resource page, a discussion forum and an end of module quiz. The resource pages contain an introduction to the module which outlines the module requirements and the skills learned upon completion of the module. In addition to this, each resource page contains worked examples and exercises for students to engage with before completing the end of module quiz. Instructional videos are embedded at the top of each resource page where staff discuss a selection of the examples in more detail. A snapshot of one of the resource pages is shown in Figure 1. Each end

of module quiz contains five questions. The discussion forums are maintained for each module where students can post questions and receive support from the course team. Students are encouraged to make use of the supporting materials before completing each end of module quiz.

Table 1 Course modules.

1.	Whole Numbers	11.	Perimeter & Area
2.	Fractions	12.	Volume and Surface Area
3.	Decimals	13.	Coordinate Geometry
4.	Percentages	14.	Median & Mode
5.	Ratio	15.	Mean
6.	Proportion	16.	Interpreting Charts
7.	Powers	17.	Sets & Venn Diagrams
8	Simple & Compound Interest	18.	Probability
9.	Unit Conversion	19.	Scatter Graphs & Correlation
10.	Compound Measures (Speed, density)	20.	Problem Solving

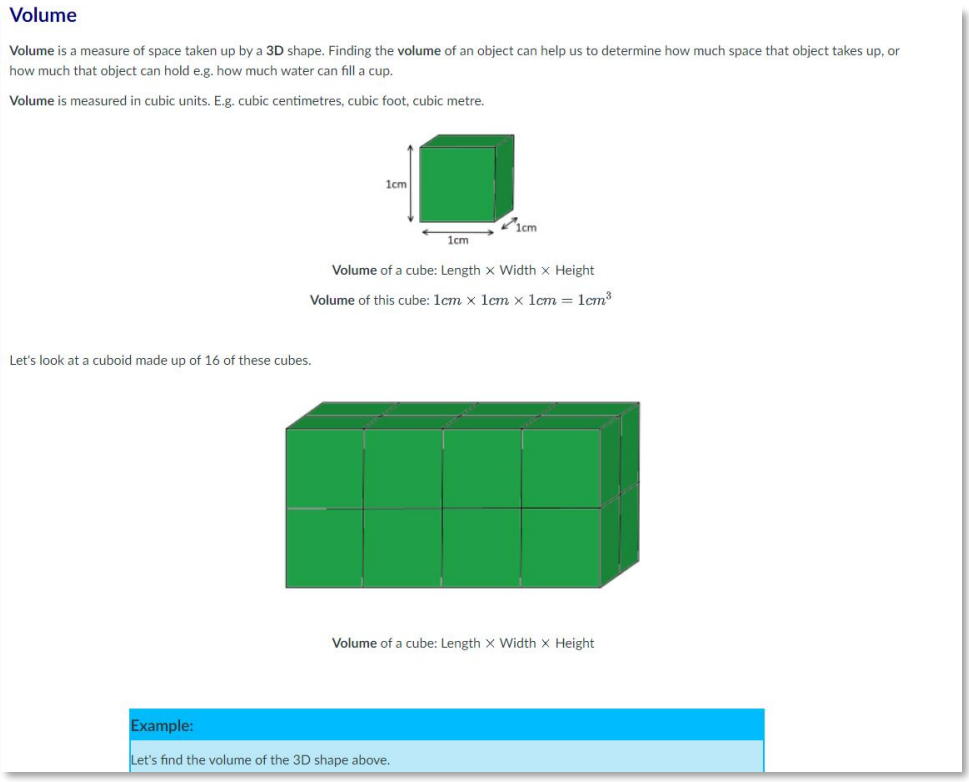

Figure 1. A snapshot of one of the resource pages.

The course landing page contains a Welcome Video, informing the students of the purpose of the course, what they are required to do and how to access the course content. There is also a section dedicated to the course team where students can learn more about the members of staff who run the course.

