

CASE STUDY

Non-mathematics undergraduates' perceptions of mathematics and preferences for digital learning resources in a technological university

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Abstract

Service mathematics plays a central role in Munster Technological University (MTU) where the majority of programmes contain at least one mathematics or statistics module. The widely acknowledged issue of low engagement continues to be a barrier to learning for many non-mathematics undergraduates and often results in low achievement which may impact progression. One of the main goals of the *SPIRIT Maths* project at MTU is to gain insights into learners' perceptions and dispositions towards mathematics and use that acumen to inform the development of digital learning tools and future interventions. This paper presents some of the findings of a student survey that focused on students' expectations of and the realities of experiencing mathematics at university, and their views on remote delivery and approaches to learning. The survey results show that many incoming students overestimate the difficulties of studying mathematics at university. The data also highlight how a significant proportion of respondents spend an inadequate amount of time on independent learning. We then consider the aspects of mathematics that learners find most discouraging, and what students report could help them to better engage with and learn mathematics. We also explore students' preferences for digital learning resources ranging from videos of worked solutions to an online bank of practice questions with feedback.

Keywords: learning mathematics, non-mathematics undergraduates, perceptions and dispositions, digital learning resources.

1. Introduction

Munster Technological University (MTU) is a higher education (HE) institution in Ireland offering more than 100 degree programmes over six campuses, with a student body of more than 18,000. Here mathematics is largely a service discipline where 77.3% of programmes contain at least one mathematics/statistics module. In the 2020-2021 academic year, 71.3% of all incoming students took a mandatory mathematics/statistics module in their first year. A typical degree programme at MTU comprises six 5-credit modules taken in each semester. The majority of mathematics/statistics modules are designed in a format of 3 hours of formal lectures, 1 hour of tutorial and/or lab work and 3 hours of independent learning per week. As students are normally assessed in all six modules in a semester, with several modules delivered as continuous assessment only, the assessment schedule is rather heavy. At the same time, many HE students work part-time jobs. A survey conducted by Technological University Dublin showed that 63% of students had part-time work in 2019 (Burns, 2020). Though there are maths-enthusiastic and well performing students in every class/cohort, a rather common hallmark in service mathematics modules is the issue of low engagement and subsequent low achievement. This in turn may impact a student's performance in other (applied)

disciplines and, ultimately, their progression. Mathematics does prove to be a challenge for a considerable proportion of non-mathematics undergraduates and especially so during the transition from post-primary school¹ into first year in university, a common phenomenon in HE (Liston & O'Donoghue, 2010; Harris & Pampaka, 2016). In some programmes at MTU, up to 40% of first-year students fail their mathematics/statistics module at their first attempt. Additionally, there can be a diversity of mathematical backgrounds in class due to the different paths into the university and varied entry requirements. These challenges sometimes interact, thus making the learning environment demanding on the student but equally presenting multiple challenges for the lecturer (Liston & O'Donoghue, 2010).

In November 2019, the *SPIRIT Maths* (Students' Perceptions Informing and Redefining Innovative Teaching of Mathematics in Higher Education) project was funded by the National Forum for the Enhancement of Teaching and Learning in Higher Education. One of the main objectives of the project was to elicit learners' views, perceptions and experiences of first-year mathematics and use the insights to create additional learning supports for students and ultimately help them to better engage with and progress in service mathematics modules. This paper reports on some of the early findings of the project.

The problem of low engagement in mathematics is not new, it is universal and often begins much earlier than university (Skilling et al., 2020; Grehan et al., 2016). At the same time, our own experience and that of our colleagues at MTU suggests that students tend to engage better in modules with a digital learning component. Moreover, emerging studies register the potential of digital tools to enhance the process of learning mathematics and also a positive effect of using digital resources for motivation and engagement with the subject (Chao et al., 2016; Hillmayr et al., 2020). These factors suggest considering, adopting and/or developing new digital learning tools to support learning of mathematics, something a student could potentially engage with at their own time and pace. Therefore, on par with looking into students' dispositions to mathematics the *SPIRIT Maths* project also explores their preferences for various potential digital learning resources.

The remainder of this paper is organised as follows. Section 2 describes the survey, study participants and methodology. Section 3 presents and discusses the survey results. Section 4 concludes with a summary of main findings.

