European Journal of Science and Mathematics Education, 2023, **11**(1), 146-166
ISSN: 2301-251X (Online)
OPEN ACCESS
Research Article

Is motivation the key? Factors impacting performance in first year service mathematics modules

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Citation: Lishchynska, M., Palmer, C., Lacey, S., & O'Connor, D. (2023). Is motivation the key? Factors impacting performance in first year service mathematics modules. *European Journal of Science and Mathematics Education, 11*(1), 146-166. https://doi.org/10.30935/scimath/12529

ARTICLE INFO

Received: 4 Jul 2022
Accepted: 3 Oct 2022

ABSTRACT

Taught to non-mathematics undergraduates (business, science, engineering, and other technical programs), service mathematics is commonly associated with poor exam performance and low skill/knowledge attainment. The primary objective of the present study was to examine the range of factors thought to impact mathematics performance in higher education and establish which of the variables (i.e., motivation, mathematical background, growth mindset, preference for understanding, and time invested in independent learning) are of value in explaining the differences in students' performance in service mathematics modules. A survey of first year business and engineering students who sat service mathematics modules was conducted. A multivariable proportional odds regression model was applied to detect and evaluate the association of each explanatory variable with mathematics performance. Motivation was found to be an important contributor to mathematics performance in first year service modules ($p \leq 0.05$), second only to mathematical background ($p<0.001$). The work also investigated trends in motivation for studying mathematics across different student cohorts, where a significant difference in motivation was found between business and engineering students ($p<0.001$). The findings are discussed in terms of implications for learners and educators and should be of interest to fellow academics, those tasked with improving retention rates and policy makers.

Keywords: service mathematics, mathematics performance, mathematics achievement, motivation, mathematical background, learning strategies

INTRODUCTION

Munster Technological University (MTU) is a multi-campus technological university based in the South-West region of Ireland with a student body of 18,000. In common with many other departments of mathematics at higher education institutes (HEIs), the Department of Mathematics at MTU, does not offer an undergraduate mathematics or statistics degree program[1]. However, in a typical year in excess of 75% of undergraduate students take at least one mathematics/statistics (henceforth mathematics) module as part of

[1] Department of Mathematics offers a number of higher diploma and master programs in data science and analytics.

their studies. These modules are delivered across a very wide range of programs and are considered service modules in the sense that home departments service in mathematics lecturers to deliver these modules.

Service mathematics may be defined as “mathematics as taught to non-mathematics specialists and students studying science, engineering, and other technical subjects” (Artigue et al., 2007, p. 1031). Service mathematics modules are typically designed with the goal of a student acquiring a solid understanding of the concepts/methods of mathematics while developing analytical skills that can be used in other disciplines, and ultimately applied in their professional career. While the resultant knowledge and skill attainment are not straightforward to evaluate, module grades are a practical means of assessing one’s knowledge attainment and thus serve as a measure of performance/achievement in a subject. Based on this metric, many students appear to struggle with service mathematics (Alibraheim, 2021; Faulkner et al., 2014; Harris & Pampaka, 2016; Liston & O’Donoghue, 2009; Rylands & Coady, 2009). Attrition rates of over 50%, attributed mainly to difficulties encountered in the mathematical content of engineering programs, have been reported (Bischof et al., 2015). The authors’ experience and module grades in some degree programs suggest that MTU students struggle in a similar manner. These difficulties may be explained by students’ insufficient mathematical background upon entry to higher education (HE) (Alyahyan & Dustegor, 2020), inadequate learning strategies (Gynnild et al., 2005; Murayama et al., 2013; Nabizadeh et al., 2019), non-domain specific factors such as academic ambition and academic resilience (Cassidy, 2016; Jerrim et al., 2020), peer influence, personality traits, environment (Golsteyn et al., 2021; Kappe & van der Flier, 2012), and (crucially) poor *motivation* (Brandenberger et al., 2018; Kaldo & Reiska, 2012; Tahar et al., 2010). Students’ motivation in particular seems to decline with the transition from post-primary to HE, which has a follow-on effect on performance (Brahm et al., 2017). Moreover, first year undergraduates’ lack of HE experiences and knowledge of the role of mathematics in their chosen degree program (Harris et al., 2014) further contribute to low engagement and poor mathematics achievement.

All of the above makes motivating students a demanding task for lecturers of service mathematics modules. Moreover, the emphasis on motivation in general becomes ever more important with the advent of online/remote education. A broad (non-specific to mathematics) university-wide survey of MTU students conducted in May 2021 highlighted that 65.7% of respondents (n=1,678) found motivation and engagement as some of the main challenges experienced in remote learning (Ó Súilleabháin et al., 2022). In a subsequent survey of MTU lecturers (December 2021) 57.6% of respondents (n=283) also quoted motivation and engagement as the top challenge in remote teaching. Motivation is arguably one of the key factors impacting the learning process and performance in service mathematics.

This paper investigates the impact of the motivational component relative to the other factors determining mathematics performance, as measured by exam grade. A survey of first year business and engineering students who sat service mathematics modules in MTU was conducted. A multivariable proportional odds regression model was then applied to answer a number of specific research questions which are detailed at the end of the following section. The results should be of interest to fellow academics, those tasked with improving retention rates and, policy makers.

BACKGROUND

Previous Research

In recent decades multiple research efforts have focused on issues affecting the learning process, and achievement, in mathematics. Such interest affirms that the problems are, as follows:

1. widespread, involving all stages of education, and
2. complex and multifaceted (Faulkner et al., 2014; Liston & O’Donoghue, 2010; Ryan et al., 2021).

We now present a review of the factors considered to impact on learning and performance in mathematics.

The ‘mathematics problem’ and transition to university

Starting at an early point in a students’ academic journey, Roykenes (2016) examines the evolution of students’ relationship with mathematics through primary and post-primary school and emphasizes the importance of previous experiences, and subsequent mathematics self-concept, in learning mathematics. Liston and O'Donoghue (2010) further highlight the fact that the 'mathematics problem', which labels mathematical issues surrounding the transition from post-primary school to HE, does not start at university but is exacerbated during the transition. The authors undertook both quantitative (Liston & O'Donoghue, 2009) and qualitative (Liston & O'Donoghue, 2010) studies, which established a number of affective factors serving as barriers to students' engagement, and subsequently performance, in first-year service mathematics modules. These include difficulty in identifying how mathematics is valuable in everyday life and careers; a belief among some of the students that mathematics should be solved routinely in a minimal amount of time; a lack of confidence when studying unfamiliar mathematics; and a reliance on procedures and surface-type approaches to learning such as repetition of questions and identification of trends in exam papers. Harris and Pampaka (2016) investigated students' problems with service mathematics lectures during their first year at university, looking specifically at students taking mathematically demanding courses, e.g., physics and engineering. Their analysis of learners' perceptions of transition to university shows the more formal format of a lecture, and students' lack of experience of the approach to mathematics in university are some of the factors impacting achievement. Symonds et al. (2010) established that the lack of mathematical preparedness, as well as the lack of awareness of the expectations of university, affect students' mathematics confidence and consequently hamper the transition. Harris et al. (2014) studied the problems encountered by first-year engineering students due to the unexpected extent of mathematics within their programs and highlighted the impact of the different values that students and lecturers ascribed to mathematical knowledge. Their findings challenge some of the established practices of teaching non-contextualized mathematics in (foundation) first-year service mathematics modules. Understanding the value of mathematics remains a central problem in service mathematics, affecting engagement and ultimately performance.

