MSOR Connections

Articles, case studies and opinion pieces relating to innovative learning, teaching, assessment and support in Mathematics, Statistics and Operational Research in higher education.

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Innovations in teaching, learning, assessment and support

Contents

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EDITORIAL

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Welcome to the second of two special issues of *MSOR Connections* containing papers from presentations at the CETL-MSOR 2021 conference held at Coventry University on 2nd-3rd September 2021. The first special issue focused on matters arising from the COVID-19 pandemic in maths, stats and operational research teaching, learning, assessment and support. A collection of ten papers on this theme can be viewed on the journal website at https://doi.org/10.21100/msor.v20i1. This second special issue moves away from the direct effects of the pandemic to look at broader innovative practice that continues to develop and emerge despite the changes to our lives brought by COVID-19.

The first paper is taken from the Keynote address by Tony Croft at the conference. Tony was one of the main founders of the **sigma** Network in the UK and provides a detailed description of the timeline of mathematics support in the UK in this piece. It is hoped it will provide some insight for younger practitioners into the development of maths support services whilst also giving more established practitioners a chance to reminisce!

The next two papers that follow discuss various aspects of the SPIRIT Maths project in Ireland. The first paper by Lishchynkska et al. provide information on a survey on students' expectations of mathematics at university. They report that around 52% of those surveyed found mathematics difficult but there was a distinct shift away from this when they were interviewed again later in the semester. Remote learning and blended learning were also discussed and came out as something that needs to considered for the future. The second SPIRIT Maths paper by Palmer et al. discusses student views on digital resources and their development having been informed by the work in the Lishchynkska et al. paper. The use of H5P and Numbas to develop videos and related questions were shown to be effective in early feedback.

Following from this there are two interesting papers on assessment. Ketnor et al. discuss the Peerwise system for assessment where questions are created by students, for students, and feedback can be given by those assessing the questions. The paper provides recommendations for the use of Peerwise from evaluating its use in the UK and Australia. Students in the UK found it to be a useful platform for revision whereas Australian students found it more useful for writing questions, showing a distinct difference in the way a single assessment system can be utilised. Martin Greenhow then provides an update on the "Maths e.g." platform, a form of assessment that has been around since 2000. The paper presents how the questions can be embedded into many learning scenarios, drawing upon experiences during the pandemic and the restrictions that were placed on our lives.

An important current topic is making documents accessible, particularly those with mathematical texts. The paper by Wouters describes how to do this using GNU TeXmacs. As many mathematical documents are made in LaTeX, GNU TeXmacs provides a solution to make LaTeX documents accessible. In the paper there is a description of how to do this with your documents and how to incorporate it into lecture notes.

The development of blended and online teaching and support is something that we have all experienced over the past few years. Potter and Blundell discuss the barriers and opportunities from using blended tutorials that support distance learning, providing perspectives from the practitioner, outside experts, and students. They show that, overall, blended tutorials were seen as positive, offering opportunities to all to have more learning, but the educator needs to focus on pedagogy and accessibility rather than technical issues; students are more resilient to technological issues than first thought. The Open University have used online delivery for longer than most so, given their experience with online teaching and support, Sue Pawley considers instead whether the “traditional times” of study support delivery are still optimal. Her case study shows that offering support at traditional times do attract the highest attendance but engagement is significantly increased when offering support outside of these times.

The pandemic has been shown to cause anxiety and stress in students, more-so than in “normal times”. The papers by Gokhool et al. and Marshall et al. consider maths and stats anxiety respectively, giving an insight into some ways into how these can be lowered. Gokhool et al. analyse engagement with maths support based upon anxiety and resilience, along with demographic and cohort factors. They show that those courses with no A level entry requirement were less resilient and more anxious about mathematics. Female and mature students were also shown to be significantly less mathematically resilient than other groups. Entry requirement, engagement with maths support and maths anxiety score all impacted mathematical resilience score, suggesting these students need to be targeted for more tailored approaches. Marshall et al. developed a series of stats anxiety workshops to help students understand what stats anxiety actually is. Although students with high stats anxiety were more likely to attend, those with help-seeking anxiety were less likely. The paper suggests some strategies to normalise help-seeking would be useful and beneficial.

