# Evaluating the Impact of Mathematics Support Using Moderation

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*Mathematics and Statistics Support has existed formally within Irish higher education for twenty years. Evaluations of the effectiveness of engaging with such student support suggest improvements in students' grades, confidence, retention, progression, completion and employability, among other factors. Distinguishing student success due to mathematics support engagement from students' other practices and use of academic resources such as lectures, tutorials, peer support and online materials is difficult. In this paper we present findings from a quantitative and longitudinal analysis of visitors and non-visitors of the UCD mathematics support centre over six years. We employed a technique from social psychology research literature known as moderation to address two research questions relating to the university mathematics module grades of students who use, and do not use the institution's mathematics support centre. Moderation analysis revealed that visiting the centre more often has a significant impact on the relationship between Leaving Certificate mathematics grades and university mathematics grades. Findings indicated that using mathematics support bridges the gap between lower and higher achieving Leaving Certificate mathematics students in terms of their university mathematics results.*

## Introduction

Mathematics and statistics support (MSS) is an optional, non-timetabled service often in the form of a dedicated physical space where students can drop in or pre-book an appointment to gain assistance with their mathematical or statistical learning. MSS was first established in Ireland at the University of Limerick in 2001 with a similar initiative established at University College Dublin (UCD) from 2003. The latest survey of MSS provision on the island of Ireland (Cronin et al., 2016) revealed that 25 of 30 (83%) higher and further education institutions surveyed offered MSS in some form with 16 such institutions providing a dedicated centre for their support. Various attempts, both qualitative and quantitative, to evaluate MSS have been conducted throughout Ireland and internationally over the past twenty years (Matthews et al., 2013). In this paper we report on a quantitative analysis, via moderation, of longitudinal UCD Mathematics Support Centre (MSC) usage data to answer the following two research questions: (1) Does visiting the MSC accentuate the positive relationship between students' prior school mathematics results and their university mathematics module results? (2) If so, for which students is it most beneficial and does the number of visits matter? The hypothesis was that visits to the MSC did accentuate the positive relationship, with more visits meaning greater accentuation of the relationship between students' second-level school mathematics results and their university mathematics results.

## Literature Review

Previous evaluative studies of the impact of MSS on students' success include both quantitative and qualitative methodologies. Dzator and Dzator (2020), utilised student surveys including open-ended questions to evidence student satisfaction and retention due to the service. Rickard and Mills (2018), and Jacob and Ni Fhloinn (2019) conducted quantitative

studies linking visits to the MSS centre with improved university results while controlling for prior academic achievement. Matthews et al. (2013), and Lawson et al. (2020) have synthesised evaluative studies on the impact of MSS in their respective literature reviews. These studies show the wide ranging positive impact of MSS on learners, staff and institutions. As MSS has become a more permanent and embedded student resource within higher education there has been an evolution in scholarship from justifying centres' existence via usage figures and positive student feedback to more sophisticated evaluative techniques such as regression analysis. However, such positive student engagement with MSS and correlations with student success measured via final grades for example, do not imply a causal relationship. As Lawson et al. (2020) state 'robust evaluation of the effectiveness of mathematics support alongside effective ways of engaging the disengaged remain the most important research areas in mathematics support.' (p.1248). In the national context, an all-Ireland survey of MSS provision (Cronin et al., 2016) asked MSS coordinators to list their most difficult challenges in providing MSS of which 'reaching the non-engaging students' and 'getting students to engage earlier [in their university life]' were the top two difficulties prioritised by 19 of 22 respondents. The issue of MSS student engagement has deteriorated further with the advent of wholly online MSS brought on by the COVID-19 pandemic. In UCD attendance figures have decreased by 59% from 4,283 to 1,762 student visits for the corresponding periods of April to December in 2019 and 2020 (Mullen et al., 2021a; Mullen et al., 2021b). This pattern of decreased MSS engagement due to COVID-19 is replicated internationally (Hodds, 2020). Thus when the return of on-campus MSS provision resumes it will be more important than ever to evidence the effectiveness of MSS on student success for a new generation of students.

## Methodology

Data was gathered over six academic years involving ten semesters between Spring Semester of 2015 and Autumn Semester of 2019. This data came from three sources, namely: (a) MSC visit data recording the number of visits, time of visit and the module code for each student visitor over the study period; (b) Assessment results in letter grade form for all students enrolled in the 27 modules in this study; and (c) students' prior mathematics learning achievement as measured by the Irish Leaving Certificate (LC) mathematics results. We note that all three data sources emanate from official sources ((a) and (b) from UCD Registry and Assessment respectively and (c) from the Central Applications Office via UCD Student Records), and thus are not student self-report data.