Dispositions towards mathematics and role of motivation

Another avenue of research focuses on students' attitudes towards mathematics and subsequent effects on performance. Campbell et al. (2019) explore the potential impact of a growth mindset on STEM achievement and propose a framework showing activities, based on different learning theories, that may encourage growth mindsets or (unintentionally) encourage fixed mindsets and hence guide the development of growth mindset interventions. Growth mindset is known to predispose one towards learning goals and to boost mathematics achievement, while fixed mindset hampers student progress and achievement (Boaler, 2013; Dweck, 2008). Harris and Pampaka (2016) discuss, amongst other topics, the phenomenon of surface (shallow) learning versus deep learning. Students' preference for one or the other is another factor influencing quality of learning and hence performance (Gynnild et al., 2005; Trigwell et al., 2013).

A growing body of research in mathematics education and education psychology focuses on students' affective domain, and specifically motivation, with a goal of understanding students' learning behavior, and the use of that acumen to intervene and improve the teaching/learning process. In educational psychology, motivation is considered one of the most essential foundations for students' academic development (Steinmayr & Spinath, 2009). Moreover, it is also found to predict students' career decidedness and decision to drop-out after the first year in HE (Bargmann et al., 2021). Motivation is generally recognized as a complex and multi-dimensional psychological phenomenon with multiple components, such as motivational beliefs, task values, goals, and achievement motives (Rowell & Hong, 2013; Steinmayr et al., 2019). Pantziara and Philippou (2015) investigate the effect of motivation and other affective constructs on the mathematics performance of sixth grade students. Specifically, the work reveals that students' performance and their interest in mathematics were influenced by fear of failure, self-efficacy beliefs, and achievement goals. Brandenberger et al. (2018) examine the role of self-determined motivation in mathematics with regard to achievement and highlight fostering student motivation as an important challenge. Kriegbaum et al. (2018) analyze the predictive power of intelligence and motivation for general school achievement. Though both intelligence and motivation were found to be strong predictors of achievement, the study established that motivation predicts school achievement *above* and *beyond* intelligence. "*This means that out of two equally intelligent students, the one who is more motivated will have higher achievement*" (Kriegbaum et al., 2018, p. 144). Furthermore, Steinmayr et al. (2019) demonstrated the relative importance of motivational constructs (i.e.,

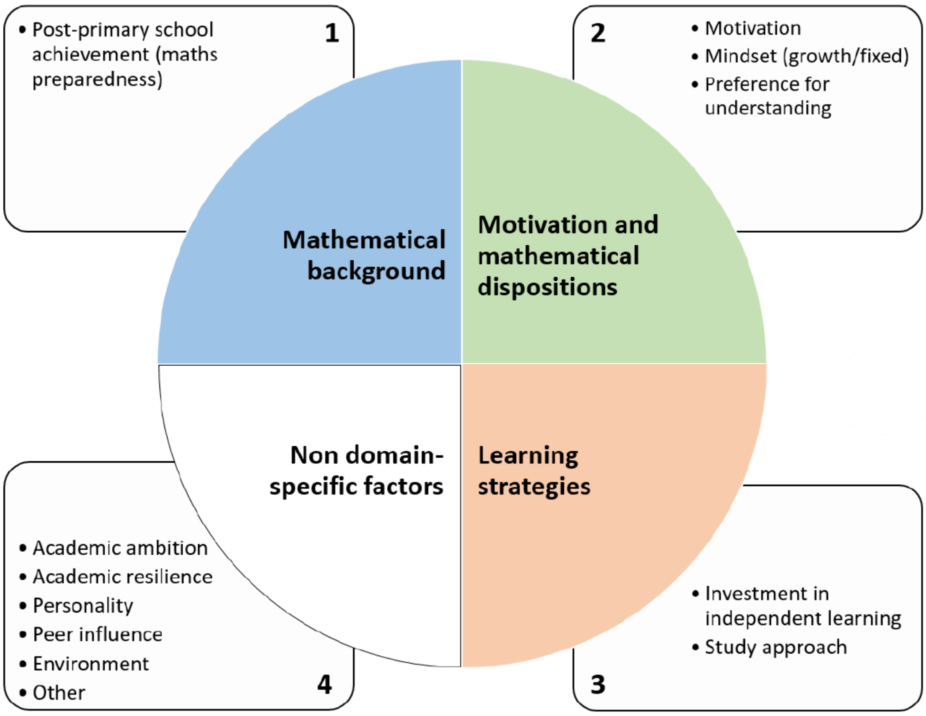

Figure 1. Authors' schematic view of factors impacting performance in service mathematics

ability self-concepts, task values, learning goals, and achievement motives) for school grades *above and beyond* differences in students' *intelligence* and *prior grades*.

Factors That Determine Performance in Service Mathematics

It is evident from the above literature that this research field is rich and varied. At the same time, issues persist, and interest in shedding light on some of these remains acute and current. From a practitioners' point of view, the argument for examining the role of motivation relative to other factors in the context of mathematics performance at university level continues to be compelling.

Based on an analysis of previous research and our own teaching observations, we now organize the factors thought to impact/determine the performance in *service mathematics in HE* into four distinct groups (**Figure 1**), as follows:

1. mathematical background (preparedness),
2. mathematical dispositions,
3. learning strategies, and
4. non-domain-specific factors (not specifically relating to learning mathematics).

Mathematical background

Amongst many factors necessary for a successful transition into university, one stands out as fundamental to the learning of mathematics – *mathematical background* (pre-university mathematics achievement or mathematical preparedness). When one does not possess background knowledge and skills necessary to function in a mathematics class in university, there is no 'fertile soil' for the seeds of interest for the subject to be sowed and for new knowledge to build on. While there is a common view that post-primary school grades are an important factor in progression through university (Alyahyan & Dustegor, 2020), it is still useful to investigate the role of mathematical background in comparison to other aspects that may also have a significant, impact on mathematics performance in HE.

Motivation and mathematical dispositions

Another group of factors addressed here is the role of students' perceptions and dispositions towards mathematics: *motivation*, *mindset* (fixed versus growth), and *preference for understanding*.

When assessing motivation for learning mathematics through the lens of expectancy-value theory (Vroom, 1964; Wigfield & Eccles, 2000) it is important to consider the value a student places on the outcome of their learning. Psychologists refer to this as valence. For the valence to be positive, the person must prefer attaining the outcome to not attaining it. Of the four categories associated with the individual's motivational values (i.e., intrinsic, attainment, utility, and cost), the utility value component, as "*the perceived usefulness of knowing mathematics for short- and long-range goals*" (Tossavainen et al., 2021), seems particularly relevant to service mathematics. While acknowledging that educational psychology recognizes a wider motivational framework, the present work focuses on the utility value component of motivation (thereafter *motivation*) as a factor potentially impacting service mathematics performance in HE.