The final paper by McGonigal reports on ongoing research into the role of language and discourse in the teaching and learning of statistics in a business setting. The short update provides information on proposed methods to consider the differences between two consecutive first year business school courses to see how their understanding develops.

Once again, we are grateful to our cohort of authors and peer reviewers for this larger-than-usual issue of *MSOR Connections*. It is brilliant to see such a vibrant community hard at work and willing to share its emerging practice. We would also acknowledge delays to production caused by ongoing pandemic effects and the UCU industrial action over ‘Four Fights’ and ‘Action for USS’, and we look forward to a day when our community can put the pandemic and the issues underlying the dispute behind us.

MSOR Connections continues to be a venue for our community to share its innovative practice, and submissions are always welcome via the journal website: https://journals.gre.ac.uk/. The journal is also always keen to attract reviewers and we have some experience of supporting those new to reviewing (including in these special issues), so please sign up via the website if you are interested in reviewing articles.

OPINION

Celebrating our past: once upon a time there was a cottage industry. Personal reflections on the development of mathematics support

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Abstract

Back in the early 1990's mathematics support was small-scale and loosely organised. Now, in 2021, it is to be found in the full range of university mission groups including those with the highest entry requirements. Today it is undoubtedly true that support centres are part of the landscape of higher education. They have evolved from offering local, drop-in support to first-year engineers to university-wide centres offering help to students in all disciplines and at all levels including postgraduates and sometimes staff. They contribute to university-wide priorities including recruitment, progression, retention, satisfaction, quality enhancement and employability. They have succeeded in raising issues such as the mathematics support of students with additional needs higher up institutional agendas and have firmly put the activities of those who work in this field on the radar of senior management of universities. This paper charts key milestones and events from the trajectory of mathematics support from 1990 to 2020 which have resulted in the thriving support services and community of practitioners that are evident today. It is based on a keynote presentation given by the author at CETL MSOR 2021.

Keywords: mathematics support.

1. Introduction

Over the last thirty years what has become known as *Mathematics and Statistics Support* has evolved from loosely organized, peripheral, and small-scale activities into a more collaborative and co-operative venture. Nowadays it is often embedded within university structures and with university oversight. There are now strong networks of practitioners freely giving their advice, resources, and time, with a common purpose of improving the student experience of mathematics and statistics.

This paper will provide a personal reflection of how we got from then to now. I start with an apology: I will mention some people by name, and either because of time limitations, or my memory or my ignorance, miss other key players. Please don't take this personally. Very many people have brought us to where we are today.

For those readers too young to be around at the start of this journey, I hope this paper will provide some historical background and perspective to the careers you are following today. For those of us who have toiled on this chalk-face for a lifetime, I hope it will provide elements of nostalgia and allow us to reminisce about 'the golden era' - the days before 'the mathematics problem' 'blighted' higher education!

I'll begin with a quotation from the report *Measuring the mathematics problem (*Hawkes, T. and Savage, M. (2000)*).* This report was, in my opinion, a watershed moment for mathematics support, as I will explain. Referring to A-level mathematics in the 1960s,

"... the 'golden age' of mathematics in which able sixth formers, aiming for university, were inspired and stretched by a very talented teaching force. Students acquired all-important study skills together

with sound mathematical knowledge and understanding which prepared them well for Higher Education."

(Savage, Kitchen, Sutherland, Porkess (2000) in Hawkes, T. and Savage, M. (2000))

Was it ever really like that? Is this unfair? Perhaps a point for discussion over a coffee! But to provide at least some balance, here are a couple more quotes:

"The standard of mathematical ability of entrants to [ ] courses is often very low ... Experience shows that a large proportion of entrants have forgotten how to deal with simple vulgar and decimal fractions, have very hazy ideas on some easy arithmetical processes, and retain no trace of knowledge of algebra, graphs or geometry, if, in fact, they ever did possess any."

(Mathematical Association Report, 1954)

"Many who are in a position to criticise the capacity of young people have experienced some uneasiness about the condition of arithmetical knowledge and teaching at the present time. Accuracy in the manipulation of figures does not reach the same standard which was reached twenty years ago. Some employers express surprise and concern at the inability of young persons to perform simple numerical operations involved in business."

