

SPIRIT Maths: Giving students what they want

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ABSTRACT. We give an overview of a teaching and learning project in Munster Technological University, called SPIRIT Maths. The project’s aim was to find out students’ perceptions and attitudes towards mathematics, establish student preferences regarding learning resources, and develop and pilot resources consistent with these preferences.

1. INTRODUCTION

Mathematics educators have long observed deep-seated difficulties that many students encounter, and have grappled with the thorny question of how to address these difficulties. How do students find the experience of learning mathematics and how does it compare to their expectations? How can we establish what the key conceptual problems are and focus our pedagogical energies on these? What exactly would help students to overcome these problems?

In Munster Technological University (MTU) we have done our share of observing and grappling, leading to several teaching and learning initiatives in MTU. Most recently, we have surveyed students to ask about their perceptions of mathematics, and what resources they think would be most helpful to them in learning it. Moreover, we have developed learning resources in response to the answers to this survey. This project goes by the name **SPIRIT Maths** – Student Perceptions Informing and Redefining Teaching in Mathematics. This article presents an overview of the project. More details on the resources developed in the course of this project as well as the survey analysis can be found in [3] and [2].

We have no illusions that we’ve found the ultimate answers to the questions above. Other students in other institutions may have different backgrounds and expectations from ours. Moreover, students are not necessarily best placed to assess what are the impediments to their learning, and what resources would help them. Nevertheless, we believe that our findings (which contained a few surprises for the experienced lecturers involved in the project) and the nature of the resources developed may be useful elsewhere.

2. BACKGROUND

MTU came into existence on 1 January 2021 as Ireland’s second Technological University, arising from the former Cork Institutes of Technology (CIT) and the Institute of Technology Tralee (ITT). For convenience we will refer exclusively, to MTU throughout this overview of our project, even though all references prior to 2021 should more

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correctly be to CIT. Mathematics is, and has long been, an important subject in MTU. Mathematics features in 58 out of 75 CAO programmes offered in MTU; in 2020-2021 it was taken by 2260 of 3169 (71.3%) of all first year students. While the mathematics department offers programmes in mathematics, notably a Higher Diploma and an MSc in Data Science and Analytics, the vast majority of the mathematics teaching in MTU is service teaching, with students in the areas of business and engineering accounting for most of staff contact hours.

Anecdotally, mathematics has been a rather unpopular subject with a reputation – somewhat deserved, alas – as having a high failure rate. In 2019-2020 as many as 50% of students failed certain mathematics modules at their first attempt. Happily, the pass rate rises significantly when one considers in addition further attempts, but it is clear that a significant number of students have problems with mathematics. This raises the following questions:

- (1) What exactly are the mathematical problems that students face?
- (2) How can we lecturers help them?

Even students who attend lectures and tutorials, and who have difficulties with their mathematics modules are remarkably slow to ask questions or to seek help from their lecturer, so the answers to these questions are not self-evident. The SPIRIT Maths project sought to address these questions head-on by surveying MTU students who have taken a mathematics module.

Having learned the answer to the second question (some answers at any rate), we developed interactive digital learning resources that these students were looking for. We also developed a diagnostic test to help identify topics that students find difficult and direct the students to those resources.

The project was carried out by 12 lecturers in the Department of Mathematics in MTU with the support of several colleagues in client departments.

3. THE SURVEYS

Two surveys were carried out, one in June 2020, and one in February 2021.¹ The two surveys were sent to all students who had already completed at least one mathematics or statistics module in MTU. The first survey captured the perceptions of students that were on site for traditional in-class delivery (pre-pandemic). Once staff in MTU – along with institutions throughout the world – were forced to pivot to remote teaching, the team was keen to also capture this aspect of the student experience. This led to additional questions on the second survey. It is worth noting that the comparisons of the responses from the two surveys revealed no statistically significant differences, so the data from the two surveys were combined for analysis.²

Below we summarise some of the key points arising from the surveys. Further details can be found in [2].

- (1) 16.1% of respondents did not realise a mandatory mathematics module was going to be part of their chosen programme.
- (2) 52.3% of respondents find mathematics difficult.
- (3) Presented with several types of learning resources such as internet resources, lecturer-provided notes and videos, textbooks, and MTU's Academic Learning Support Centre, it is notable that an overwhelming majority favoured resources

¹It should be pointed out that while this places them in the midst of the COVID-19 pandemic, the project was planned before such a situation could have been envisaged.

²In total, 1633 students were invited to participate, from which 310 responses were obtained.

provided by the lecturer. This suggests that students don't make use of external resources such as the Khan Academy nearly as much as might have been suspected.