A growth *mindset* in this context indicates a person's belief they can learn and get better at mathematics if they work hard, whereas a fixed mindset relates to accepting that mathematical ability is innate and something that cannot be changed (Boaler, 2015). A strong belief in one's capabilities to succeed in mathematics is critical to learning. When not addressed, fixed mindset can pose a serious obstacle to learning (Boaler, 2013).

Curiosity about a subject and hence *preference for understanding* and making sense of the subject differentiate someone who is focused on conceptual understanding from a surface-learner who is not interested in knowing why 'this stuff works' (Herrmann et al., 2017). The latter attitude does not lead to high quality learning (Gynnild et al., 2005).

Learning strategies

Students' approaches to learning can be a significant differentiating factor impacting the quality of learning and subsequently exam performance (Gynnild et al., 2005; Murayama et al., 2013; Nabizadeh et al., 2019). Both, *study habits* (i.e., working regularly versus just before the exam) and *time invested in independent learning* (outside of classroom) may contribute to performance and are worth considering in this context.

Non-domain specific factors

It is also necessary to acknowledge the factors such as *academic ambition* and *academic resilience,* the presence or absence of which can significantly affect one's personal goals, perseverance, and commitment to learning, and subsequently impact achievement (Cassidy, 2016; Jerrim et al., 2020). *Academic grit*, as a characteristic encompassing 'consistency of interests and perseverance of effort', has also been shown to affect achievement (Kaya & Karakoc, 2022). *Peer influence*, *personality traits*, *environment* (e.g., learning conditions, class dynamics, timetable), and possibly other non-domain-specific factors (i.e., not specific to learning of mathematics) can all potentially play a role in performance (Golsteyn et al., 2021; Kappe & van der Flier, 2012).

Steinmayr and Spinath (2009) concluded that when predicting domain-specific achievement (e.g., mathematics performance), domain-specific motivational constructs are more useful predictors than general constructs. Furthermore, many of the non-domain-specific factors are challenging to measure and quantify, with some approaches involving use of psychometric scales with up to 30 items (Cassidy, 2016; Hirschi & Spurk, 2021; Rudd et al., 2021), which is not straightforward or practical to implement in a university setting. Therefore, the non- domain-specific group of factors are considered outside the scope of this study.

Present Study and Research Questions

While the majority of research considering motivation as a predictor of performance was conducted in school settings and mostly concerned general academic achievement (Brandenberger et al., 2018; Kriegbaum et al., 2018; Pantziara & Philippou, 2015; Skilling et al., 2020; Steinmayr et al., 2019), the problem of students' varied performance in service mathematics at university, and specifically in relation to the motivational factor, deserves detailed analysis. Moreover, it is commonly thought that mathematical background (pre-university, school achievement) is the best predictor of mathematics performance at university, and that, in general, prior academic achievement is the best predictor of academic success in HE (Alyahyan & Dustegor, 2020; Faulkner et al., 2014; Gynnild et al., 2005). However, it is reasonable to expect that motivation is more important for academic achievement in HE where restricted entry requirements are applied hence students are somewhat pre-selected based on their mathematics background.

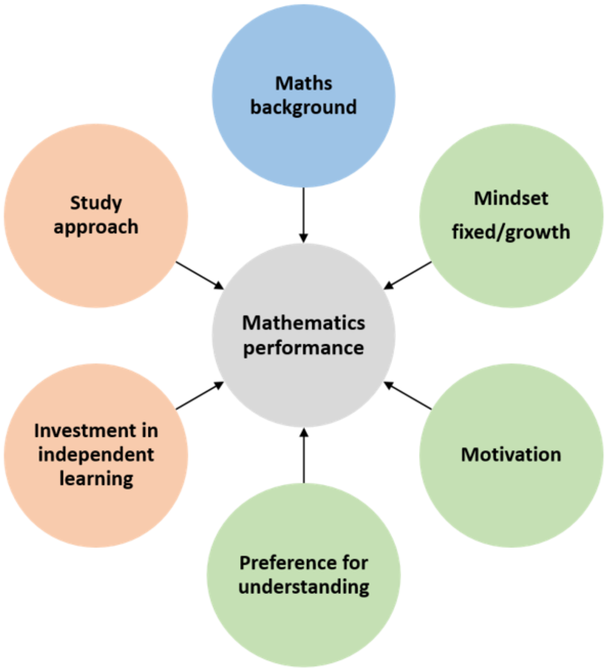

Figure 2. Causal structure investigated in this work

This work aims to explore the hypothesis that *motivation* may have a bigger impact than *mathematical background* in determining mathematical performance of non-specialist undergraduate students. To investigate further, this contribution looks specifically at the impact of domain-specific factors (shown in **Figure 1**) on first year mathematics performance in service modules. The causal structure under investigation is shown in **Figure 2**, however, as there may be possible interactions/interdependencies between the explanatory variables, these are also investigated.

Specific research questions (RQs) posed in this work are, as follows:

1. **RQ1.** Which of the explanatory variables (motivation, mathematics background, mindset, preference for understanding, investment in independent learning and study approach) are of value in explaining mathematics performance (Sem1/Y1 mathematics modules)?
2. **RQ2.** Is motivation a stronger predictor/indicator of performance in service-mathematics modules than mathematics background?
3. **RQ3**. Are there relationships between the explanatory variables?
4. **RQ4.** Is motivation similar across different student cohorts (by degree program)?

METHODOLOGY

Participants

This study focused on two of the largest first-year cohorts at MTU (Cork campuses), business and engineering students. All students in these cohorts were contacted by email and invited to participate in the study by taking an online survey, with a reminder email sent a week later. The survey was issued twice, over two-week periods, in June 2020 (student intake 2019) and in February 2021 (student intake 2020). Comparison of the results from the two instances of the survey revealed no statistically significant difference ($p>0.05$), hence the data from the two surveys were combined for a complete analysis. In total, 1,633 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 breakdown of respondents is collated in **Table 1**. Results presented later indicate the total number of responses (n) to a given question.

Table 1. Student cohorts that completed the survey

Intake	Program 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%)

Data Collection

A survey was purpose-designed by the authors and fine-tuned based on the feedback from piloting and discussions with other mathematics lecturers at the University. The survey focused on students' mathematical dispositions and learning strategies. Data on participants' mathematics achievement in post-primary school exit exam (Leaving Certificate[2]) and grade in the semester one of first-year mathematics module were also collected via the survey. The former was a measurement of *mathematical background* (preparedness) and the latter was a measure of *mathematics performance*. The survey questions were closed type. The anonymous online survey was set up and administered in MS Forms. Survey questions pertinent to this study and the corresponding factors they aimed to gauge are shown in **Table A1** (**Appendix A**).

Data Analysis

The outcome variable, *mathematics performance*, is an ordinal variable with five categories corresponding to the grade obtained in a respondent's semester one mathematics module. *Mathematics performance* was analyzed with a multivariable proportional odds regression model, with an odds ratio (OR) greater than 1.0 indicating that a higher grade was associated with the corresponding explanatory variable. OR statistics are complemented with supporting confidence intervals (CIs). Five explanatory variables were included in the model: *motivation*, *mindset*, *preference for understanding*, *investment in independent learning*, and *leaving certificate points* (mathematical background). One of the six candidate explanatory variables (*study approach*, **Figure 2**) was eliminated prior to the analysis based on sample size considerations.