(Board of Education Report of 1925)

These are cited in the Cockcroft Report (1982). So, the first take-away message is that the 'mathematics problem' is certainly not new! However, there are significant differences today: widening of access to higher education, an increasing focus on quality assurance and accountability, substantial fee levels, and societal need for a more mathematically and statistically competent workforce and a more numerate society. These factors provide a rationale for academia to work harder to ensure that students have a worthwhile experience of mathematics whilst at university.

2. The arrival of mathematics support

The term 'cottage industry' in the title of the paper is one which has been cited frequently in the mathematics support literature. Dictionary definitions include: 'a small, loosely organized, decentralized industry' and 'a limited but enthusiastically-pursued activity'. These are apt descriptions for much of the work in the early days of mathematics support (c1990). Work was certainly decentralised with little or no oversight save by the one or two enthusiasts who took it on as almost individual pursuits. Within the literature of mathematics support we attribute the original reference to Joe Kyle, University of Birmingham, who wrote that he regarded mathematics support as *"a form of cottage industry practised by a few well meaning, possibly eccentric individuals"* (in Marr, C, and Grove, M., (Eds) (2010)). I really can't imagine who he was referring to!

Pioneering work in Australia by Milton Fuller led to the establishment of the Mathematics Learning Centre at Central Queensland University (c1984). Fuller was influential in Glyn James' application to the BP Education Fund to establish support at Coventry (1991) and thereafter developed by Duncan Lawson and colleagues to become the outstanding services at Coventry today. Early pioneers were Ian Beveridge and Rakesh Bhanot at the University of Luton (c1993) who organised the first *National Conference on Supporting Mathematics in Further and Higher Education*. One of the delegates there indicated that support was delivered by "*dedicated enthusiasts struggling to cope with a desperate situation which is getting worse each year, usually with inadequate resources*" (Beveridge, 1999). In an early attempt to gather a community of like-minded individuals, the Mathematics Support

Association (MSA) was formed. MSA newsletters were published until 1999. Copies are archived on the **sigma** Network website.

The Loughborough University Mathematics Support Centre was established in 1996, in the Department of Mathematical Sciences, primarily to serve the large engineering cohorts many of whom were struggling with mathematics. I was appointed to both tutor and to develop the service which rapidly expanded to offer help to any student in the university. Dedicated statistics help followed and other staff in the Department offered additional hours of drop-in support. Clare Trott was appointed as a tutor. Later, she would go on to specialise in the support of students with neuro-diversities and to pioneer this nationally. The help leaflets we developed at Loughborough attracted the attention of Professor John Blake, Director of the MSOR Network (University of Birmingham), which funded the printing, distribution and development of the series known as *Facts and Formulae*. In the following years hundreds of thousands of these leaflets helped students and resource centres around the UK.

3. Reasons for the establishment of mathematics support

Broadly speaking, whatever provision had been in place prior to the 1990's, there was a sea-change following the introduction of the GCSE examinations, which replaced O-levels, in 1986. The first GCSE examinations took place in 1988 and the first cohorts entered university in 1990. It was widely accepted that the GCSE *"brought a decline in students' concept of proof and in their technical fluency and understanding of algebra."* (Hawkes, T. and Savage, M. (2000)). One consequence was a dramatic fall in the number of students taking A-level mathematics from >80,000 (total Mathematics and Further Mathematics entries) to around 50,000. A-level mathematics was perceived as too hard for too many. A knock-on effect was felt by engineering departments many of which found themselves unable to recruit sufficient numbers of undergraduates with A-level mathematics and resorted, at worst, to requiring only a pass at GCSE. Clearly this qualification provided an insufficient mathematical background for success in traditional engineering courses. Provision of mathematics support was an attempt to alleviate this situation. The demographics of the university student population had changed significantly too. In the 1960's only around 5% of 17–30-year-olds studied at university. By 2013 this figure had reached 38% and is now around 50%. It is therefore not surprising that the level of academic support provided for students to succeed needed to change.