2. Methodology

This study focused on two of the largest first-year cohorts at MTU (Cork campus), Business and Engineering students. A survey was purpose-designed by the authors and fine-tuned based on the feedback from piloting and discussions with other mathematics lecturers in the University. The survey concentrated on several areas related to learning of mathematics: students' expectations and actual experience of the university mathematics, views on remote learning, learning strategies and preferences for potential digital learning supports. The survey consisted of a combination of closed-ended questions ('tick box' responses with '*choose one*' or '*select as many as apply*' options) and ranking/rating questions (see questionnaire in the Appendix). Two open-ended questions were asked at the end of the survey where students could respond with comments and suggestions regarding

¹ In the Republic of Ireland students commence primary school at 4 or 5 years of age and have 8 years of education before enrolling in post primary education for a further 5-6 years. Most students start in post-primary school at 12 or 13 years of age. Following this many students then enrol at a HE Institution (Citizens Information, 2019).

additional learning resources and their experiences of studying mathematics at MTU-Cork. The anonymous survey was delivered online using MS Forms. The survey was issued twice to all students in the above cohorts, in June 2020 (student intake 2019) and in February 2021 (student intake 2020). Comparisons of the distribution of responses from the two instances of the survey revealed no statistically significant differences ($p > 0.05$), hence the data from the two surveys were combined for further analysis. In total, 1633 students were invited to participate in the survey, of which 310 responded giving an overall response rate of 19.0% (mapping to a margin of error of less than 5% at a 95% level of confidence). We note that while it is possible that students who failed in 2019-2020 may have completed the survey twice, there is no evidence of this from the analysis of the open-ended question responses (undertaken separate to this paper). A detailed breakdown of respondents is collated in Table 1.

Table 1. Student cohorts that completed the survey

Intake	Programme type		Total
	Business	Engineering	
2019	26 (30.6%)	59 (69.4%)	85 (100.0%)
2020	65 (28.9%)	160 (71.1%)	225 (100.0%)
Total	91 (29.4%)	219 (70.6%)	310 (100.0%)

Statistical analyses were performed using *RStudio 1.4.1103* for Windows. Descriptive statistics were used to summarise the student responses to questions, numerically as frequencies and percentages, and graphically using bar charts and pie charts. Chi-squared tests followed by Fisher's tests or binomial tests were used to determine the difference in proportions across response types. Multiple comparisons of responses to the same question were controlled for using the Bonferroni correction method. All statistical test results were interpreted using a 5% level of significance.

3. Results and discussion

3.1. Challenges, students' expectations and the reality of university maths experience

Overall, 52.3% of all respondents reported finding mathematics difficult (Table 2). Notably, the survey revealed that 16.1% of respondents did not realise a mandatory mathematics module was going to be part of their chosen programme (Q1 and Q2 in the Appendix). Moreover, 19.8% of these respondents reported mathematics being difficult. These results indicate that a proportion of undergraduates might be less mathematically prepared than is required for studying at university and consequently may find mathematics classes more challenging than others.

Table 2. Student expectations and challenges

Do you find Maths difficult?	Frequency (%)	When choosing your degree course did you realise a Maths module was going to be compulsory?	Frequency (%)
No	148 (47.7%)	No	50 (16.1%)
Yes	162 (52.3%)	Yes	260 (83.9%)
Total	310 (100.0%)	Total	310 (100.0%)

The survey also asked students about their perceptions/anticipations of university mathematics (in comparison with the post-primary school experience) and also their actual experience of mathematics at the University (Q3 and Q4 in the Appendix). When the survey was issued, all participants have had at least one full semester of university mathematics. As shown in Figure 1, their views change. Some respondents who, for example, thought university mathematics was going to be much harder than at school had 'migrated' to the view that mathematics in university is only 'a bit harder' than at school ($p < 0.001$). Furthermore, the percentage of those expecting a 'much harder' mathematics is nearly halved after the students have actually experienced it. Overall, 81.9% of all respondents found first-year mathematics similar or only 'a bit harder' than at post-primary school. These findings are encouraging, yet not entirely unexpected, given both the known phenomenon of 'mathematics anxiety' and the care many mathematics educators take with service teaching. Weekly tutorial classes for small groups (20 students max) where each student gets individual attention and help with their maths work is one of steps taken in MTU to achieve this.