Follow-up support is an important part of diagnostic testing and the Engineering Council also recommended that prompt and effective support should be available to students whose mathematical background is found wanting by the tests (Engineering Council, 2000). Support is built into the MIC in such a way that students are required to interact with certain supporting materials before they are able

to move on to the next module. A range of facilities are built into Canvas which enable course designers to control how users progress through the course. Each module requires students to

1. view the resource page;
2. score at least three out of five in the end of module quiz.

Students are not able to progress to the next module until the above requirements are completed. There is no limit to the number of times a student can take each of the quizzes which means that if a student fails to achieve the required score, they are able to retake the quiz as many times as required with no subsequent consequences. Each quiz is automatically marked upon submission. Question response types include multiple choice, freetext and "*arrange in the correct order*". When creating each quiz, course designers are able to provide a range of correct answers for each question type. Upon submission of the quiz, Canvas identifies the students' responses which match the pre-provided "*correct*" answers for each question and marks them as correct. Answers that do not match the pre-provided "*correct*" answers are marked as incorrect. This enables students to have instant feedback on their quiz submissions and allows them to immediately identify any areas that need extra attention. In this way, students can identify and address any mathematical or numerical difficulties as they progress through the course, with the aim that upon successful completion they will be equipped with the essential skills that are needed to succeed in their course. The questions within each quiz are not randomised, although this is a feature which will be added in the future. A sample End of Module Quiz is included in the appendix.

3. Methodology

Before completing the MIC, students are asked to complete a short Welcome Survey which gathers information on their previous mathematical background and the mathematics qualifications acquired before commencing their university degree programmes. The survey takes the form of an online canvas quiz accessed via the MIC homepage. A copy of the Welcome Survey is shown in table 2.

Table 2. Welcome Survey.

#	Text	Option
Q1	Please type your course of study in the box below.	Freetext
Q2	When were you last in full-time education?	Less than 1 year ago
		Between 1 and 3 years ago
		Between 3 and 10 years ago
		More than 10 years ago
Q3	Have you completed a foundation year for your course of study?	Yes
		No
Q4	Please select the highest-level mathematics qualification you have achieved.	A Level Mathematics or equivalent
		AS Level Mathematics or equivalent
		GCSE Mathematics or equivalent
		Core Maths
		Level 2 Functional Skills Mathematics
		Other mathematics qualification

The data collected as part of the Welcome Survey is discussed in Section 4. As mentioned in Section 3, all students are also required to complete each of the twenty end of module quizzes. Students are required to score at least 3/5 in each of the end of module quizzes. If the minimum score is not met,

students are able to retake the quiz as many times as needed until they achieve the required score. There is no time restriction for each quiz and students can complete the quizzes at a time that is most convenient for them. They do not have to complete the quizzes on campus, they have the ability to do so at home, on their own devices. The scores achieved in each quiz are categorised according to School in section 4.

4. Results

In total, 505 students completed the Welcome Survey of which 499 competed the first module of the course and 434 completed the final module. Approximately one third of students who completed the MIC had previously completed a foundation year as part of their studies. Just over 25% of students were last in full time education more than one year ago. This is typical in the Faculty of Science & Engineering at the University of Wolverhampton. GCSE mathematics was the highest mathematics qualification on entry for approximately 61% of students with just over 27% having A level or equivalent qualifications. The performance of these students in the MIC modules will now be discussed.

4.1. Overall Score

Figure 2 illustrates the distribution of overall scores for all students who engaged with more than one quiz in the MIC. Here, score is taken to be the sum of the scores achieved for each of the twenty end of module quizzes. It is clear that there were few students that achieved an overall score below 60. This was to be expected as the course requirements stipulated a minimum score of three out of five for each end of module quiz in order to progress.

