RESEARCH ARTICLE

# Computer Science Students' Perspectives on the Study of Mathematics

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## Abstract

In 2019, the Department of Mathematics and Statistics at Maynooth University commenced a project which sought to address, through the provision of mathematics learning supports, the issues of poor engagement and retention of computer science students studying mathematics. In this paper, we present preliminary engagement and performance data along with interviews conducted with eight students. We discuss how the quantitative data seemed to indicate that computer science students were engaging at similar levels to their peers, but several factors, including the quality of this engagement and their mathematical backgrounds may explain their poor exam performance. It also emerged that, while students were largely negative about their experiences in large lectures and their awareness of the relevance of mathematics to computer science, they were generally positive about smaller teaching situations such as tutorials, mathematics support drop-in and opportunities to work with their peers.

Keywords: Mathematics Learning Support, Computer Science, engagement, relevance, retention, study groups.

## 1. Introduction

Over many years, Department of Mathematics and Statistics (Department) staff at Maynooth University (MU) identified the performance of Computer Science (CS) students with mathematics as a concern. This problem, along with the broader issue of CS non-progression and engagement rates at MU are similar to those reported by the Higher Education Authority (HEA) in Ireland (Frawley *et al.*, 2017). Research indicates that appropriate engagement with Mathematics Learning Support (MLS) can impact positively on student retention and progression (Berry *et al.*, 2015). In 2019, MU commenced an 'ICT and STEM Enhancement' project funded by the HEA's Innovation and Transformation call. One strand of this project relates to the provision of MLS to target the engagement and retention of CS students taking mathematics. In this paper, we aimed to address two research questions:

1. What are the backgrounds, experiences and challenges of CS students studying mathematics at MU?

2. What, if any, additional MLS can be provided to address the issues that CS students are experiencing with their study of mathematics at MU?

To address these questions, we initially considered one year of the Department's first-year student engagement and performance data. This data includes MSC attendance records. We subsequently conducted semi-structured interviews with undergraduate CS students. In this paper, we present an overview of the mathematical programme that CS students experience at MU, and the support available to them. We discuss the main themes that emerged from the interview data analysis. We consider what answers they provide to our research questions and we briefly summarise the initiatives we established as a result.

## 2. Background, Literature Review and Methodology

### *2.1 Computer Science and Mathematics at Maynooth University*

At MU, undergraduates who want to study CS modules can do so in different ways. For almost all routes, CS must be accompanied by mathematics in first year, and by at least two modules of mathematics in second year. These are large service mathematics modules and not CS-specific. All first-year service mathematics students sit a proficiency test at the start of the academic year. A passing grade is 20 or higher (out of 60) and those who fail are automatically registered for an online Mathematics Proficiency Course (MPC) which is designed to cover topics that fill knowledge gaps considered pre-requisites for mathematics in HE.

Students studying mathematics receive weekly assignments. Prior to a small-group tutorial, one question is graded by their tutor and contributes to continuous assessment (CA). MU also has a busy Mathematics Support Centre (MSC), where the main service provided is drop-in. The MSC also runs weekly student-led workshops. If students' tutorial attendance, homework submission or MPC engagement falls below acceptable levels, they are contacted by the First-Year Monitor. Monitoring considers all students taking first-year service mathematics and does not focus on any specific subgroups, e.g. CS, Finance or Biotechnology students.

### *2.2 Literature Review*

In the past decade, several studies have featured or focused on retention and progression rates in relation to CS in HE. Research published by the HEA in 2019 considered those entering HE in Ireland in 2007-08 and whether they had graduated their institute by 2016. They found that students in computing courses had the lowest rate of completion, 55% across the combined levels 6 (higher and advanced certificates), 7 (ordinary bachelor's degrees), and 8 (higher diplomas and higher bachelor's degrees) on the national framework of qualifications (NFQ) when compared to other courses (Pigott and Frawley, 2019). This figure is 37% when we look exclusively at level 8 computing courses. In a similar study from 2018, which also included non-CS courses, the HEA considered progression rates of first-years into the second year of computer science courses across HE and all NFQ levels from the 2014-15 to 2015-16 academic years. They also compared the non-progression rates to those from 2013-14 to 2014-15, which were 22% and 21% respectively, well above the national average of 14%. When we look exclusively at level 8 degrees in universities, the rate is somewhat better at 11% (Liston *et al*., 2018). In the UK, a comparison of retention rates across disciplines in HE for 2010-11 found that CS had the lowest continuing rate of 91%, meaning 9% of students either left with a lesser degree than originally intended or did not continue their studies (Woodfield, 2014).