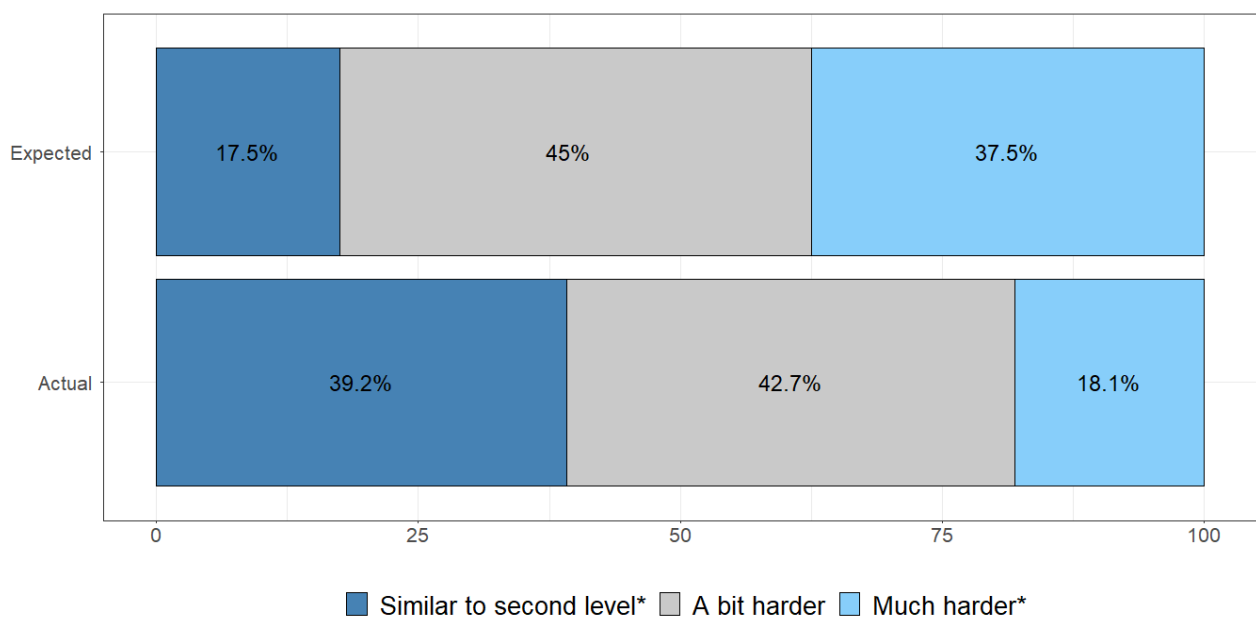


Figure 1. Shift in students' views on university mathematics after experiencing it ($n = 309$). *Changes from *Expected* to *Actual* were found to be statistically significant ($p < 0.001$).

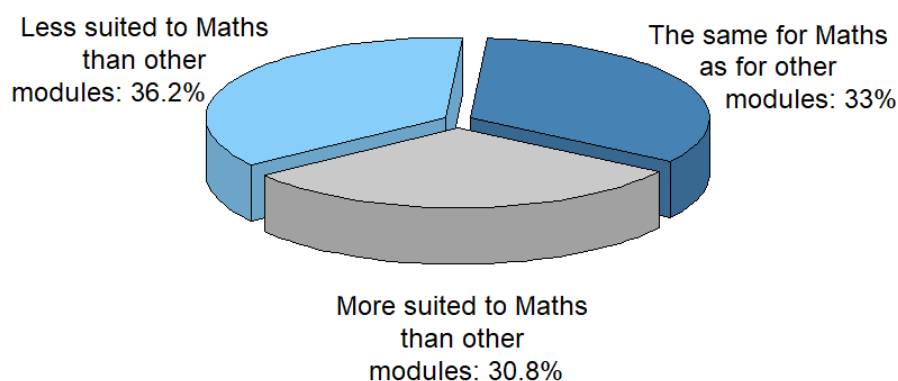


Figure 2. Views on the suitability of mathematics for remote delivery (n = 224).