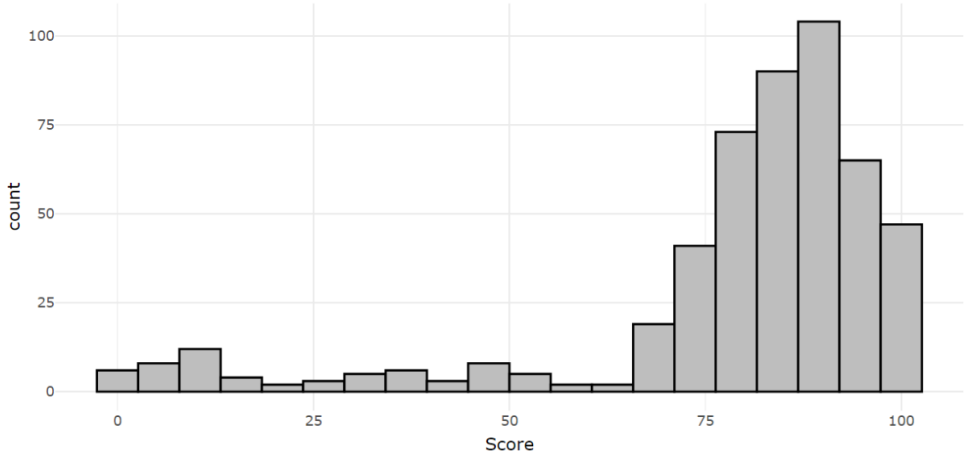

Figure 2. Overall scores for all students who engaged with more than one quiz in the Mathematics Induction Course.

It is still to be welcomed that the overwhelming majority of students scored more than 60/100 on the MIC.

The scores for each end of module quiz reveal interesting results. Figure 3 illustrates the proportion of students who achieved each of the possible scores in the end of module quizzes on their last attempt. The number of students scoring zero in the quizzes increases towards the end of the course. Again, this can be expected as not every student completed the course. Some further investigation into the reason why this is the case might be needed to determine how much of this is due to students simply self-removing from the course, or whether there was a module where students have not been able to achieve the minimum score and were consequently prevented from completing the course.

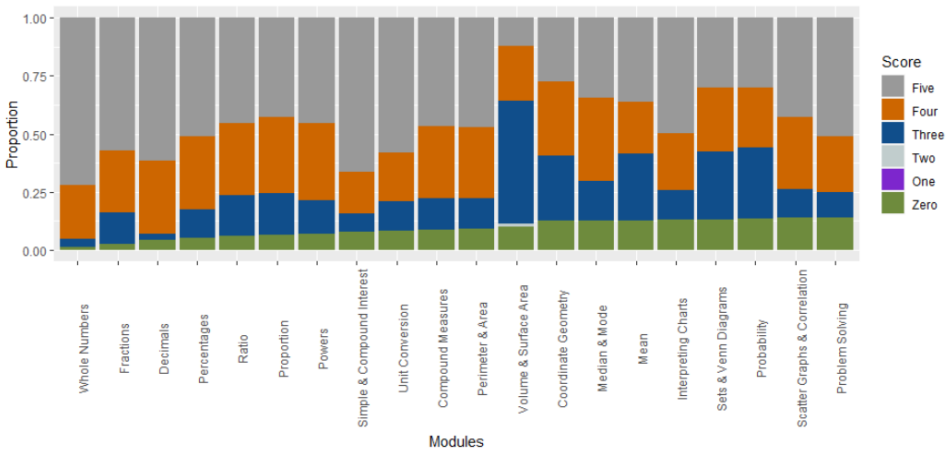

Figure 3. Proportion of students who achieved each of the possible scores in the end of module quizzes on their last attempt

The scores of zero can be discounted form the analysis at this stage as this indicates that the student did not submit the quiz. The proportion of students not submitting the quizzes grows steadily as a small number of students disengage with the MIC. A deeper analysis is ongoing to fully understand the reasons for this non-engagement and to see if it mirrors the student's course modules.

Module 12, Volume & Surface Area stands out as the first module where students seemed to experience difficulty in large numbers. The proportion achieving 5/5 in this module is much smaller than in the preceding modules. More analysis is needed to understand the reasons for this drop in level of performance.