In 1999, a Gatsby Seminar (funded by the Gatsby Charitable Foundation) was held at the Møller Centre in Cambridge. This brought together practitioners from universities with the aim of evidencing the decline in preparedness of incoming students for the demands of university. Several delegates, including Lawson, provided detailed quantitative analyses following diagnostic testing which confirmed this decline. His ongoing research published afterwards demonstrated that: incoming undergraduates tested in 2001, having achieved a grade B in mathematics A-level, scored an average mark of 33.8 (out of 50), compared with students entering in 1991 who had achieved a grade N (a fail grade), 34.4/50 on the same questions (Lawson, 2003). A later study (Lawson, 2004) showed that those entering with A-level mathematics grade D in 1991 had an average score of 37.3 whilst students entering in 2001 with the same qualification scored only 29.1. Using the diagnostic test as a 'fixed metric', it appeared that there was roughly a decline of one A-level grade per two years during the 1990s.

The report *Measuring the mathematics problem* (Hawkes, T. and Savage, M. (2000)) followed from the seminar. It was seminal in that many of the anecdotal complaints about the challenges of teaching mathematics were evidenced and legitimised. Due to the wide diversity of types of university represented, no longer could a university claim that *"we don't have students like that in our university*". Two of the recommendations in that report were that (i) students embarking on mathematics-based degree courses should have a diagnostic test on entry, and (ii) prompt and effective support should be available to students whose mathematical background is found wanting.

4. A movement gaining traction

A delegation led by Sir Alan Williams (VC, Leeds) and Professor Mike Savage (Leeds) secured a meeting with government ministers to raise awareness of the challenges. The delegation met the Universities Minister, Margaret Hodge, and the Schools Minister, Stephen Timms, himself a mathematics graduate. The Secretary of State for Education and Skills at the time was Charles Clarke, also a mathematics graduate. The message delivered did not fall on stony ground. Clarke asked Professor Sir Adrian Smith to lead an inquiry into post-14 mathematics education. The resulting report *Making Mathematics Count* (Smith 2004) contained wide-ranging recommendations including the establishment of the National Centre for Excellence in the Teaching of Mathematics (2006) which continues today. The curriculum development body Mathematics in Education and Industry (MEI) was funded to set up and manage national initiatives to encourage and enable more students to study Further Mathematics (and later worked much more broadly). Importantly for universities the Smith Report noted *"Higher education has little option but to accommodate to the students emerging from the current GCE process*" (Smith, 2004, p 95). The need for mathematics support had been legitimized and effectively mandated from the highest levels.

Incidentally, Charles Clarke went on to edit the book *The 'Too Difficult' Box: The Big Issues Politicians Can't Crack* (2014), explaining why politicians find some issues too difficult to deal with, notably,

- difficulty identifying the problem;
- difficulty identifying the solution;
- difficulty working out how to implement a solution;
- difficulty overcoming vested interests;
- existing legal constraints;
- the lengthy process required to bring in legislation;
- a lack of political energy.

Perhaps many of us will see parallels with the mathematics problem and how this persists today!

By now a fair wind was behind those activists trying to develop solutions. In 2002, with funding from LTSN (the Learning and Teaching Support Network - later part of the Higher Education Academy, now Advance HE), HEFCE (Higher Education Funding Council for England) and the Gatsby Charitable Foundation, the websites **math**centre and **math**tutor were established (Figure 1). The former, intended to replicate a drop-in centre, was open-access, required no registration, and was populated with resources on key topics. **math**tutor was much more structured and was intended to mimic a personal tutor taking the student through all required material in a structured way. For the younger members of the readership, it is relevant to point out that technology has developed at a very rapid pace since 2000, and when **math**tutor was established it was not possible to stream the video resources - they were made available to all universities on a set of DVDs. This might seem strange to those who have grown up with fast broadband and the ability to make and watch videos on a variety of platforms. This was not the case as recently as 20 years ago and making videos necessitated hours in a TV studio with technical professionals. In 2010, **stats**tutor was launched largely due to the pioneering efforts of Alun Owen, Ellen Marshall and colleagues.

Figure 1. Screenshots of **math**centre, **math**tutor and a Facts & Formulae leaflet.