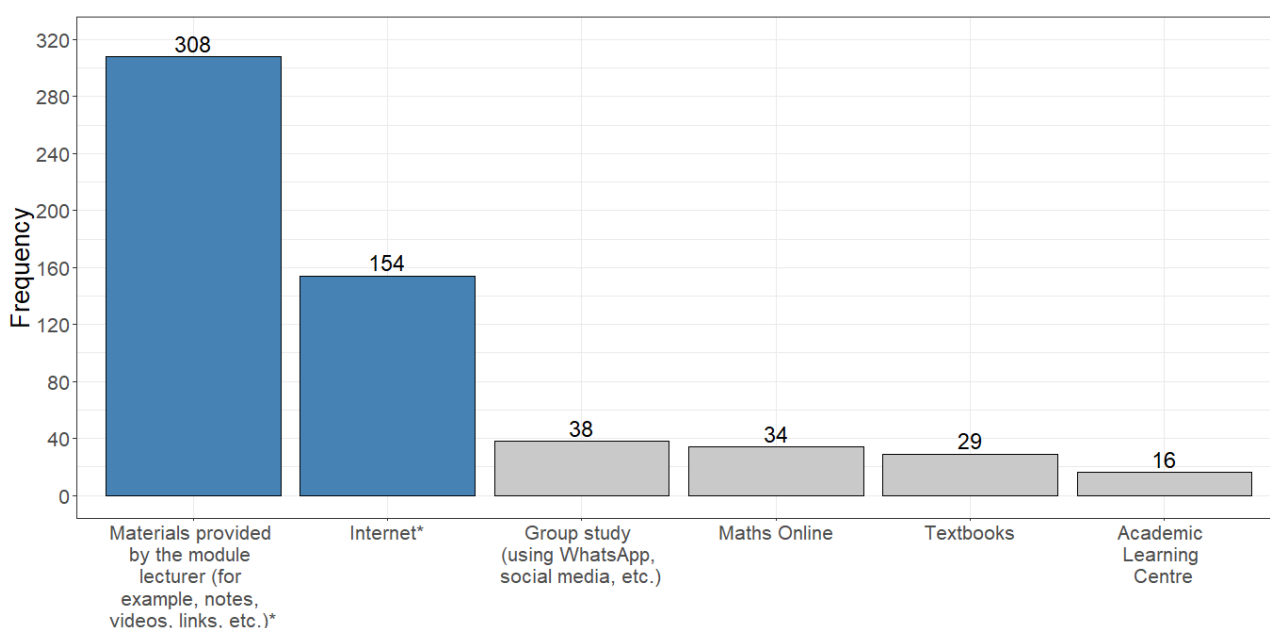


Figure 3. Use of resources during remote delivery². *Material provided by the module lecturer and Internet are the two most used resources during remote delivery ($p < 0.001$).

3.2. Views on remote learning experience

Given the remote teaching and learning environment the survey participants were experiencing, we also asked questions related to the suitability of mathematics for remote delivery and to gauge students' usage of various learning materials and resources available to them in the online setup (Q5 and Q6 in the Appendix). Figure 2 displays a nearly equal split between students' opinions of remotely delivered mathematics ($p > 0.05$). The absence of consensus on the most desirable teaching mode is

² *Maths Online* is a non-mandatory e-learning resource for students, implemented via the Canvas Virtual Learning Environment, which contains a range of learning resources on various mathematics topics to complement studying mathematics at MTU. The *Academic Learning Centre* is a support service where students can choose to get free face-to-face and/or remote help with mathematics. The centre offers pre-booked one-to-one appointments as well as drop-in sessions and occasional thematic group sessions.

evident and needs to be taken into account when planning future deliveries that might include a remote component. A sharp move to a fully remote delivery would not be justified and would likely not be welcomed by a significant proportion of learners. However, students' views on a more blended approach would be worth further investigation.

Figure 3 presents a breakdown of the usage of various learning materials and resources (where multiple responses could be selected (see Q6 in the Appendix). Students appear very focused on using lecturers' material (308 out of 310 respondents) and this should be considered when developing new resources. In future, it might be prudent to link any extra or supporting resources from the platform used by the lecturer as a primary source of sharing module materials.

3.3. What's to dislike about maths?

As mathematics teachers it may be sometimes hard to see matters from the student perspective. In order to shed some light on this the survey participants were asked to choose one aspect they disliked most about mathematics (Q7 in the Appendix). Interestingly, 88 students (28.5%, $n=309$) found nothing disagreeable with learning mathematics. On the other hand, 43.4% of the remaining 221 respondents quoted the '*need to practise to master methods*' as the main discouraging factor (Figure 4). Lecturers may often observe that students do not like practising mathematics, especially when problems/questions get longer (Rameli & Kosnin, 2016), but interestingly this response is more prevalent than '*need to think and understand rather than learn off*', '*doesn't make sense*', '*too difficult*', '*don't know why I have to do it*' and '*I don't like numbers*' ($p < 0.001$). Though mastering the methods is a necessary and integral aspect of the process of learning mathematics, perhaps some steps can be taken to make this experience more agreeable to a student who is not training to become a mathematician. For example, adopting digital practice tools, which students tend to enjoy, could potentially allow students to practice independently, at their own time and pace, thus making the learning process more engaging and hopefully productive (Chao et al., 2016). The formative assessment aspect of such approaches is known to be beneficial for learning and engagement (Rakoczy et al., 2019; Ní Fhloinn & Carr, 2017). Furthermore, Lyakhova et al. (2021) report a higher-than-expected cognitive engagement by students aged 16+ when using a mathematics 'Box Set' of enrichment video materials, which included activities and exercises.

Discovering that 18.6% of respondents disliked most the '*need to think and understand rather than learn off*' indicates that some students may not realise that thinking and understanding the concepts and methods is the most important element of learning and practicing/applying mathematics (Stacey, 2006). Perhaps this idea, together with the value of developing 'mathematical thinking', may need to be emphasised in introductory first-year mathematics lectures.