The factors which may have influenced these trends have been considered by researchers. Several papers examine social integration within a variety of CS courses. For example, Biggers *et al*. (2008) studied undergraduate CS students that were registered at the Institute of Technology, Atlanta, comparing survey responses of those who graduated to those that dropped out. Lack of awareness of the relevance of the course material, low exposure to real world applications, tedious boring workloads, low levels of human interaction and a perception that CS is antisocial were identified as significant contributors to course non-completion. In Ireland, the National Forum for the Enhancement of Teaching and Learning in Higher Education (National Forum) identified, in a 2015 briefing paper *'Student Non-Completion in ICT* [Information Communication Technology] *Programmes',* that high attrition rates had been associated with a range of factors including '*the limited mathematical skills and problem solving abilities of some students entering ICT programmes*' and '*poor awareness of the level of maths and computer skills required to succeed in such programmes*' (National Forum, 2015, p. 4-5).

### *2.3 Methodology*

When this project was announced, there was a short period during which we could consider student data and use it to inform our services for the 2019-20 academic year. We began by examining all the Departmental quantitative engagement and performance records of first-year Arts students, within which we compared those students studying CS with their non-CS classmates. Some of these initial results were surprising as they appeared to contradict MU internal reports and research on CS student engagement (Colby, 2005). Therefore, we decided to investigate further by conducting semi-structured interviews. These were identified as the most effective way to gather additional data from the CS students (Sarantakos, 2012). Eleven questions were designed which targeted areas identified as being important to student academic success with mathematics, based on previous MU studies, research literature and the authors' experiences.

Ethical approval was received, and, in April 2019, details of the project were announced to students via Moodle and in the MSC. In total, eight students responded to the call for interviews, two from each of the four years of study, and interviews were conducted in May 2019. Each interview was recorded and transcribed. All identifying information was removed prior to the data analysis. The authors used Thematic Analysis to analyse the interviews (Braun and Clarke, 2006), which were read and coded independently by the authors. The authors met and discussed their findings to identify any common themes.

## 3. Results and Discussion

Due to the different variances in the CS and non-CS groups, it was not possible to conduct significant statistical analyses or comparisons. However, we present the initial quantitative data in Section 3.1 because we used it, in addition to the outcomes in Section 3.2, to guide our initial MSC interventions.

### *3.1 Quantitative Departmental and MSC Data*

We began by considering proficiency test results for 2018-19 and from these, we observed that CS students, on average, appeared to enter MU with weak mathematical backgrounds. This was not unexpected and consistent with findings in other studies (National Forum, 2015). For example, if we consider first-year Arts, the mean result out of 60, for the entire class was 26.29 (n=211), for CS students it was 16.52 (n=30) and for non-CS it was 28.06 (n=181).

We then examined the Department's engagement records and found that CS students seemed to be engaging and performing at similar levels to their non-CS peers during 2018-19. See Table 1 and Table 2.

| | **All students n=203** | **CS n=30** | **Non-CS n=173** |
|---|---|---|---|
| Mean number of tutorials attended (out of 20) | 11.92 | 13.13 | 11.74 |
| Mean number of assignments submitted (out of 20) | 14.10 | 15.57 | 13.86 |
| Mean percentage assignment grade | 44.39 | 45.92 | 44.14 |

Table 1. First-Year Arts Tutorials and Assignment Data 2018-2019

| | **All students n=119** | **CS n=19** | **Non-CS n=100** |
|---|---|---|---|
| Mean number of MSC visits per attendee | 12.73 | 11.21 | 13.02 |
| Mean total time spent in MSC (in minutes) | 850.02 | 588.68 | 898.20 |

Table 2. First-Year Arts MSC Attendee Data 2018-2019

Albeit based on one year of data, these apparent similarities in engagement and assignment grade data were surprising to us. The most noticeable difference was in the category 'mean total time spent in MSC'.

Finally, we considered the final module results of these students, see Table 3.

| **Modules** | **All students (%)** | **CS (%)** | **Non-CS (%)** |
|---|---|---|---|
| Calculus 1 (n=203) | 42.13 | 29.43 | 44.34 |
| Introduction to Statistics (n=166) | 49.14 | 38.83 | 51.33 |
| Linear Algebra 1 (n=162) | 53.41 | 48.70 | 54.48 |

Table 3. First-Year Arts Mean Module Results 2018-2019

The differences in the module results between each group were substantial. When coupled with the similar homework grades obtained by each group, the data in the tables indicated, at least on a surface level, that while CS students appeared to be engaging appropriately with mathematics, their exam grades were well below the class average. This exam data seemed in line with the aforementioned 2018 HEA report but at odds with literature on CS student engagement (Colby, 2005).