Statistical analyses were performed using RStudio 1.1.456 for Windows (R Core Team, 2021). Descriptive statistics were used to describe the characteristics of students in relation to grades, perceptions, motivations, and background. The distribution of the *Leaving Certificate points* for the respondents, treated as a continuous variable, is summarized graphically and categorical variables are presented as frequencies and percentages. Before fitting the multivariable proportional odds regression model, relationships between the explanatory variables were explored using Cramer's V (negligible: $V<0.1$, weak: $0.1\leq V<0.3$, moderate: $0.3\leq V<0.5$, strong: $V\geq 0.5$), (Cohen, 1988) for the categorical variables and using t-tests and ANOVA for *Leaving Certificate points* and the categorical variables.

The assumption of proportional odds was assessed using the Brant test (Brant, 1990). Chi-squared tests were used to assess whether *motivation* differed between business and engineering students. This was followed by post-hoc binomial tests to determine how *motivation* differed within business students and within engineering students. Multiple comparisons of responses were controlled for using the Bonferroni correction method. All statistical test results were interpreted using a 5% level of significance.

Ethical Considerations

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

RESULTS

In this section, the results of the study are presented. First, a summary of survey responses and analysis of some general trends are given. Next, the results of multivariable proportional odds regression model are

[2] The Leaving Certificate is the final exam of the Irish post-primary school system and the university matriculation examination in Ireland. Admission to universities is by the points achieved in the Leaving Certificate. Points are awarded on a 0-100 scale for each subject, mathematics being a mandatory exam (State Examinations Commission, 2022).

Table 2. Breakdown of first year grades in mathematics

Grade category	Frequency	Relative frequency
<40	30	9.8%
40-49	41	13.4%
50-59	63	20.7%
60-79	105	34.4%
80-100	64	21.0%
Did not complete module	2	0.7%
N/A	5	
Total	310	100.0%

Table 3. Breakdown of responses to survey questions

Categorical variable	Response	Frequency	Relative frequency
Motivation (n=310)	I just want to pass the module	105	33.9%
	I want to be able to apply maths methods in my other modules	82	26.5%
	I want to get better at maths	69	22.3%
	I want to develop a sufficient maths background to get a job with an analytical component	40	12.9%
	Other	14	4.5%
Mindset (n=310)	Fixed	102	32.9%
	Growth	208	67.1%
Preference for understanding (n=310)	Yes	179	57.7%
	No	131	42.3%
Investment in independent learning (n=308)	None	32	10.4%
	One hour per week	105	34.1%
	Two hours per week	121	39.3%
	Three or more hours per week	50	16.2%
Study approach (n=224)	I review material at least 4 days a week.	26	11.6%
	I review material at least 2 days a week.	71	31.7%
	I dedicate a day to catch-up per week.	66	29.5%
	I review relevant material only before an assessment.	58	25.9%
	I do not review material at all	3	1.3%

described. We then examine the relationships between the explanatory variables. Data on *motivation* across different student cohorts is also presented.

Preliminary Results and Descriptive Statistics

Mathematics performance

Data on students' performance in their first-year semester one mathematics module are presented in Table 2. All grade categories are represented in the sample. We note that the proportion of respondents who failed (grade below 40) is somewhat smaller than average but this is not unexpected as these are often the students who do not engage well with the modules and thus are harder to connect to and entice to participate in a survey.

Motivation and mathematical dispositions

Motivation (Q1): A detailed breakdown of responses to the survey question on utility value motivation is presented in Table 3, showing that 33.9% of respondents are only focused on passing the module.

The responses in the 'other' category included 'enjoying maths' (n=7), "*like doing my best at everything logical*", "*want a broad knowledge and be able to apply skills in future jobs*", and "*maintain a high average grade across all my modules*". Since there were so few unrelated observations in the 'Other' category, this was excluded from further analysis.

Mindset (Q2): In terms of mindset, 67.1% of survey respondents were found to have a growth mindset and 32.9% - fixed mindset (n=310).

Preference for understanding (Q3): The breakdown between the respondents choosing preference for understanding the material and those that do not is 57.7% and 42.3%, respectively (n=310).

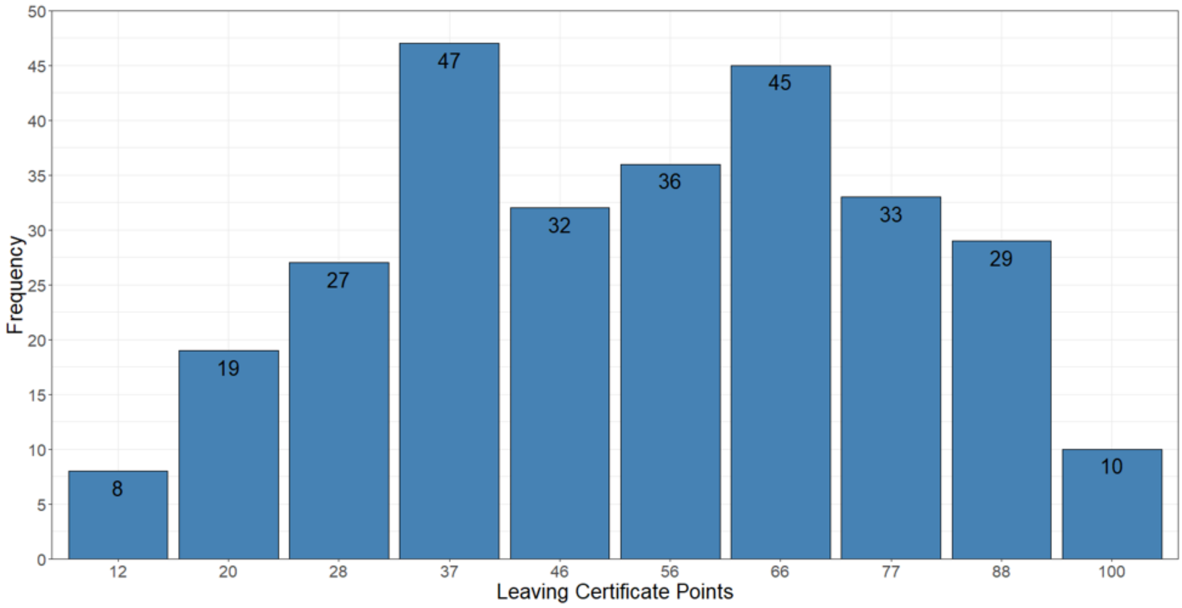

Figure 3. Mathematical background: Breakdown of Leaving Certificate points in mathematics (n=286)

Learning strategies

Investment in independent learning (Q4): The survey found that a large proportion of first-year students (44.5% of respondents) spend one hour or less per week learning mathematics independently, which is well below the recommended level. Notably, 29.2% of these respondents failed their mathematics module or achieved a low grade (below 50).