The 'Other' responses were varied but included some interesting insights from the student perspective. For example, '*getting something wrong and not knowing where/why you went wrong*' and not knowing/seeing how the mathematics topics and methods might be applied in the chosen degree course or in the future career.

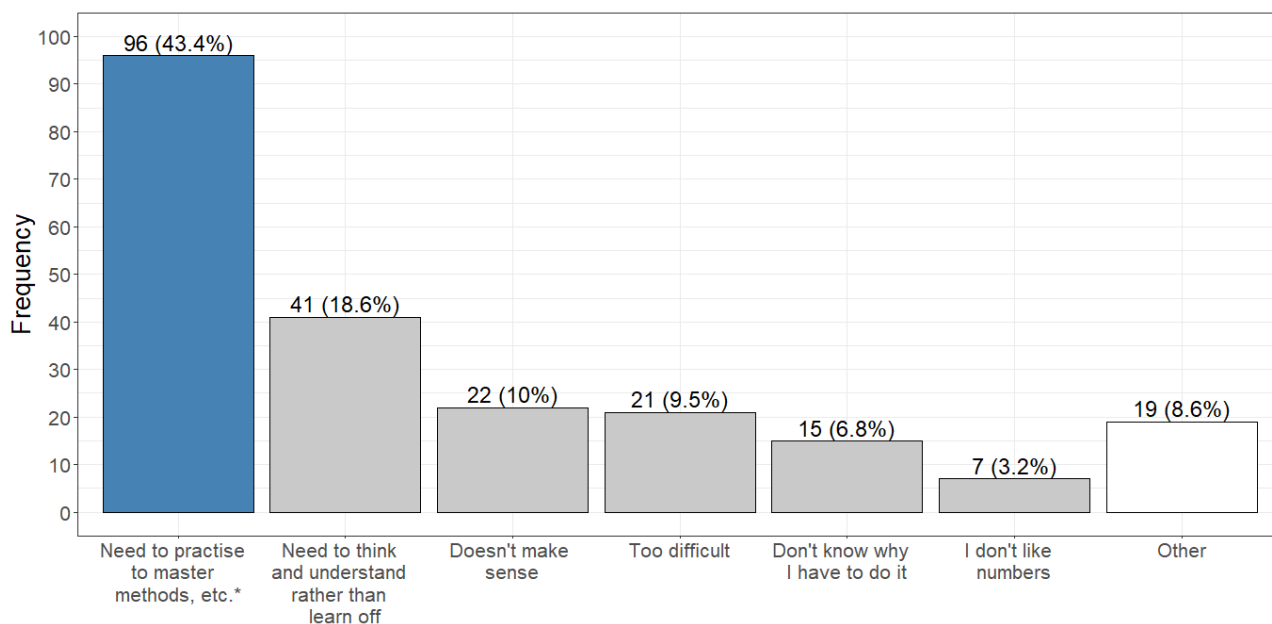


Figure 4. Aspects of learning mathematics that students dislike most (n = 221). 88 students (not shown here) stated they disliked *Nothing*. **Need to practise to master methods, etc.* was the main aspect of learning mathematics that students disliked the most ($p < 0.001$).

3.4. Study approach

Students' approaches to learning can be a significant differentiating factor impacting the quality of learning and exam performance (Herrmann et al., 2017). The survey found that a large proportion of first-year students (44.5% of survey respondents) spent one hour or less per week learning mathematics independently, which is far from the recommended study approach (Figure 5, Q8 in the Appendix). The authors are interested in what can be done to affect the situation and also to find out what the students think could help their learning of mathematics. The latter question was posed in the survey, asking the participants to rank a range of options devised to assist the learning process (Q9 in the Appendix). Figure 6 shows that 46.4% of respondents gave the highest ranking to frequent low percentage quizzes/assessments as stimuli for engagement. Having clearly identified goals to be met each week, i.e., a study schedule, was second most preferred learning support (39.2% of respondents). The latter is straightforward to implement via various platforms and should be a best practice standard. The preference for a low stakes formative assessment is not incidental either. In Drumm & Jong (2020) a student describes frequent low-stakes graded quizzes as being an important factor for students' engagement with lecture material. Furthermore, in order to address low attendance at tutorials and low engagement with the module, Carroll et al. (2017) describe how they implemented an e-assessment in mathematics modules with a large cohort of Business Studies students in their first year. A positive effect on all aspects of successful engagement, i.e., student participation, attendance and enjoyment, was observed in the study. This could lead one to wonder what other digital resources could aid the process of learning mathematics and exam preparation?