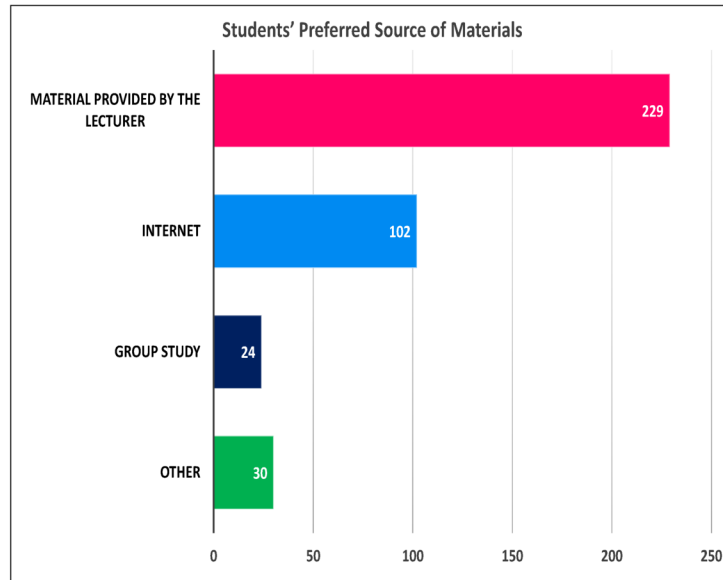


FIGURE 1. Students' preferred source

- (4) The 'need to practise to master methods' and the 'need to think and understand rather than learn off' are the two main things students dislike about learning mathematics.

Somewhat encouragingly, 28.5% of 309 students said there is nothing they dislike about learning mathematics. Of the remaining 221 respondents, 43.4% disliked the need to practise to master methods, and 18.6% said they dislike 'the need to think and understand rather than learn off'³.

- (5) There is no consensus among learners on the most desirable teaching mode (online or in-person) for mathematics, with roughly equal numbers of students thinking mathematics is more suited to online delivery, less suited to online delivery and equally suited to online delivery compared to other disciplines. This suggests that a fully remote delivery of mathematics modules would not be welcomed by a significant proportion of learners.
- (6) Surprisingly, while initially students expected mathematics to be significantly harder at third-level than at second-level, by the time they had completed their mathematics module, 81.9% of all respondents found first year mathematics in MTU similar or only 'a bit harder' than at second-level.
- (7) While 55.5% of students say they do two or more hours per week of independent work on mathematics, 34.1% of students said they do one hour, and 10.4% said they do no independent work on mathematics.

³Respondents could choose more than one response here, so there may be an overlap between these cases.

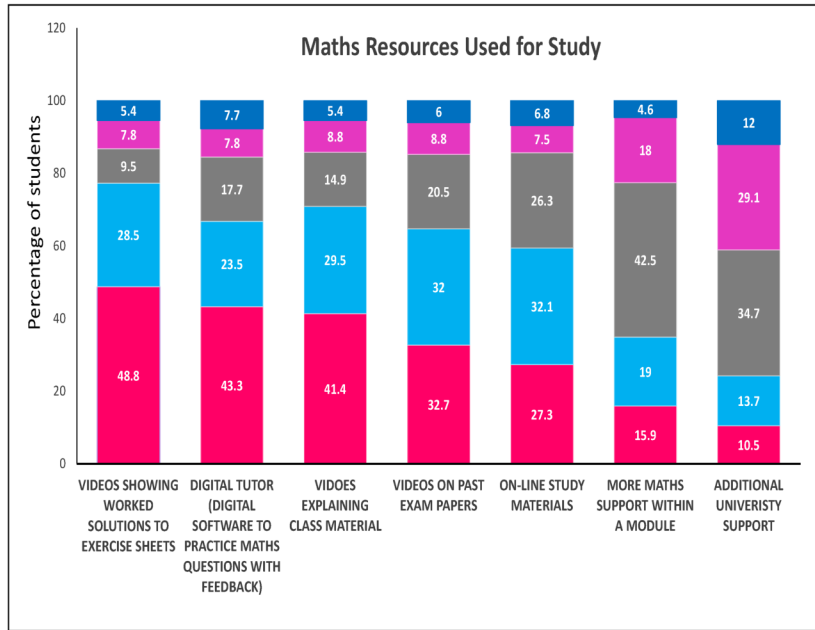


FIGURE 2. Students' preferences of resources

4. THE DIAGNOSTIC TEST

A comprehensive review of the literature of diagnostic testing at third level, particularly in Ireland, revealed that a lot of diagnostic testing is concerned with testing students on various topics that they are supposed to know about going into third level. Those tests typically establish a cut-off score such that students scoring below that score would be identified as 'at risk' of struggling with maths at third level.