4.2. Overall Score by School

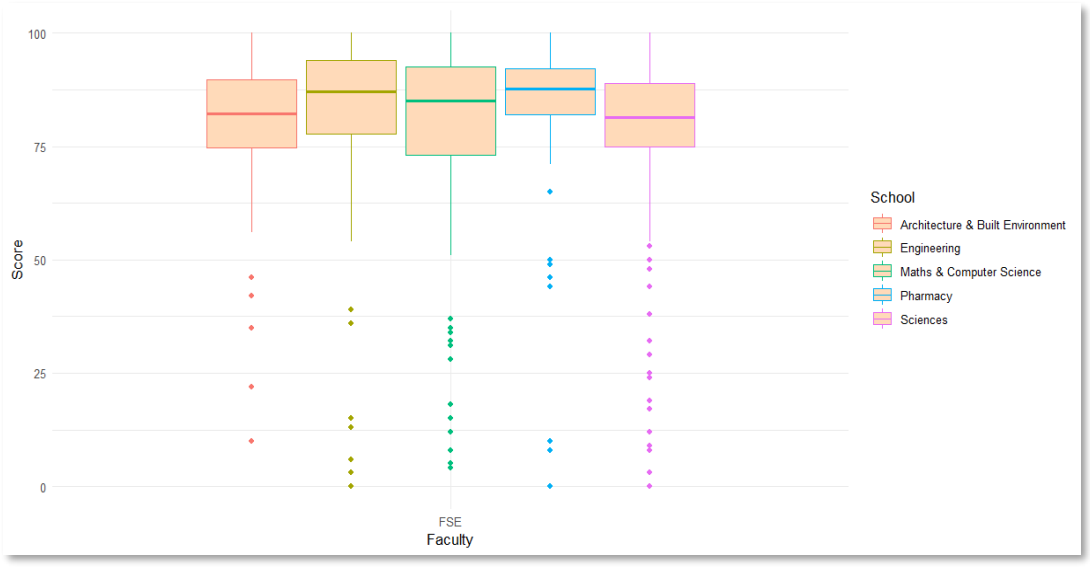

Figure 4. Distribution of scores across five academic schools.

Figure 4 illustrates the distribution of scores across each of the five schools within FSE. Students in the School of Pharmacy performed better than their counterparts and this is probably due to slightly higher average entry requirements in Pharmacy than in the other schools. The spread of scores is

widest in the School of Mathematics & Computer Science which at first glance is slightly surprising given that mathematics courses are housed within this school. However, there are a variety of courses in Computer Science including some Higher National Diploma (HND) courses where mathematics entry requirements are quite low.

The outliers in the different schools represent students who disengaged with the MIC and possibly also with their general courses although this requires more investigation.

4.3. Foundation Year

Approximately 30% of the students had completed a foundation year prior to their current course of study. Figure 5 illustrates the distribution of scores for those who have completed a foundation year compared to those who have not. Performance is similar between the two groups but there is a slight indication that students who have completed a foundation year do slightly better on the MIC than those that have not.

Figure 5. Distribution of scores for students who had and had not completed a foundation year prior to their current course of study.

When the scores are broken down by whether or not students have completed a foundation year within the different schools some interesting trends begin to emerge which will be of interest to learning & teaching panels with the schools. Figure 6 illustrates the distribution of scores for those who have completed a foundation compared to those who have not, broken down by School. In two of the schools, students who have completed a foundation year out-perform those who have not. In the School of Pharmacy and the School of Sciences, students who have completed a foundation year perform very slightly less well than their classmates. However, in the School of Engineering, students who have completed a foundation year perform considerably less well than their classmates. This is concerning for staff in the School of Engineering given the mathematics heavy nature of engineering courses so this indicates that additional support will be required for these students.