5. The sigma years

From 2005-2010 **sigma,** as a Centre for Excellence in Teaching and Learning (CETL), was awarded £4.85m as part of HEFCE's CETL programme. Led from Loughborough and Coventry, **sigma** (unlike many CETLs) was always outward-facing. Mathematics support was inspired, directly funded or supported at dozens of universities. Further funding followed when **sigma** was asked to lead the mathematics support strand of the National HE STEM Programme. In 2013 HEFCE was keen for **sigma**'s work to continue and an additional injection of funding was made until 2016. The Universities Minister, David Willetts wrote: *"Another important initiative is **sigma** - it is establishing approachable mathematics support services at institutions across the country. Thanks to their work, politics students suddenly confronted with a regression analysis have someone to turn to. STEM undergraduates too are receiving expert support to bring their maths skills up to speed."* (Willetts, 2013). By the end of HEFCE funding, **sigma** had directly facilitated the establishment of 36 centres across England and Wales.

From 2012, the work of **sigma** was upheld by the **sigma** Network, managed by voluntary members. A re-branded website, and a new JISCMail mailing list enabled the Network to champion the cause and provide developmental activities and mentoring for practitioners. Strong links with all parts of the UK and Ireland were developed and encouraged the formation of the Irish Mathematics Learning Support Network and the Scottish Mathematics Support Network. Welsh language versions of the *Facts & Formulae* were produced in collaboration with partners in Wales. Colleagues beyond the UK were inspired to develop centres, notably in Norway, the Czech Republic and Switzerland. Those working in these centres have become significant contributors to the growing international community of leaders, teachers and scholars of mathematics support.

After the end of external funding, the **sigma** Network continued to thrive with David Bowers working tirelessly to establish it more formally, now bound by a constitution and answerable to an AGM. It has since been responsible for producing newsletters, establishing Special Interest Groups, offering workshops, training of postgraduates, providing advice for those working with students who have various additional needs, and encouraging student partnership projects. The field has provided fertile ground for pedagogic research projects, masters and PhD students. **math**centre is being gradually updated and made more accessible not least through the efforts of Emma Cliffe at Bath.

An aim of the CETL programme was to recognise, reward and celebrate good teaching. **sigma** contributed to this aim through the **sigma** prize programme. Many colleagues from the UK and Ireland have had their contributions recognised in this way. In 2011, **sigma**'s own contribution was highlighted by it winning the Times Higher Award for Outstanding Support for Students.

6. The mathematics problem persists 2010-2020

Despite these efforts, sadly the problem persists and, in some ways, has worsened. In 2011, a report from the Advisory Committee on Mathematics Education (ACME) noted:

"We estimate that, of those entering higher education in any year, some 330,000 would benefit from recent experience of studying some mathematics at a level beyond GCSE, but fewer than 125,000 have done so".

(ACME Mathematical Needs 2011)

Disciplines, which were traditionally not so mathematical, are relying more on mathematics and statistics. The Biotechnology & Biological Sciences Research Council (BBSRC) in its Strategic Plan 2010-2015 - *The Age of Bioscience* - noted:

"As bioscience becomes increasingly quantitative, there is also an urgent need to raise the mathematical and computational skills of biologists at all levels."

(BBSRC 2010)

The Social Sciences and Humanities are now also generating work for mathematics support practitioners:

"The UK is weak in quantitative skills, in particular but not exclusively in the social sciences and humanities…. another reason for the poor skills of undergraduates is the dearth of academic staff able to teach quantitative methods"

(British Academy 2012)

7. Concluding remarks

Mathematics support has come a long way since its early days as a cottage industry. Joe Kyle went on to write:

> *"…. Now only a few years on, we see that the concept of mathematics support has not only become firmly embedded in UK Higher Education, but colleagues have moved on to gather data on the way students use such resources and look for optimal strategies for the delivery of this support, and this is perhaps the most convincing evidence of acceptance. Mathematics support came of age in the first decade of the 21st century. What might once have been described as a cottage industry now plays a respected and widely adopted role in Higher Education*."

(Kyle, J, in Marr & Grove, 2010)

Clearly there is much for the community to celebrate despite the mathematics problem persisting. Perhaps the issue of mathematical preparedness might well be in the 'too-difficult box' (Figure 2) but nevertheless there are many of you still trying hard to crack the problem.

Figure 2. The 'too-difficult box'.

Thank you to everyone who has played a part in taking us from the cottage industry to our healthy community, evidently thriving today. The challenges are still there but the people in this room and with us online are amongst those who will face them head-on, and make a difference.