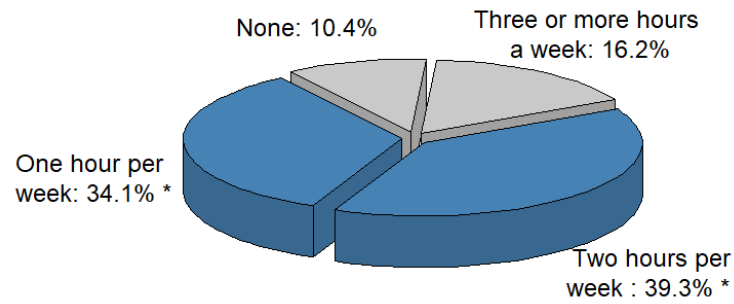


Figure 5. Time spent by students working independently (n = 308). *Students responded they mainly work independent on average *One hour per week* or *Two hours per week*. As opposed to a minority of students responding *None* or *Three or more hours a week* ($p < 0.001$).

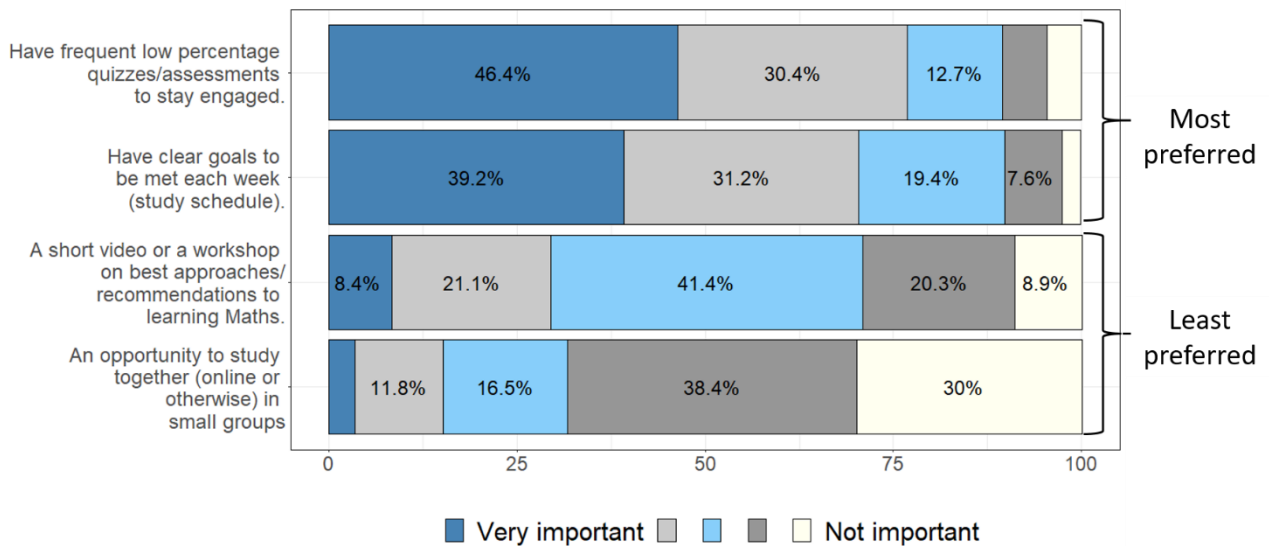


Figure 6. Students' views on most helpful learning supports, ranked in terms of importance (n = 222), with frequent low percentage quizzes/assessments and having clearly identified goals to be met each week as most helpful ($p < 0.001$).

3.5. Students' preferences for digital maths learning resources

In the knowledge of students' enhanced engagement observed in modules with a digital learning component, the survey also focused on which digital learning resources students perceived would be most beneficial to their learning. A range of potential digital supports was listed, and respondents had to rate them in order of effectiveness or usefulness. Figures 7 and 8 present the proportional breakdown of responses (Q10 and Q11 in the Appendix).

In relation to the digital resources that were rated as the most effective, students' most preferred options were video related learning resources, e.g., videos on worked solutions (48.8%), explaining class material (41.4%) and past exam papers (32.7%), (see Figure 7) - along with a digital tutor (43.3%, $p < 0.001$).

Regarding digital resources that were rated as the most useful, students' most preferred options were learning resources containing a bank of practice questions and a web portal with searchable topics (65.5% and 50.7%, respectively, $p < 0.001$).