Study approach (Q5): Over 27.2% of respondents do not exercise a regular approach to study and either do not review the material at all or review it only before an exam. A close examination of the latter group reveals though that only 23.0% of these respondents (which constitutes 6.2% of all participants) show low performance in mathematics (failed the module or achieved a grade below 50).

The variable *study approach* had the lowest response rate (n=224) and since the variable *Investment in independent learning* provides a measure of a student's learning strategy it was decided to exclude the variable *study approach* from the multivariable proportional odds regression model.

Mathematical background

Figure 3 presents a breakdown of mathematical background (*Leaving Certificate points* in mathematics) of survey participants that are included in the multivariable proportional odds regression model. The chart displays a wide variation in mathematical background between MTU entrants, who seemingly come from all population cohorts.

Association of Explanatory Variables with *Mathematics Performance* (RQ1 and RQ2)

Table 4 presents the results of the multivariable proportional odds regression model for *mathematics performance*. The model shows that students who were motivated to learn mathematics beyond passing the module were more likely to achieve a higher grade than students who just wanted to pass the module. In particular, for students who wanted to get better at mathematics (OR, 2.04 [95% CI, 1.12-3.74]), for students who wanted to apply mathematics methods in other modules (OR, 2.46 [95% CI, 1.34-4.55]) and for students who wanted "*to develop a sufficient maths background to get a job with an analytical component*" (OR, 3.61 [95% CI, 1.71-7.73]). As expected, students with high Leaving Certificate points were more likely to achieve a higher grade in their semester one mathematics exams than students with low Leaving Certificate points (OR, 1.04 [95% CI, 1.03, 1.05]). There was insufficient evidence to determine the effect of student *mindset*, *preference for understanding*, and *investment in independent learning* on *mathematical performance*. Likelihood ratio tests indicated that the variable *Leaving Certificate points* explained the largest amount of variation in *mathematics performance* followed by *motivation*.

Table 4. Summary of the multivariable proportional odds regression model for mathematics performance (Nagelkerke R^2=31.5%)

Variables	Odds ratio	95% confidence interval		p-value
		Lower	Upper	
Motivation (*I just want to pass the module* as reference point)				
I want to get better at maths	2.04	1.12	3.74	0.020
I want to be able to apply maths methods in my other modules	2.46	1.34	4.55	0.004
I want to develop a sufficient maths background to get a job with an analytical component	3.61	1.71	7.73	<0.001
Mindset (*fixed* as reference point)				
Growth	1.29	0.80	2.08	0.297
Preference for understanding (*no* as reference point)				
Yes	0.86	0.55	1.34	0.492
Investment in independent learning (*none* as reference point)				
One hour per week	0.55	0.26	1.17	0.121
Two hours per week	1.01	0.47	2.14	0.967
At least three hours per week	0.98	0.40	2.42	0.985
Leaving Certificate points	1.04	1.03	1.05	<0.001

Table 5. Strength of association between explanatory variables (n=286)

Explanatory variables	Mindset	Preference	Investment
Motivation	Weak (*V*=0.24)	Weak (*V*=0.23)	Weak (*V*=0.15)
Mindset		Negligible (*V*=0.01)	Negligible (*V*=0.08)
Preference			Weak (*V*=0.15)

Table 6. Relationships between Leaving Certificate points and the categorical explanatory variables (n=286)

Motivation	MLCP	Mindset	MLCP	PforU	MLCP	IIL	MLCP
I just want to pass the module.	44.7[a]	Fixed	50.8[a]	No	52.4[b]	None	59.5[a]
I want to get better at maths.	52.8[a]	Growth	55.9[a]	Yes	56.8[b]	One hour per week	55.0[ab]
... apply maths methods in my other modules.	62.8[b]					Two hours per week	55.8[a]
... to get a job with an analytical component.	64.0[b]					At least 3 hours per week	44.9[b]

Note. For the variables with more than two levels, mean values sharing a letter in their superscript are not significantly different at the 5% level of significance according to a post-hoc comparisons using the Bonferonni correction method; For variables with two levels, mean values sharing a letter in the in their superscript are not significantly different at the 5% level of significance according to Welch's t-test; MLCP: Mean Leaving Certificate points; PforU: Preference for understanding; & IIL: Investment in independent learning

Relationships Between the Explanatory Variables (RQ3)

The results of Cramer's V did not establish any strong associations between the categorical explanatory variables included in the model (see **Table 5**). However, a one-way ANOVA followed by post-hoc comparisons using the Bonferroni correction method for multiple comparisons indicated that, for the variable *motivation*, students who wanted to apply mathematics methods in other modules or wanted to develop a sufficient mathematics background to get a job with an analytical component had higher Leaving Certificate points than those who just wanted to pass the module or wanted "*to get better at maths*" (see **Table 6**).

For the variable *investment in independent learning*, post-hoc comparisons indicated that those students who did three hours or more independent study had significantly lower Leaving Certificate points than students who did no independent study or between one and two hours per week (**Table 6**). To examine the relationships between explanatory variable *Leaving Certificate point*s and binary variables, *mindset* and *preference for understanding*, Welch's t-test was performed. There was insufficient evidence at the 5% level of significance to suggest Leaving Certificate points were different for students with a fixed mindset compared to a growth mindset or for students who expressed a preference for understanding and those who did not.

Motivation Trends in Different Student Cohorts (RQ4)

Results from the chi-squared test showed significant difference between the business and engineering student cohorts when asked "What is your main motivation for doing well in your maths modules in MTU?" ($p<0.001$, see **Figure 4**). The follow-up binomial tests (controlled for multiple comparisons using the

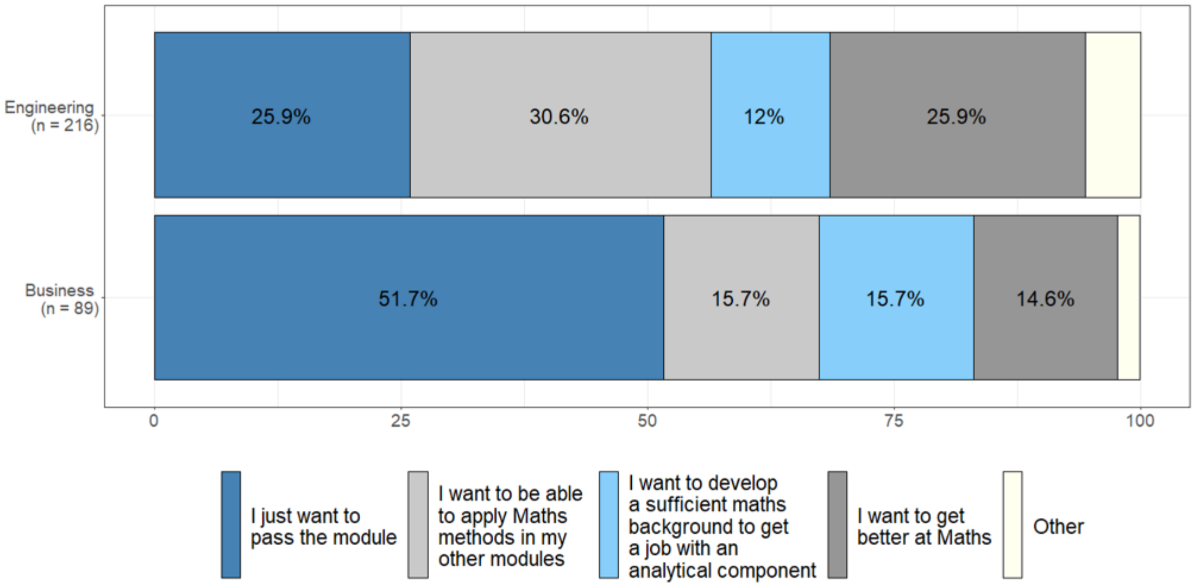

Figure 4. Trends in relation to the motivation within student cohorts (n=305). Chi-squared test showed significant difference between the business and engineering student cohorts when asked "What is your main motivation for doing well in your maths modules in MTU?" (p<0.001)