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CASE STUDY

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

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Abstract

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

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

1. Introduction

Munster Technological University (MTU) is a higher education (HE) institution in Ireland offering more than 100 degree programmes over six campuses, with a student body of more than 18,000. Here mathematics is largely a service discipline where 77.3% of programmes contain at least one mathematics/statistics module. In the 2020-2021 academic year, 71.3% of all incoming students took a mandatory mathematics/statistics module in their first year. A typical degree programme at MTU comprises six 5-credit modules taken in each semester. The majority of mathematics/statistics modules are designed in a format of 3 hours of formal lectures, 1 hour of tutorial and/or lab work and 3 hours of independent learning per week. As students are normally assessed in all six modules in a semester, with several modules delivered as continuous assessment only, the assessment schedule is rather heavy. At the same time, many HE students work part-time jobs. A survey conducted by Technological University Dublin showed that 63% of students had part-time work in 2019 (Burns, 2020). Though there are maths-enthusiastic and well performing students in every class/cohort, a rather common hallmark in service mathematics modules is the issue of low engagement and subsequent low achievement. This in turn may impact a student's performance in other (applied) disciplines and, ultimately, their progression. Mathematics does prove to be a challenge for a considerable proportion of non-mathematics undergraduates and especially so during the transition from post-primary school[1] into first year in university, a common phenomenon in HE (Liston & O'Donoghue, 2010; Harris & Pampaka, 2016). In some programmes at MTU, up to 40% of first-year students fail their mathematics/statistics module at their first attempt. Additionally, there can be a diversity of mathematical backgrounds in class due to the different paths into the university and varied entry requirements. These challenges sometimes interact, thus making the learning environment demanding on the student but equally presenting multiple challenges for the lecturer (Liston & O'Donoghue, 2010).

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

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

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

2. Methodology

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

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

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

Table 1. Student cohorts that completed the survey

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

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

3. Results and discussion

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

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

Table 2. Student expectations and challenges

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

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

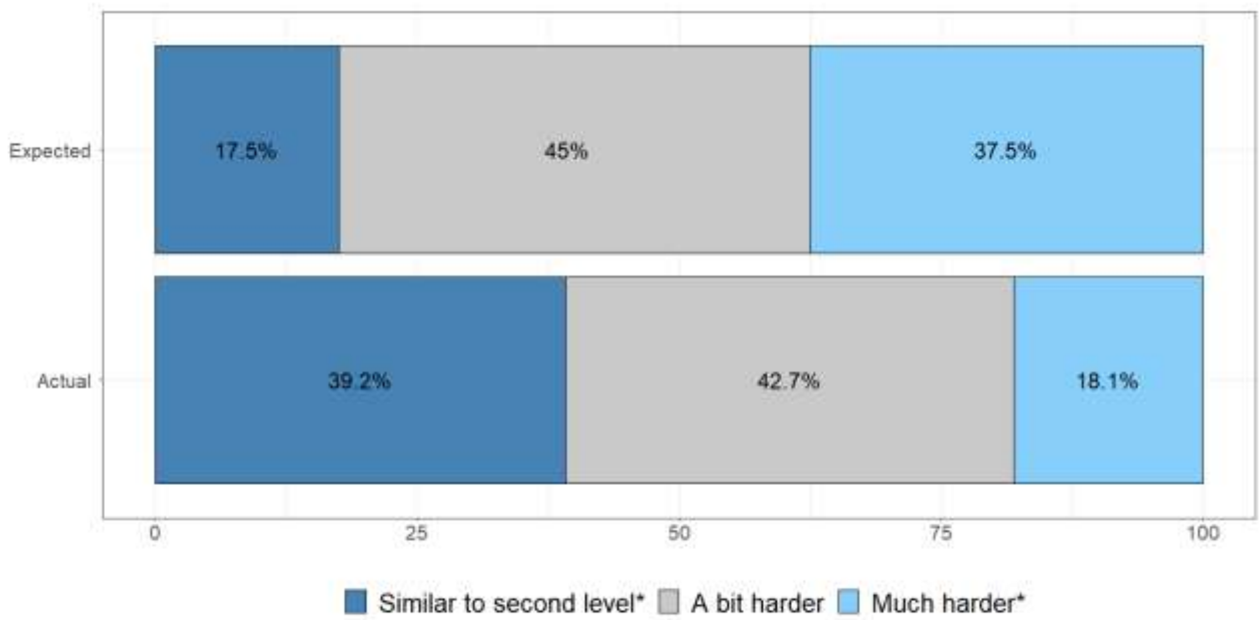

Figure 1. Shift in students' views on university mathematics after experiencing it (n = 309). *Changes from *Expected* to *Actual* were found to be statistically significant ($p < 0.001$).