The team took a slightly different approach and developed a diagnostic test that would allow immediate feedback to both students and lecturers. The purpose of the test was to identify topics that students find problematic, rather than 'at risk' students. The final diagnostic test is quite short, consisting of 15 short questions that test core knowledge, such as the following:

- Without the use of a calculator, solve for p :

$$\frac{492^{84} \times 492^7}{492^{13}} = 492^p$$

- Solve for v :

$$T = \frac{2v}{g} + 5$$

with the possible choices listed below:

- (1) $v = Tg - 7$
- (2) $v = \frac{g(T - 5)}{2}$
- (3) $v = \frac{Tg - 5}{2}$
- (4) $v = \frac{2(T - 5)}{g}$

$$(5) v = \frac{Tg}{7}$$

$$(6) v = \frac{g(T+5)}{2}$$

$$(7) v = \frac{Tg}{2} - 5$$

Each question answered incorrectly is highlighted and students are invited to either:

- (1) Explore a recommended SPIRIT Maths Digital Resource.
- (2) Watch a video of the solution.
- (3) Book a one to one meeting in the Academic Learning Centre.

The Diagnostic Test is available via Maths Online, a specialised module developed by the Academic Learning Centre in MTU. This module is automatically accessible to every student that takes a maths or stats module through Canvas, the Virtual Learning Environment (VLE) used in the University. It can also be imported by lecturers into their own Canvas modules if they wish to do so. Lecturers can see the results of the diagnostic test and take appropriate action as needed.

5. THE DIGITAL RESOURCES

As seen above, students are very focused on their own lecturer's materials. While there are many excellent resources on mathematical topics on the internet, students are much more likely to engage with materials provided by their lecturer.

With this in mind, the SPIRIT Maths team set about developing digital resources easily accessible from Canvas. We picked two of the biggest first year maths modules, MATH6051 (First Year Business) and MATH6014 (First Year Engineering) in MTU Cork. There are over 500 students taking these modules which is why the team decided to focus on them first.

The team developed three interlinked and complementary resources:

- (1) H5P interactive self-test questions.
- (2) Corresponding videos showing worked solutions.
- (3) Bank of practice questions developed using Numbas.

H5P is a tool widely used to create interactive content. H5P content is responsive and mobile-friendly, which means that users will experience the same rich content on computers, smartphones and tablets alike. All the user needs is a web browser. It also can be easily integrated into Canvas, as well as other VLEs.

The H5P questions created by the team enable students to input their answer in the provided box and verify it by clicking the 'check' button. If the answer is incorrect, they can choose to either watch the video solution to that particular question or practise a similar question in Numbas.

Another useful feature of H5P is that reports of submitted answers are available to the lecturer which will help the lecturer to understand where most of the difficulties lie.

Aligned then to each H5P video are worked out solutions the team created as well as a bank of Numbas questions. The videos with the solutions were created using packages such as Explain Everything and Educreations.

Numbas is an e-assessment tool supported by an open source platform which is particularly suitable for maths-related topics as it allows easy randomisation of variables and names. It also can provide instant feedback and hints. So, after watching a video,

the student can choose to attempt a similar question in Numbas. If the student answered a question correctly, a green tick will appear to confirm this. If, on the other hand, the student is unsure of how to proceed, they can choose to open a hint. After each hint they can continue with the question, or reveal the full solution. The student then can choose to try a similar question of the same type.

Numbas has been extensively used in MTU Cork in mathematics modules and has been proven to be a very effective tool [1]. Figure 3 illustrates the three interlinked resources developed by the team for a typical engineering question.

The figure illustrates three interlinked resources for a problem involving the exponential function:

- Top Left (Numbas Exercise):** An exercise titled "Exercise : Solve for x in the following equation, rounding your answer to 3 decimal places:" with the equation $6e^{3.1x} = 23$. It includes a text input field for the answer and a "Check" button.
- Bottom Left (Video Solution):** A video player showing a handwritten solution for the equation $3e^{-2.7x} = 8$. The solution involves dividing both sides by 3, resulting in $e^{-2.7x} = \frac{8}{3}$. A callout box explains: "MULTIPLICATION by 3 cancels DIVISION by 3".
- Right (Numbas Question Page):** A question page for "Solve for x " with the equation $4e^{-4.9x} = 9$. It includes a text input field, a "Submit part" button, and three hints: "Hint 1 - how to start", "Hint 2 - a little more help", and "Hint 3 - finishing the question". At the bottom, it shows progress: "Solve for x : 0/2" and "Total: 0/2", along with buttons for "Try another question like this one" and "Reveal answers".

Blue arrows indicate the interlinking: a downward arrow from the exercise to the video, and a curved arrow from the video to the question page.

FIGURE 3. Interlinked resources for a problem involving the exponential function.

In summary, SPIRIT Maths sought to address the challenges that students encounter in learning mathematics in MTU, noting that this is predominantly service teaching. The type of resources described above were chosen in response to primary data obtained through a survey of MTU students. Preliminary feedback from a focus group, as well as initial analysis of Canvas data for one of the piloted modules (MATH6051) suggests that the use of the resources correlates with a higher module grade and that the resources are effective for self-directed learning. However, the results of our survey underline the importance of lecturers promoting the resources to their students. It is also important to obtain ongoing feedback and to incorporate this when revising the resources.

It is of course difficult to draw firm conclusions on what are the determining factors on a student's module grade. Nevertheless, the initial analysis encourages us to roll out similar resources throughout the university in future.

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