Bonferroni correction method) investigating the difference in responses within cohorts, found for the majority of business students (51.7%) just passing the module is the primary aim, with 15.7% seeing their module as a foundation element for other modules. This contrasts with the engineering students where almost 30.6% see their module as a foundation for future modules, and only 25.9% are just motivated to pass their module. Interestingly, a greater proportion of business students see their module as an opportunity to develop a sufficient maths background to gain employment in a role with an analytical component (15.7% versus 12.0%).

DISCUSSION

This study explored the factors that can potentially impact student performance in service-mathematics modules using a quantitative approach. There were four main findings:

1. *Motivation* and *Leaving Certificate points* (mathematical background) were both found to be associated with *Mathematics performance* (semester one mathematics grade).
2. The variable *Leaving Certificate points* was found to have the strongest association with *mathematics performance* amongst all considered factors, while *motivation* is the second strongest contributor to explaining *mathematics performance*.
3. There was an association between *motivation* and *Leaving Certificate points* and between *investment in independent learning* and *Leaving Certificate points* but there were no strong associations between the other explanatory variables.
4. *Motivation* differed between business and engineering cohorts.

In addition to these main findings, descriptive statistics summarizing student responses were presented. In the following section we discuss each main finding in turn in the context of previous work and consider implications for future interventions.

Association of Explanatory Variables with the *Mathematics Performance* (RQ1)

Mathematical background

It is no surprise that mathematical background played an important role in determining mathematics performance as this finding has been replicated in previous studies (Alyahyan & Dustegor, 2020; Faulkner et al., 2014; Gynnild et al., 2005). The mathematics taught in first year at university builds on knowledge and skills taught throughout an individual's schooling and it follows that without this knowledge understanding of follow on topics is difficult. In addition, students who perform well prior to university may do so as they possess many of the other traits that are potentially associated with mathematical performance.

Motivation and mathematical dispositions

The finding that *motivation* has a strong association with *mathematics performance* (2.04≤OR≤3.61), second only to *mathematical background*, is significant and encouraging. It suggests that matters related to learning mathematics could be positively influenced with interventions that target student motivation. While motivating non-specialist students to study mathematics is not a trivial task, effective steps can be taken at various levels of the university. As a starting point, creating an 'early warning' system which would allow early intervention with students who are 'low on motivation spectrum', and thus may be most in need of support in mathematics, might be worth considering.

While some association between *mindset* and *mathematics performance* was observed, our results did not produce sufficient evidence to support the significance of the effect. At first glance, this is surprising and appears to be in conflict with the growth mindset school of thought (Boaler, 2015; Dweck, 2008). However, the research has shown that mindsets can predict mathematics (and science) achievement *over time*. Perhaps, the observations in this work, taken at just one point in time, would not have been sufficient to gauge the effect. A larger sample in future studies may also allow for detecting the effect that is possibly present but is not as strong as the others. It is encouraging to find that a large proportion of students have a growth mindset and hence believe in their ability to learn and improve at mathematics. Still, there is a need to work with students who have a fixed mindset (nearly a third of respondents) in order to affect the attitude, which is linked to issues with confidence, effort and learning behavior. Boaler (2015) provides plenty of advice and measures on how to "unleash" students' mathematical potential and self-belief with creative teaching approaches and inspiring messages to students, e.g., 'everyone can learn maths to the highest levels', 'mistakes are valuable', 'questions are really important', 'depth is much more important than speed' and many more.

No significant association between *preference for understanding* and *mathematics performance* was found in this work. Numerous studies have investigated the relationship between learning approaches and academic achievement with mixed results. Gijbels et al. (2005) did not find evidence for a relationship between learning approaches and academic achievement for first year psychology students, but this differs to the findings of Gynnild et al. (2005) where undergraduate engineering students were surveyed on their attitudes and approaches to learning mathematics and the results were examined in the context of their grades in a first year calculus course. A descriptive analysis showed that students who adopted a passive approach to learning, focusing on memorizing rather than understanding, tended to have lower grades than students' intent on in-depth understanding of phenomena and principles. Studies by Herrmann et al. (2017), Trigwell et al. (2013) (including a variety of degree programs and examinations), and Zakariya (2021) (engineering students taking a mathematics examination) found a significant negative effect of the surface approach to learning on academic achievement, but, in contrast, no significant effect of the deep approach to learning was established. These 'inconsistencies' are intriguing and call for further, more detailed, investigation.

The absence of a strong correlation between *preference for understanding* and *mathematics performance* may be partially explained by the difficulty to accurately measure the attribute. Perhaps, a scale of several more nuanced questions following Biggs et al. (2001) could be implemented to better gauge the association. The study by Herrmann et al. (2017) noted "*that assessment systems in HE might not always reward high quality learning outcomes*", which is an important consideration when using examination grades as a measure of student understanding. One potential strategy to affect this is structuring assessments in such a way as to encourage and reward deep understanding. For example, in an exam, there should be a fair balance of tasks requiring only procedural work and those testing the conceptual understanding. The finding that 42.3% of respondents are not keen on understanding the material suggests that the surface approach to learning is widespread and if it does result in poor knowledge retention then it is an issue that needs to be addressed.

Learning strategies

The analysis did not indicate that there was an association between *investment in independent learning* and *mathematics performance*. Although somewhat unintuitive, this result is consistent with prior studies that did not detect a reliable relationship between time spent studying and academic performance in HE (Plant et al., 2005; Richardson et al., 2012; Schuman et al., 1985). It is proposed the quantity of study is only associated with academic performance when the quality of study is considered (Plant et al., 2005). Plant et al. measured the quality of study by assessing students' participation in deliberate practice and self-regulated learning. They found that students with higher grades tended to 'engage in deliberate studying, take active steps to ensure their practice time will be of high quality and encourage the improvement of performance', 'study alone in an environment unlikely to contain distracters' and that 'study is typically carefully scheduled'. Following from this, initiatives directed at helping incoming students develop good study skills and a working approach to learning in HE environment may include information supports as well as personalized coaching (West-Burnham & Coates, 2005). To support the former, a 'Stay on top of your Maths' resource (Stay On Top of Your Maths, 2019), which provides tips on good study habits specific to mathematics in addition to other topics promoting the role/value of mathematics, was developed at MTU.