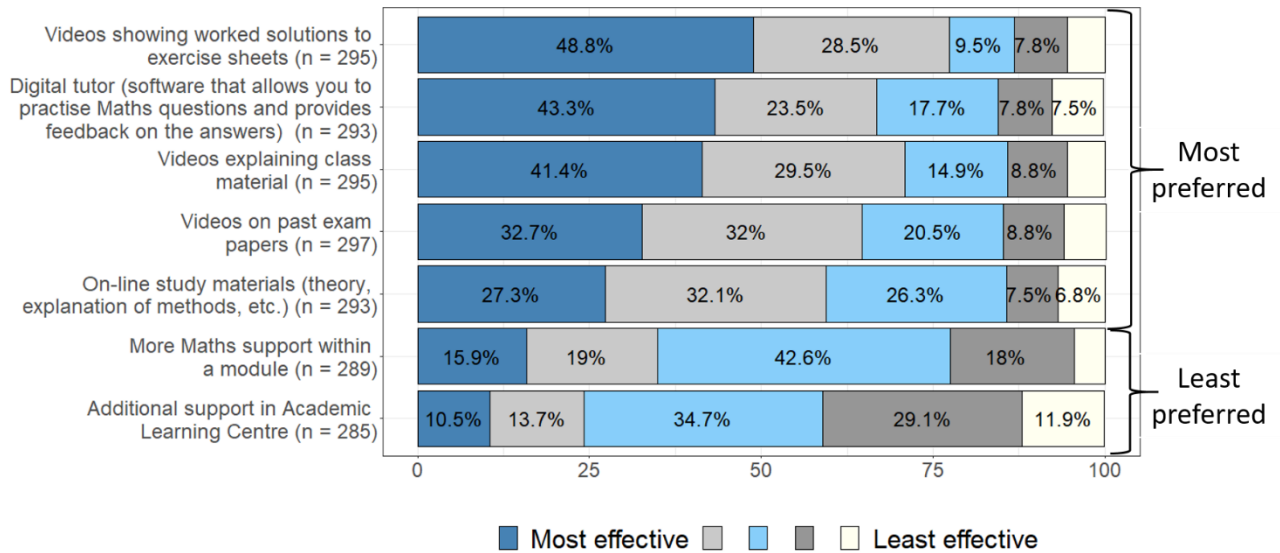


Figure 7. Digital resources rated in terms of effectiveness. Students' most preferred options were learning resources involving videos, along with a digital tutor ($p < 0.001$).

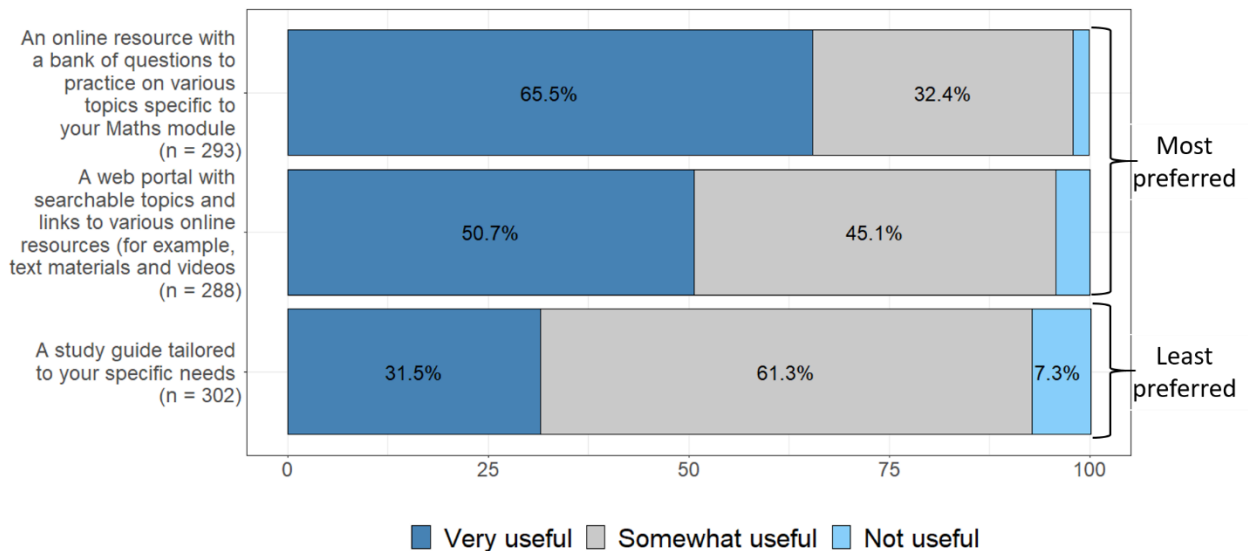


Figure 8. Digital resources rated in terms of usefulness. Students' most preferred options were resources containing a bank of questions and a web portal with searchable topics ($p < 0.001$).