To comply with General Data Protection Regulations (GDPR) and the university's Office of Research Ethics the data was aggregated in the form of 227 'bins'. A bin represents a group of (not necessarily distinct) students with four traits in common. These traits are: (1) mathematical module type, (2) the year group of student enrolment, (3) the university letter-grade module result achieved by the student, and finally (4) the number of MSC visits the student made for that module (including non-visitors).

The 27 modules in the study fell into six types of university mathematics module which were MATH1, MATH2, ACM1, ACM2, MST and STAT. MATH1 denotes a mathematics module taken in stage one of a student's undergraduate degree programme, ACM2 denotes an Applied and Computational Mathematics subject taken in stage two, STAT denotes statistics modules taken in either stage one or two and MST denotes another type of mathematical module again taken in stage one or two. The two year-groups category from which the students first completed the module were 2015-2016/17 (five semesters) and 2017/18-2019 (five semesters). The final letter-grade result these students received in their respective module(s) are A, B, C, D, or F, where F denotes a failing grade of less than 40%. The passing grades A-D are commensurate with how UCD defines these grades numerically[1]. Finally, the number of times the students visited the MSC for each module fall into four distinct categories, 0, 1, 2-4 or 5+ visits in the relevant time period.

The reasons for these category choices were to maximise the number of data observations subject to preserving student anonymity in compliance with GDPR and ethical guidelines. There were 12,163 unique students in the study but 25,768 bin entries. Thus, each bin had between 3 and 1,766 entries, with a bin entry representing one module taken by one student. Hence a student can be in a bin multiple times if the student was enrolled to more than one mathematics module of this study and received the same final grade and used the MSC the same amount of times for those modules. A student can also be in multiple bins if the student was enrolled to more than one mathematics module of this study and received a different final grade and/or used the MSC a different number of times for those modules.

The LC mathematics level (Higher or Ordinary) and grade for each entry was provided by UCD Student Records. These grades were converted to a 12-point ordinal scale shown in Table 1. An average of these converted results was taken to create the average LC result for each bin. For example, the average LC result for bin 1 was 10.03, a H3 grade. The final university mathematics module grade was also converted from 'A to F' to '5 to 1' where A=5, B=4, C=3, D=2 and F=1. The average LC result for each bin, the final university mathematics module result for each bin (fixed for each bin e.g. bins 1 to 4 all received an A), and the number of MSC visits category for each bin, were used to create 227 observations.

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[1] A: 70-100%, B: 60-69.99%, C: 50-59.99%, D:40-49.99%, F:<40% (https://maths.ucd.ie/tl/grading/en02)

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**Table 1**

*Conversion of Leaving Certificate Grades to a 12-point Scale*

| Scale | Leaving Certificate grade and percentage |
|---|---|
| 12 | H1: Higher Level, 90-100% |
| 11 | H2: Higher Level, 80-89.99% |
| 10 | H3: Higher Level, 70-79.99% |
| 9 | H4: Higher Level, 60-69.99% |
| 8 | H5: Higher Level, 50-59.99%; O1: Ordinary Level, 90-100% |
| 7 | H6: Higher Level, 40-49.99%; O2: Ordinary Level, 80-89.99% |
| 6 | H7: Higher Level, 30-39.99%; O3: Ordinary Level, 70-79.99% |
| 5 | H8: Higher Level, 0-29.99%;   O4: Ordinary Level, 60-69.99% |
| 4 | O5: Ordinary Level, 50-59.99% |
| 3 | O6: Ordinary Level, 40-49.99% |
| 2 | O7: Ordinary Level, 30-39.99% |
| 1 | O8: Ordinary Level, 0-29.99% |

*Note.* Leaving Certificate grades and percentages sourced from https://www.theleavingcert.com/points-calculator/

## Data Analysis

Data was analysed using moderation, a statistical method which studies the effect of a moderator variable (in this study the number of visits to the MSC) on the relationship between an independent or predictor variable (LC mathematics result) and a dependent variable (university mathematics module result). A moderator variable can change the direction and/or the strength of the relationship between an independent and dependent variable (Baron & Kenny, 1986). Moderation can be tested using hierarchical multiple regression, looking at the interaction effect between the moderator and predictor variables and whether this interaction is significant in predicting the dependent variable.