In addition to the factors discussed, we note that it is possible the absence of relationship between *investment in independent learning* and *mathematics performance* in the present study reflects the nature of the material in a first-year semester one module at MTU which focuses on consolidation of prior learning to ensure that all participants have the required knowledge regardless of their entry route. This suggestion is supported by the finding that students with lower Leaving Certificate points tended to study for longer than students with high Leaving Certificate points (**Table 6**). It is likely that students with higher Leaving Certificate points already had good working knowledge of the module material and did not need to spend as long studying.

Motivation – Second Strongest Contributor to *Mathematics Performance* (RQ2)

The authors were interested to see whether *motivation* is more important than *Mathematical background* for academic achievement in HE, where restricted entry requirements are applied and hence students are somewhat pre-selected based on their mathematics background, however, the analysis indicated that mathematics background explained a larger amount of variation in mathematics performance than motivation. The results of the survey found that students enrolled on the business and engineering courses achieved a wide range of Leaving Certificate points (**Figure 3**) so the entry requirements for these courses did not necessarily pre-select students with sufficient mathematical experience.

For the *utility value component of motivation* considered in this study, initiatives designed to increase students' perceptions of the relevance of mathematics in their chosen degree program and future career are recommended. Interventions based on the utility-value framework have been found in general to be effective in promoting academic performance in science (Harackiewicz et al., 2012). The approaches of these interventions varied depending on the educational setting, but all aimed to demonstrate the value of the course material to the students' lives and future goals (Eccles & Wigfield, 2002). Three main approaches have been adopted:

1. direct communication of utility-value by the instructor,
2. activities in which students are asked to engage in tasks where they reflect on their own perceptions of utility-value (Hulleman & Harackiewicz, 2009), and
3. greater contextualization of mathematics within disciplines (Aikens et al., 2021; Harris et al., 2014).

The success of approaches (1) and (2) has depended on the students' own expectancy of success in understanding the material (Canning & Harackiewicz, 2015) so often both approaches have been combined (Acee & Weinstein, 2010; Gaspard et al., 2015; Kosovich et al., 2019). Interestingly, at workshops held jointly between the Department of Mathematics at MTU and the Irish Mathematics Teachers Association, motivation was identified as a major stumbling block for the development of students' algebra skills at post-primary level. A series of motivational videos aimed at older post-primary school students were produced where current MTU students demonstrated where they use algebra on their degree program. Motivational videos of this type involving peers and slightly older cohorts can be combined with self-reflection exercises to demonstrate the value of mathematics to incoming first years. The contextualization of mathematics content within disciplines is not always straightforward, especially in early years at HE where the same service module may be delivered to diverse cohorts by degree program. Nevertheless, it may be possible to show an array of applied problems to such cohorts of students in order to (i) demonstrate the ubiquity of mathematical frameworks and (ii) have an example of interest and value to each student in the class.

While it is encouraging to see that motivation is linked to mathematical performance, the discovery that 33.9% of respondents only aim to pass the module is a cause for concern (**Table 3**). Engaging and motivating this rather substantial group is a serious challenge for a lecturer. The previously mentioned interventions aimed at demonstrating the utility-value aspect of motivation can be reinforced by initiatives aimed at tackling broader issues surrounding motivation and promoting engagement with the course material. Several studies analyzed broader motivation interventions in education and demonstrated promising results for optimizing academic performance (Lazowski & Hulleman, 2016; Richardson et al., 2012). Some of the measures, such as goal-setting interventions, efforts focused on raising self-efficacy and mastery experiences, setting graded tasks, and providing feedback on successful performance may potentially be effective with mathematics performance. These works underscore the fact that "*motivation can be a key* ***process*** *or* ***mechanism*** *for enhancing student learning outcomes*" (Lazowski & Hulleman, 2016). Motivation influences student engagement, which is central for learning mathematics (Skilling et al., 2020), and, crucially, affects the choice of a specific learning behavior (Campos-Sánchez et al., 2014).

Relationships Between the Explanatory Variables (RQ3)

The analysis found that students who wanted to apply mathematics methods in other modules or wanted to develop a sufficient maths background to get a job with an analytical component had higher Leaving Certificate points than those who just wanted to pass the module or wanted to get better at maths (**Table 6**), indicating that attributing greater value to mathematical knowledge improved mathematical performance prior to entering HE. Surprisingly, when examining the relationship between, *Leaving Certificate points* and *Investment in independent learning*, it was found that students who spent the least amount of time studying during semester one had the highest mean Leaving Certificate points. This could be a result of the large amount of overlap between the content in the Leaving Certificate examination and the material covered in semester one mathematics modules for the students surveyed. The main aim of both the semester one business and engineering modules is to ensure that all students have covered core topics regardless of their different entry routes. It is likely that students who performed well at Leaving Certificate were able to stay on top of the course material with less effort than those who struggled with the Leaving Certificate material. The relationship between *investment in independent learning* and *mathematics performance* may be stronger for modules that cover new material. The analysis did not suggest that there were associations between *mindse*t and *Leaving Certificate points* or between *Leaving Certificate points* and *preference for understanding*. Looking at these results together, it is clear that sufficient mathematical background is key to mathematical performance but the reasons for this may be more than simply ensuring there is 'fertile soil' for new knowledge. In addition to providing 'fertile soil', mathematical background may also serve as a proxy for other important traits that contributed to prior achievement (see **Figure 5**). This may explain why prior learning such a good predictor of Mathematics performance is as it captures many of the positive traits to date over the course an individual's education. A detailed investigation of the relationships indicated in the **Figure 5** schematic, as well their evolution throughout student's career in HE, is a compelling scope for future work.

Motivation Trends in Different Student Cohorts (RQ4)

The comparison of trends between business and engineering students (**Figure 4**) indicates a noticeable difference in motivation for doing well in a service mathematics module between the two cohorts. This is not an entirely unexpected result, and it most likely reflects the type of student in each program and their views on relevance of mathematics to their discipline. Nevertheless, the small proportion (15.7%) of business students who see service mathematics as a foundation for other modules is concerning and suggests that more work may need to be done to communicate the value and importance of mathematics in the course. Our results here echo previous works that studied different students' cohorts, e.g., Kaldo &and Reiska (2012) observed a significant difference in university students' attitude towards mathematics, with science students having a more positive attitude than non-science students.