4. Conclusions

Mathematics is a mandatory part of HE for many students and yet 16.1% of the surveyed students were not aware of this requirement ahead of choosing their programme of study. This points to a communication failure which needs to be addressed. Likewise, there is a need to communicate to all stakeholders (e.g., prospective students, teachers, career guidance councillors) that many students find first year mathematics at university to be less challenging than they originally expected. Furthermore, only 9.5% of those surveyed stated that mathematics is too difficult to study. This information may relieve some of the anxiety students experience regarding mathematics learning.

This survey highlights the fact that many students dedicate far less time to independent learning than recommended. This may reflect overassessment or the need to engage in part-time employment. We recommend further research into student engagement and performance which investigates these potential factors. From a teaching perspective, the preference for frequent low percentage quizzes/assessments and clearly identified weekly goals provide guidance on how we might proceed. Likewise, the students' preference for materials provided by their lecturer should be noted when creating supplementary learning resources.

While some students are comfortable with learning mathematics remotely, the majority desire that at least part of their learning is delivered in the more traditional mode of face-to-face delivery albeit supplemented with a wide variety of digital resources. The survey data indicate that students viewed videos of worked solutions and an online bank of practice questions with feedback as the most useful, effective and favoured types of digital learning supports. These results have informed the development of a suite of digital tools recently implemented and piloted at MTU (a short video demonstration is available at www.spiritmaths.com).

5. Acknowledgements

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6. Ethical approval

SPIRIT Maths project received ethical approval to carry out the study from the MTU-Cork Research Ethics Committee in April 2020.

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Appendix. Questionnaire

- Q1 Do you find maths difficult?
- Yes
 - No
- Q2 When choosing your degree course did you realise a maths module was going to be compulsory?
1. Yes
 2. No
- Q3 Before entering college did you expect maths at third level to be ...
1. Similar level to Leaving Cert maths
 2. A small bit harder than Leaving Cert maths
 3. A considerable step up from Leaving Cert maths
- Q4 After entering college I found the level of maths.
1. Similar to Leaving Cert maths
 2. Somewhat harder than Leaving Cert maths
 3. A considerable step up from Leaving Cert maths
- Q5 Which one of the following statements do you agree most with? *Choose one.*
1. I find remote learning more suited to maths than other modules.
 2. I find remote learning the same for maths as for other modules.
 3. I find remote learning less suited to maths than other modules.
- Q6 Which of the following resources do you use for your maths study?
Choose as many as apply.
1. Materials provided by the module lecturer (for example, notes, videos, links, etc.)
 2. Textbooks
 3. Internet
 4. Academic Learning Centre
 5. Maths Online
 6. Group study (for example, PALs Group study (using WhatsApp, social media, etc.)
 7. Other (please specify)
- Q7 What do you dislike most about Maths?
Choose one
1. Nothing
 2. Need to think and understand rather than learn off
 3. Need to practice to master methods etc.
 4. Too difficult
 5. Doesn't make sense
 6. Don't know why I have to do it
 7. I don't like numbers
 8. Other (please specify)
- Q8 On average, how much time per week did you spend working independently* on your maths module? *Choose one.*
- * Working independently relates to any work additional to lectures (either live and/or pre-recorded) and tutorials/labs.
- None
 - One hour a week
 - Two hours a week

- Three or more hours a week
- Q9 In relation to learning maths remotely, what would be most helpful to your learning?
Please rank in order of importance (1 is VERY important and 5 is NOT important).
- Have clear goals to be met each week (study schedule).
 - Have frequent low percentage quizzes/assessments to stay engaged.
 - A short video or a workshop on best approaches/recommendations to learning Maths.
 - An online meeting with 3rd/4th year students explaining do's and don'ts of learning Maths at MTU.
 - An opportunity to study together (online or otherwise) in small groups.
- Q10 What would be the most effective resources to help you master your maths at MTU?
Rate on the scale of 1 to 5, where 1 is not effective and 5 is very effective
- Videos on past exam papers
 - Digital tutor (software that allows you to practice maths questions and provides feedback on the answers)
 - Videos showing worked solutions to exercise sheets
 - Videos explaining class material
 - More maths support within a module
 - Additional support tutorials in Academic Learning Centre
 - On-line study materials (theory, explanation of methods etc.)
- Q11 How would you rate the following digital resources in terms of their usefulness to you?
Each item rated on the scale: not useful, somewhat useful, very useful.
- A study guide tailored to your specific needs
 - An online resource with banks of questions to practice on various topics specific to your maths module
 - A MTU web portal with searchable topics and links to various online resources such as text materials and videos