### *3.2 Interview Data*

One of the main themes to emerge from the interviews was the teaching approach used in different classroom situations. All eight students were negative about the traditional lecturing method of '*chalk and talk*' with one stating that you are '…*just writing notes and you're not thinking about what they're saying'.* Prior to COVID-19, lecturers in the Department did not typically upload full sets of notes online. Respondents reported different teaching methods in their other subjects: '...*they're all done up you can scroll through it with the lecturers. If you fall behind, you can scribble something down*…*you can even have it on your phone*…'.

Other negative comments referred to the fast pace of lectures, the large class size and difficulty in asking questions '…[even though] *every lecturer says don't be afraid to ask questions*…*you're not going to put your hand up in a class of 400 to ask something*'. Half of our respondents directly linked their lecture experience to their subsequent disengagement: '*there's no point in me coming to lectures. I'm not going to learn anything, I might as well just study*'. These experiences are similar to findings in other studies (Grehan *et al.*, 2016), although negative experiences in relation to mathematics lectures are not new or unique to MU or indeed to CS students. (Mann and Robinson, 2009, Tinto 1997).

We passed this student feedback on to the Department as lecture style and format do not fall under the remit of MLS. Nevertheless, lectures are an important part of the student experience and can influence the level of engagement with MLS. Tinto (2006, p. 4) states that '*… the classroom is, for many students, the one place, perhaps only place, where they meet each other and the faculty. If involvement* [engagement] *does not occur there, it is unlikely to occur elsewhere*'. The provision of supports such as an MSC, tutorials and assignments to complement lectures and lecture material is recommended in several studies (Macrae *et al.*, 2003), and can *'…provide students with opportunities to build and enhance academic and social skills in a positive, supportive, intentionally constructed environment.*' (Bean and Eaton, 2001, p. 86).

If we consider themes which emerged from comments in relation to tutorials, assignments and the MSC, it appears that these supports were largely successful, and the respondents were highly involved or engaged as a result. Indeed, all themes related to tutorials and the MSC were positive. The importance of small group teaching and learning in STEM is well researched (Springer *et al.*, 1999), and students who engage with MSCs tend to be very positive about their experiences (O'Sullivan *et al.*, 2014). The teaching approaches used in both tutorials and the MSC were endorsed by students who felt that material was '*explained in the tutorials in such a way that was very easy to understand'*, when compared to lectures, and that '*The MSC was incredibly useful, especially if you need a little push on some questions*'. Respondents also appreciated the smaller class sizes and found it easier to ask questions. In regard to the MSC, students also identified that the atmosphere '…*motivates you as well to do the work*'.

Group work and the opportunity to work with peers, was of particular importance to five of our interviewees: '*Whenever I work on my own I get quite frustrated*', but '*working in groups was really helpful because I could ask* [peers] *a question* [...] *and then continue on*'. While the use of social interactions by students can influence their level of engagement and how they deal with their mathematical difficulties (Grehan *et al.*, 2016), social isolation is identified as a major issue for CS students (Crenshaw *et al.*, 2008). The positive and social experience reported by interviewees corresponds to a sense of networking and community in smaller classes which is important for engagement (Crenshaw *et al.*, 2008). However, this was not the case for all students. One felt that

they did not benefit from studying in groups as they '*… end up helping* [peers] *figure it out and I get nothing done…*'. Research shows that students may need direction on how to work together effectively (Oakley *et al.*, 2004).

While the majority of respondents were positive about homework, some felt like they were '*churning out assignments*' and that it was a '*big learning curve, especially in first year*…'. In Grehan *et al.* (2016), 15 of 16 students interviewed reported difficulties with their assignments at the start of the academic year, and eight of these reacted by attending the MSC.

Students were asked about the relevance or usefulness of mathematics for CS and, while all reported different levels of awareness, a number of themes emerged from their comments. In particular, students questioned the level of coordination between the departments in relation to connecting the two subjects for students: '…*I think there was a disconnect in first year like, you were just kinda doing two separate subjects*'. Baldwin *et al.* (2013, p.74) refer to '*the awkward place for mathematics in undergraduate computer science curricula*', and our interviewees identified inconsistent messaging and communication from CS staff about the importance of mathematics. One student recalled a CS lecturer saying that '… *you need a bit of maths, but we'll cover the maths in our course*'. Baldwin *et al.* (2013, p.74) also claim that '*mathematics courses align poorly with the needs of computer science*', and this is evidenced by some of our respondents who did not see how their first-year mathematics lectures were relatable to CS: '*If I was in first year and I didn't know any of this* [importance of maths] *I'd be like, why would I want to do maths!?*' In fact, only two students remembered the relevance of mathematics being explicitly communicated by teaching staff in their first year, though three students indicated that they heard via their social interactions. The two final-year students, who said that the relevance of mathematics became clearer after second year, indicated that knowing this earlier would have an impact: '*if someone from the CS department came in and showed* [us] *all the courses that you can do in final year and said you need this maths for doing that, you need to know number theory for that, calculus for doing that, I think I would have chosen subjects differently*'.