Interestingly, Musso et al. (2012) studied different student cohorts by *performance* and established different determinants of mathematics performance: basic cognitive abilities–for low-performing students;

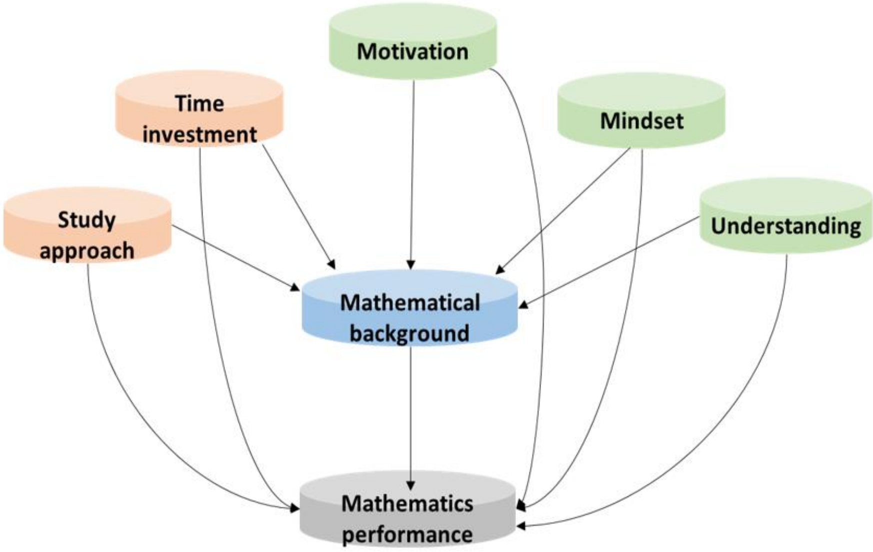

Figure 5. Updated causal structure to be investigated in future work

learning strategies and self-efficacy–for mid-performers; self-regulation and background variables (e.g., interest in the task)–for high-performing students. This suggests that different strategies may need to be used when trying to affect the engagement and performance in different cohorts. A natural continuation of the present study would be to investigate whether there is any difference in motivation and its association with mathematics performance between low-, mid- and high-performing students. A larger survey would also allow us to explore the research questions for different cohorts, program, or performance wise, separately.

Limitations, Considerations for Future Research, and Recommendations for Stakeholders

Limitations

The present work was exploratory in nature and focused on two (albeit large) student cohorts in one particular university. While the 19.0% response rate obtained maps to a margin of error of less than 5% at a 95% level of confidence, a larger survey, or higher response rate, should allow a more comprehensive analysis. In this study, performance in service mathematics modules was significantly influenced by *motivation* and *mathematical background*, however, the students surveyed may not be considered representative of all university students in Ireland. A larger, and more nationally representative, sample may allow more robust analysis and potentially facilitate greater inter discipline comparisons and stronger generalizations. As noted in the earlier analysis, the factors motivating the cohorts differ substantially, so treating these as a heterogeneous sample may be worth exploring.

The use of a single module grade may not be considered an ideal measure of performance and a more holistic measure might be considered in any further study. Likewise, a study which looks at knowledge retention at a defined point in time post the module assessment, such as a standardized test, may be a better measure of performance than the one considered in the present study.

The questions asked in the survey did not assess some of the more detailed aspects of students' learning strategies and without this further information it was not possible to understand how learning strategies affected mathematical performance in this study.

Considerations for future research

It is evident from this study that the factors that affect performance in mathematics modules are wide ranging and inter-linked. Future work should try to capture and analyze further aspects of students' mathematical dispositions and learning strategies such as measures of deliberate practice, organization, study environment and learning approach. For reasons discussed earlier, non-domain-specific factors (i.e., academic ambition and resilience, peer influence, timetabling and others) were excluded from this work. Further studies aiming to evaluate the contribution of these factors would be of interest. A larger study might

Table 7. Recommendations for stakeholders

Stakeholders	Recommendations
Students	Make students aware of the following: • The value of mathematics for many career choices. • The importance of learning for understanding and not just achieving a pass grade. • The importance of engaging with mathematics module, good mathematics study skills and approach to learning in HE. More is expected than at a school level.
Lecturers	Early focus on motivating the students and conveying the utility value of maths.
Student's department	• Communication between students' departments and mathematics lecturers regarding the relevance of mathematics to their degree program. • Early communication of the utility of mathematics in their discipline to the incoming students.
Student support services	Setting up and managing an 'early warning' system to allow early intervention with students who are 'low on motivation spectrum', and thus may be most in need of support in mathematics.
Management	• Promotional activities for prospective students should provide clear information about mathematical content of various degree programs. • Making students aware of dedicated mathematics supports. • Facilitating further research on the topic.
National department of education	Ensuring further research on these issues is prioritized and supported.

also focus on students at the end of their university experience in order to gauge their full experience of mathematics at university.

Other considerations for further research include the following:

1. deeper, more nuanced, analysis of the effect of surface versus deep approaches to learning on mathematics performance,
2. investigating the role of post-primary school mathematics achievement as a proxy for mathematical dispositions/attitudes and learning behavior traits (as suggested in **Figure 5**),
3. comparing the associations between motivation and mathematics performance in low-, mid- and high-performing students, and
4. designing and trialing suitable interventions aiming to improve motivation.

Recommendations to stakeholders

While this study did not focus on intervention strategies, some general recommendations for stakeholders are outlined in **Table 7**.

CONCLUSIONS

This study explored the factors that may impact *mathematics performance* in a first-year university service mathematics module. Although a number of factors discussed above have been found to be influential in the literature, for the students surveyed in this study, it was found that *mathematics background* and *motivation* (utility value component) had the strongest association with *mathematics performance*. In light of this, the authors feel that interventions based around motivating students and developing their perceptions of the value of mathematics to their own studies and future career might produce a positive, long-term impact on *mathematics performance*.

In our own experience, the focus for educators is often on improving resources and developing interventions to increase engagement but it is possible that focusing early motivational efforts on conveying the utility value of mathematics, will result in positive cascading effects on other factors thought to affect mathematics performance such as engagement and study habits.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approve final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Ethics: The authors stated that the *SPIRIT Maths* project received research ethical approval to carry out the study from the MTU-Cork Research Ethics Committee on April 15, 2020.

Acknowledgements: The survey was conducted within the SPIRIT Maths Project, which was part of MTU's 'Strategic Alignment of Teaching and Learning Enhancement 2019' funding allocation from the National Forum for the Enhancement of Teaching and Learning in Higher Education in partnership with the Higher Education Authority. The authors also acknowledge the encouragement and support from the Teaching and Learning Unit at MTU.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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APPENDIX A

Table A1. Student survey: Factors gauged and corresponding questions

Motivation and mathematical dispositions	
Motivation	Q1. What is your main motivation for doing well in your maths modules in MTU? *Choose one.* ○ I just want to pass the module ○ I want to get better at maths ○ I want to be able to apply maths methods in my other courses ○ I want to develop a sufficient maths background to get a job with an analytical component ○ Other (please specify)
Mindset (fixed/growth)	Q2. Which of the following two statements best describes your opinion of maths? *Choose one.* ○ Maths ability is something about a person that cannot be changed very much ○ Nearly everyone is capable of understanding maths if they work at it[3]
Preference for understanding	Q3. When I am solving a maths problem I do not worry about why the formula works. ○ True ○ False
Learning strategies	
Investment in independent learning	Q4. On average, how much time per week did you spend working independently on your maths module? * *Working independently relates to any work additional to lectures (live &/or pre-recorded) and tutorials/labs.* ○ None ○ One hour per week ○ Two hours per week ○ Three or more hours per week
Study approach	Q5. Which of the following best describes your study approach to your maths module? ○ I review material at least 4 days a week. ○ I review material at least 2 days a week. ○ I dedicate a day to catch-up per week. ○ I review relevant material only before an assessment. ○ I do not review material at all.

[3] Question adapted from (Code et al., 2016).