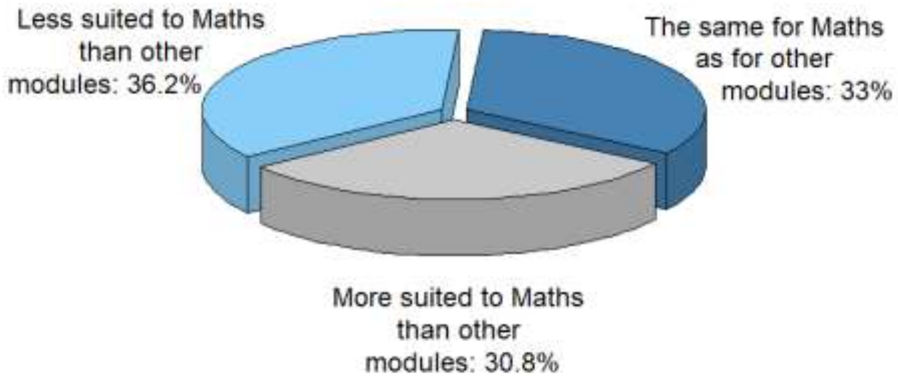

Figure 2. Views on the suitability of mathematics for remote delivery (n = 224).

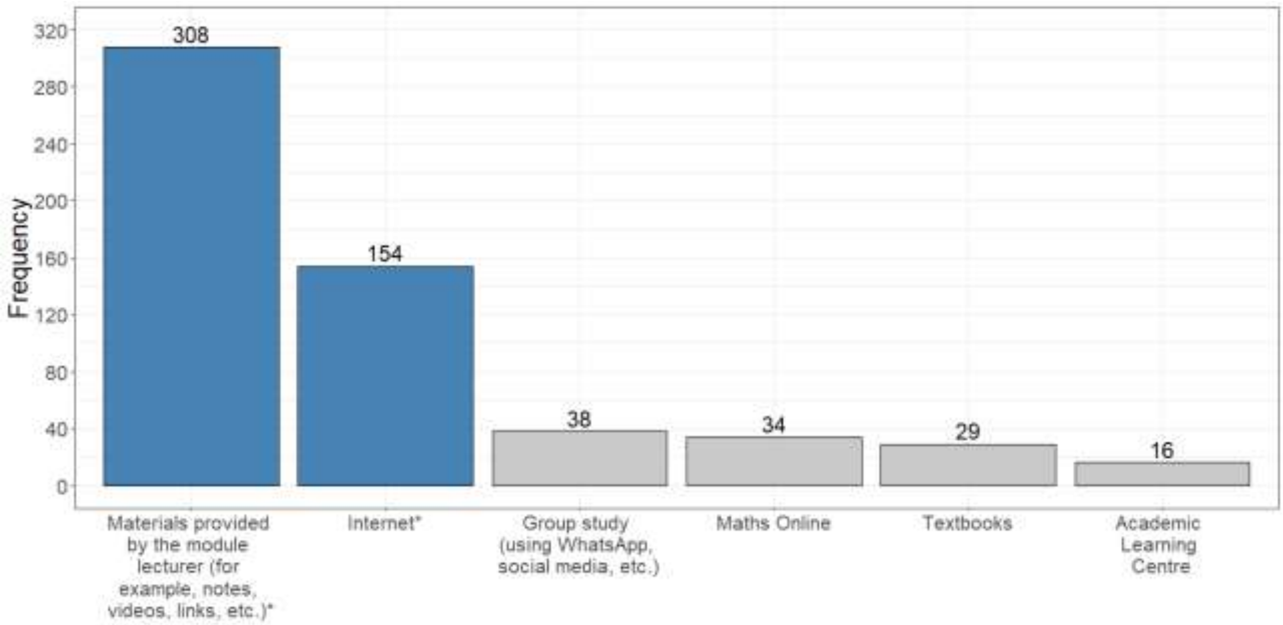

Figure 3. Use of resources during remote delivery[2]. **Material provided by the module lecturer* and *Internet* are the two most used resources during remote delivery ($p < 0.001$).