## Results

Moderation analysis was used to answer the research questions: (1) Does visiting the MSC accentuate the positive relationship between students' prior school mathematics results and their university mathematics module results? (2) If so, for which students is it most beneficial and does the number of visits matter? The significance of the interaction effect between visiting the MSC and LC grades in predicting university mathematics grades was investigated. Figure 1 shows the spread of the average LC mathematics results of the bins with the mean and plus/minus one standard deviation highlighted. Note that the minimum UCD entry requirement mathematics grade is O6/H7 and many of the 27 modules included in the analysis require at least O2/H6 so the histogram is left-skewed. Table 2 presents the bivariate correlations for the three variables.

**Figure 1**

*Average Leaving Certificate Mathematics Results Histogram*
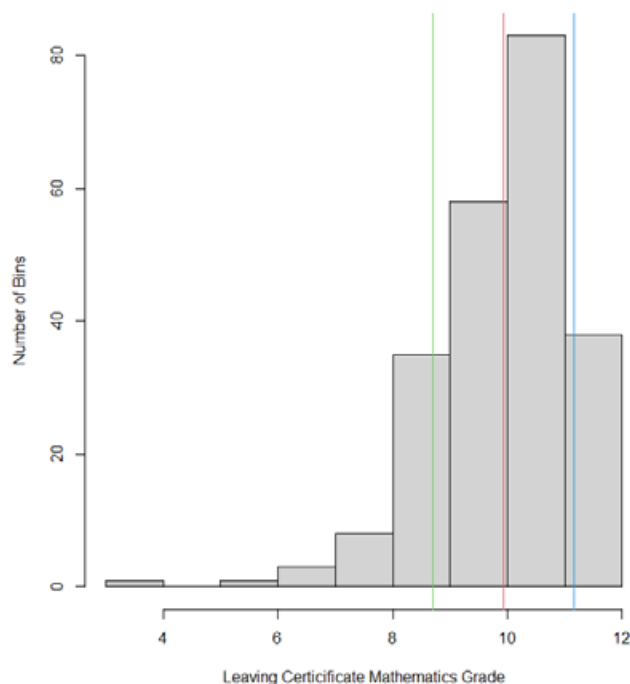


*Note.* The red, blue and green lines show the mean, and one standard deviation above and below the mean.

**Table 2**

*Correlation between Leaving Certificate Mathematics results, Final University Mathematics results, and MSC visits*
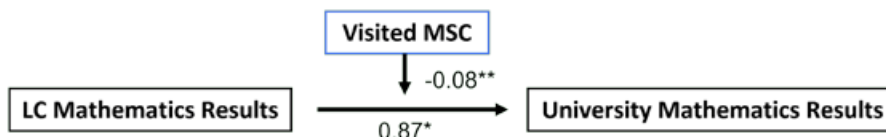
|  | LC Mathematics Result | Final University Result | MSC Visits |
|---|---|---|---|
| LC Mathematics Result | 1 | | |
| Final University Result | 0.48* | 1 | |
| MSC Visits | -0.30* | 0.072 | 1 |

*Note.* * indicates $p<0.01$.

Using Hayes' (2017) PROCESS model 1 in SPSS, the moderating effect of visiting the MSC was investigated, as shown in Figure 2.
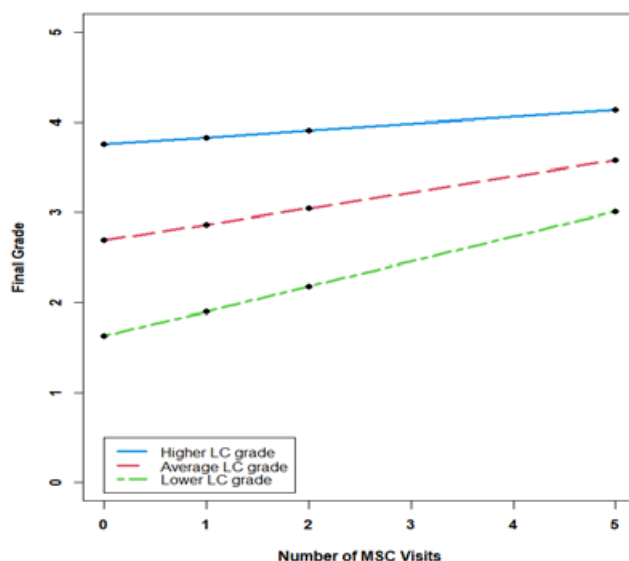
**Figure 2**

*Visiting the MSC moderating the relationship between Leaving Certificate mathematics results and university mathematics module results.*



*Note.* *unstandardised coefficient, s.e = 0.12, p = 0.00.  **unstandardised coefficient, s.e. = 0.03, p = 0.01.