Another theme which emerged across several questions was references by students to their mathematical background. Three students, who attended MU straight from school, indicated that they did not feel prepared: '*I would have liked a week or two-week intense course for precalculus before I came into college*...*That would have helped a lot*'. While this is consistent with national reports featuring CS students (Pigott and Frawley, 2019), there was almost no engagement from interviewees with the MPC. This course was set up to tackle the mathematical deficiencies that students have entering MU, but respondents suggested that it was forgotten about or not used because of its non-compulsory nature. This suggests that the MPC needs to be better advertised and its purpose more clearly communicated to students.

Five students indicated that they did feel prepared, referencing the role of supplemental instruction prior to starting university. One student mentioned private tuition, and the other four were mature students. A study of mature students over a ten-year period at the University of Limerick, suggests that '*The initial challenges which mature students face, however, are likely to have been counteracted by their motivation to succeed*' and add that '...*mature students tend to exhibit more desirable approaches to academic learning*' (Faulkner *et al.*, 2016, p. 347). The four mature students in this study all praised the precursory summer course they attended at MU: '*If you are weak at math or anything like that then I highly recommend having that as an option for people to go…*'. The *National Strategy for Higher Education 2030* report (Department of Education and Skills, 2011) recommends such preparatory courses to ensure a positive first-year experience.

## 4. Conclusion and Next Stage

In this paper we considered quantitative data for one group of first-year students, and interviews from eight CS students. Thus, our preliminary findings are not necessarily representative of all CS students. Nevertheless, the data did provide interesting insights which partially answered our two research questions.

On average, CS students are entering MU with weak mathematical backgrounds, and this may be a significant contributing factor to their poor performance in mathematics examinations. Studies have shown, for example Burke *et al*. (2013), that the mathematical background of first-year students is the biggest indicator of their progression into second year. Interviewees referenced their mathematical backgrounds when describing difficulties with the subject, and while several highlighted the importance of having extra academic support in their transition to HE mathematics, none had engaged with the MPC to any extent. In an effort to increase the quality of student engagement with the MPC, the Department has made it a mandatory part of CA for all first-year students.

Interviewees reported negative experiences with large lectures, but were very positive about other teaching environments, and they described positive participation with tutorials and the MSC. The quantitative data indicated similar trends and this suggested to the authors that CS students may have focussed on getting their homework completed, rather than on gaining a fuller understanding of the material. This may also have influenced their poor performance on exams when they needed to attempt the material on their own. The Department is reconsidering its monitoring system (Burke *et al.*, 2013) to see if there are additional checks that could be put in place to measure the quality of student engagement and also whether certain subgroups, such as CS, need to be considered separately.

The interviewees also felt that communication between the Departments, and from staff to students, could be improved, especially in terms of clarifying the role of mathematics in CS. As a partial answer to the second research question the authors, in consultation with the Department of CS, drafted a document outlining connections between undergraduate service mathematics modules and CS modules at MU. These lists were distributed to lecturers and shared with students. Some of the authors also spoke at first-year CS orientation events in order to present a more collaborative image of the two Departments. Interviewees also highlighted the benefits of group work, though the quantitative data suggested that CS students may not have been using the MSC appropriately. Following a subsequent literature review, we decided that we would launch an MLS study group initiative in 2019-20 for both first and second-year CS students. At orientation, the potential benefits and pitfalls of study groups were introduced to students (Oakley *et al.*, 2004). The study groups are student-led and students are encouraged to bring questions to discuss in order to maximise the benefits of peer learning. Tutors meet with these groups once a week in the MSC to guide their learning and ensure they are working effectively. Tutors also check attendance and provide encouragement, intervening if students show any signs of disengagement. Due to their success, these study groups have continued in the MSC (Mac an Bhaird *et al*., 2021).

While this paper reports on the initial phase of this project, related research is ongoing. For example, the authors are considering a longitudinal study of Department quantitative data in relation to CS student engagement and performance. The findings from this project, which finishes in 2022, could be used by MU to consider the future structure of CS courses and the provision of mathematics for CS students.

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