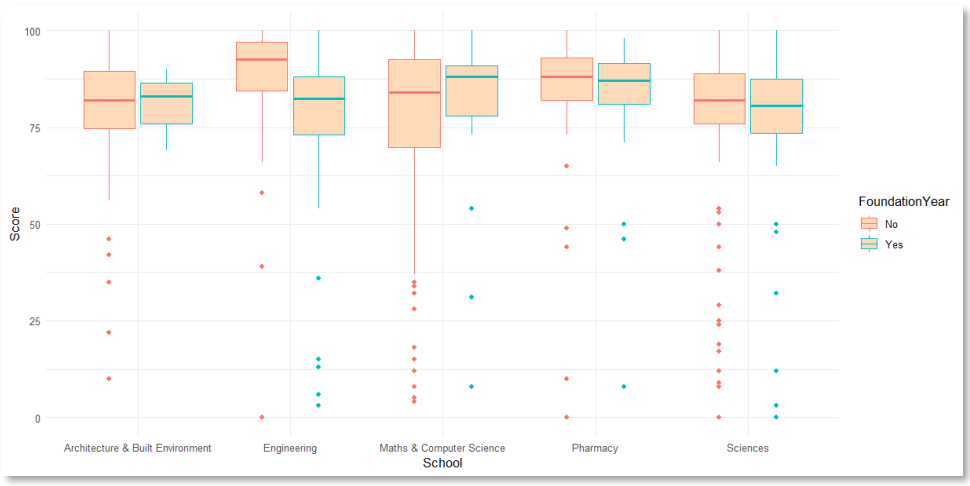

Figure 6. Distribution of scores for students who had and had not completed a foundation year prior to their current course of study, broken down by academic school.

4.4. Previous Mathematics Qualifications

Unsurprisingly, those with A level mathematics or equivalent do perform better in the MIC than students with other qualifications as illustrated in Figure 7. The performance of students with GCSE or equivalent lags slightly behind but not so far behind as to be a concern for staff. The lowest level of performance is exhibited by students with Functional Skills Level 2 Mathematics. These fourteen students represent a very small proportion of the intake, but it is certainly clear that some additional support will be needed for these students.

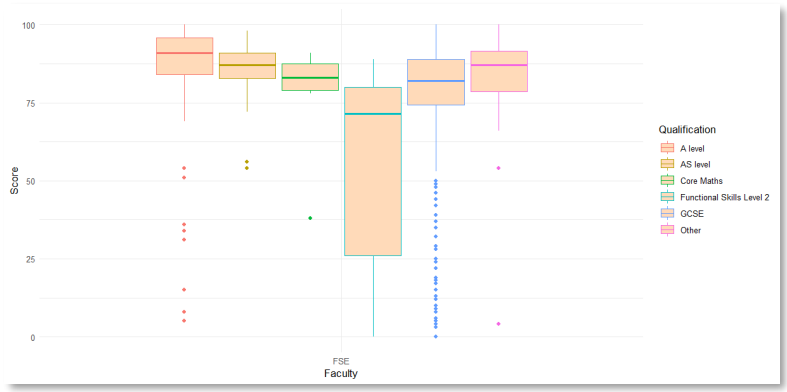

Figure 7. Distribution of scores for students by prior qualification.

5. Discussion

A common challenge with this type of research is obtaining permission to use students' data as part of the project. This was no different here. Approximately 37% of the total number of students registered on the MIC did not grant permission for the team to use their data which meant that 37% of the total data collected was omitted from the evaluation. The inclusion of this data may have made a difference to the outcomes and results.

Another limitation in this study is that not every student who began the course went on to complete all modules. Approximately 14% of those who completed the welcome survey (and granted permission to

use their data) did not complete all modules within the MIC. This data may help to understand the reason why students opt out of the MIC as well as their general studies.

The data on the number of attempts required before a student passed a module or the course as a whole would be a very interesting addition to this study. Unfortunately, this data was not available due to implementation issues with the Canvas learning management system at the university. Data from a post course survey of students' perceptions about the MIC would have also been useful and this feature will be added in future iterations of the MIC.