**Figure 3**

*The number of visits to the MSC moderates the relationship from Leaving Certificate mathematics results to final university mathematics results.*



*Note.* Regression of the university final mathematics result on the number of MSC Visits at specific values of LC mathematics grade is shown. Results compare for lower (1 standard deviation below the mean), average (mean), and higher (1 standard deviation above the mean).

Visiting the MSC does influence the strength of the relationship between LC results and university mathematics results as a significant interaction effect was found with an unstandardised coefficient of -0.08 (s.e. = 0.03, $p$ = 0.01). Simple slopes analysis,  (Preacher et al., 2006), shown in Figure 3, reveals that the more visits a student makes to the MSC, the higher their final university mathematics grade is; this effect is more pronounced for students with lower LC results. In other words, Figure 3 compares the final university mathematics results of lower (one standard deviation below the mean), average (mean), and higher (one standard deviation above the mean) LC mathematics students. The positive effect of visiting the MSC is strongest for the lower achieving students (the steep green line) compared to the higher achieving students (flatter blue line). Notably there is a positive difference after just one visit to the MSC, and with an increasing number of visits, for all three groups. In summary, a greater number of visits to the MSC is related to higher university mathematics results, particularly for the lower achieving students.

**Discussion and Conclusion**

Determining the impact of MSS engagement on student success in subsequent examination performance is a difficult task. Simple analyses can be prone to a post hoc fallacy, whereby improvements in students' performance can be ascribed to a single intervention – or to a range of them – and do not necessarily take into account the wide variety of other potential influences on students' academic performance. Simply put, correlation is mistaken for causation. Thus rigorous and careful analyses are required to ensure the efforts of such student academic support provision is not undermined. This is

achieved in the present paper by undertaking a robust statistical analysis (moderation) of a very large cohort consisting of 12,163 students over a considerable time period of six years.

We have provided evidence that students from lower second-level school mathematical backgrounds experience a greater benefit from engaging with their institution's mathematics support centre than their higher-achieving peers. Students from higher school mathematics backgrounds experience a ceiling effect but still benefit from greater interaction with mathematics support. As hypothesised, students who had used mathematics support five times or more experienced the greatest accentuation in the relationship between their LC mathematics results and final university mathematics results but it is clear that even those who visited the MSC only once still benefited in comparison to non-users. This aligns with previous research indicating that just one visit to a MSS centre can benefit students (Jacob and Ni Fhloinn, 2019). These findings also build on existing Irish and international research demonstrating second-level mathematics performance as a predictor of third-level mathematics performance. The advancement made in the current study however distinguishes student success due to mathematics support engagement from students' other practices. While this may be unsurprising it is important to document nonetheless.

Short-term effect analyses and/or small sample size studies claiming positive effects of MSS on student mathematics performance are strengthened by such longitudinal studies as carried out here. Such studies bolster claims that MSS provision works for those students who avail of it, and can be used as evidence to encourage those who have yet to utilise its services. In addition, utilising a large data set involving dozens of university modules and thousands of students allows for generalisations that MSS works for academic modules of varying mathematical rigour (e.g. service versus specialist courses), and students of varying mathematical aptitudes, to be made. Thus this paper sets a baseline for examining trends among different student cohorts' engagement (or non-engagement) with their institution's MSS offering.

Student engagement with MSS, especially from those with lower mathematical attainment backgrounds, must continue to be encouraged so that all such students can gain these benefits. We intend to build on this work to examine whether university students from non-traditional entry routes (e.g. mature, international, HEAR[2], DARE[3] and QQI-FET[4]) benefit (or lose out) disproportionally from MSS engagement (non-engagement) than their peers who enter university from more traditional routes.

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[2] HEAR stands for Higher Education Access Route (https://accesscollege.ie/hear/).

[3] DARE stands for Disability Access Route to Education (https://accesscollege.ie/dare/)

[4] QQI-FET stands for Quality and Qualifications Ireland Further Education and Training ( https://www.qqi.ie/Articles/Pages/FET-Awards-Standards.aspx).

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