With the onset of the Covid-19 pandemic in the UK in March 2020, and with restrictions on social distancing still enforced at the beginning of the 2020/21 academic year, on-campus face-to-face teaching could not take place. The MIC is an online course which meant that few modifications needed to be made to the course itself in preparation for the start of the academic year. The biggest impact the restrictions had on the MIC was the initial launch of the course. For the first time, all students registered on the MIC in 2020/21 were starting their degree courses entirely online. In previous years, staff have joined face-to-face classes during the first week of the semester to introduce the MIC to incoming students. During the visits, staff would demonstrate what is required to complete the MIC whilst also explaining the purpose of the course and ensuring students were aware of the support that was available to them. Any initial questions were also addressed at this time. As an alternative, a Welcome Video was created and placed on the course landing page to outline the essential information that was usually communicated during the class visits. Additionally, on-campus support such as drop-in sessions could not take place. This meant that support was mainly provided via email, responding to comments on the discussion forums and Microsoft Teams meetings. In previous years, very few students attended the drop-in sessions, so it is unclear whether the absence of this provision has had an impact on the overall student experience.

The absence of class visits may have also had an effect on the number of students granting permission for their data to be used. Usually, any initial questions surrounding the research project and the usage of student data were addressed at the time of the on-campus class visits. It is possible that with the absence of this face-to-face interaction, initial questions and requests for clarification were not addressed before the option of granting permission was introduced and therefore may have affected their decision to grant permission of the usage of their course data.

Upon reflection, the initial design phase and the setting up of the course took the most amount of time. Extensive research took place to inform decisions taken on which numerical and mathematical topics would be included in the course, including researching topics on the GCSE Mathematics syllabus and speaking with members of staff. Developing the twenty module resources and quiz questions also took a great deal of time to prepare.

One essential development when designing this course was identifying which style of questions worked for the purpose of the MIC and which did not. Due to the number of students who take part in the MIC each year, it was essential that all quizzes could be automatically marked. The number of quizzes in the MIC, coupled with the ability of students to retake each one as many times as required, would have created an immense amount of marking that would have been impossible for the course team to manage without the facility of automatic marking. Not to mention the pace at which feedback must be given to students to be of any benefit meant that this facility was essential for the course to run successfully. Canvas provides a range of question styles when creating an online quiz. Certain question styles can be automatically marked whereas others require manual marking. One issue that quickly became apparent in the early developmental phase was the inappropriate use of certain question styles. In order to mark a question as correct, Canvas looks for a match between the pre-provided "*correct*" answers and the students' submissions. If the answer is not an exact match, it will

be marked as incorrect. This meant that for certain free text questions, if there was an insignificant mistake such as a typo or an incorrectly spelt word, the answer was marked as incorrect even though the answer was in fact correct. Consequently, student submissions were having to be checked by the course team to correct any mismarking. Careful consideration of the question style utilised was needed to ensure that automatic marking was successfully implemented.

The facility for the quizzes to be automatically marked enabled students to have instant feedback for each quiz. Furthermore, it enabled students to complete the course at a maintained pace that suited them without interruption caused by having to wait for the course team to mark their quiz submissions.

The next step for the course team is to look at the impact that the MIC is having on student performance at university and how the MIC can be used to make predictions about students' subsequent performance at the end of Semester one and at the end of year one. The course team also plan to investigate how the results of the course can be used to target supports for students.

The course team also plan to gather student feedback to help inform and develop the course further for future iterations of the MIC.

6. Resource availability

The resources for the Mathematics Induction Course are available from the authors on request.

7. References

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8. Appendix

8.1. Whole Numbers End of Module Quiz

#	Text	Option
Q1	Calculate $-12-(-8)$	-5 -21 -4 1
Q2	A bank account is at $-£22.£50$ is deposited into the account. A phone bill of $£38$ is then paid from the account. How much is left in the account?	Freetext
Q3	Tickets to an exhibition cost $£11$ per adult and $£6$ per child. Tickets for 3 adults and 6 children are bought. Four $£20$ notes are used to pay for these tickets. How much change should be expected?	Freetext
Q4	Calculate $-14\div-2$	7 -7 -16 -12
Q5	It costs $£360$ per night to rent a villa. If 12 people wish to rent the villa for 7 days, how much will each person have to pay given that the price is evenly split?	Freetext