3.2. Views on remote learning experience

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

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

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

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

3.3. What's to dislike about maths?

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

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

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

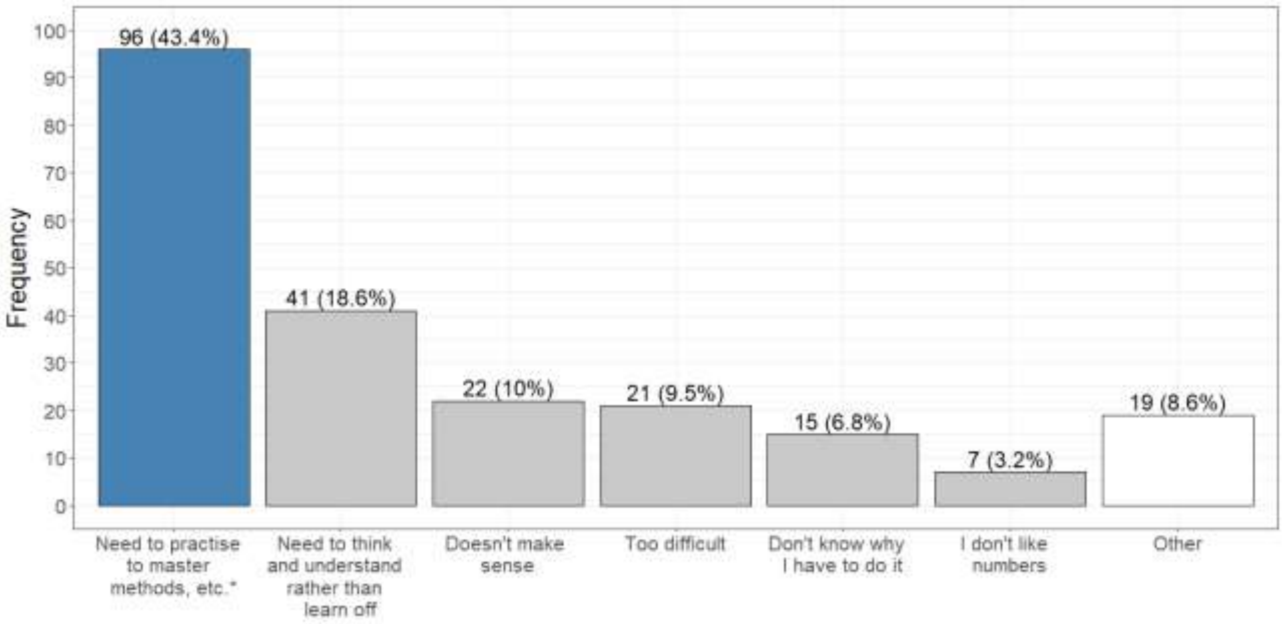

Figure 4. Aspects of learning mathematics that students dislike most (n = 221). 88 students (not shown here) stated they disliked *Nothing*. **Need to practise to master methods, etc.* was the main aspect of learning mathematics that students disliked the most ($p < 0.001$).

3.4. Study approach

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

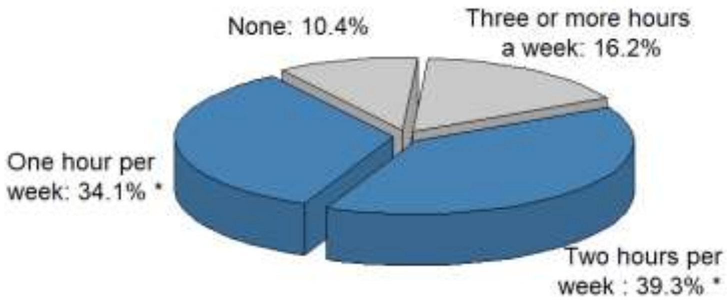

Figure 5. Time spent by students working independently (n = 308). *Students responded they mainly work independent on average *One hour per week* or *Two hours per week*. As opposed to a minority of students responding *None* or *Three or more hours a week* ($p < 0.001$).

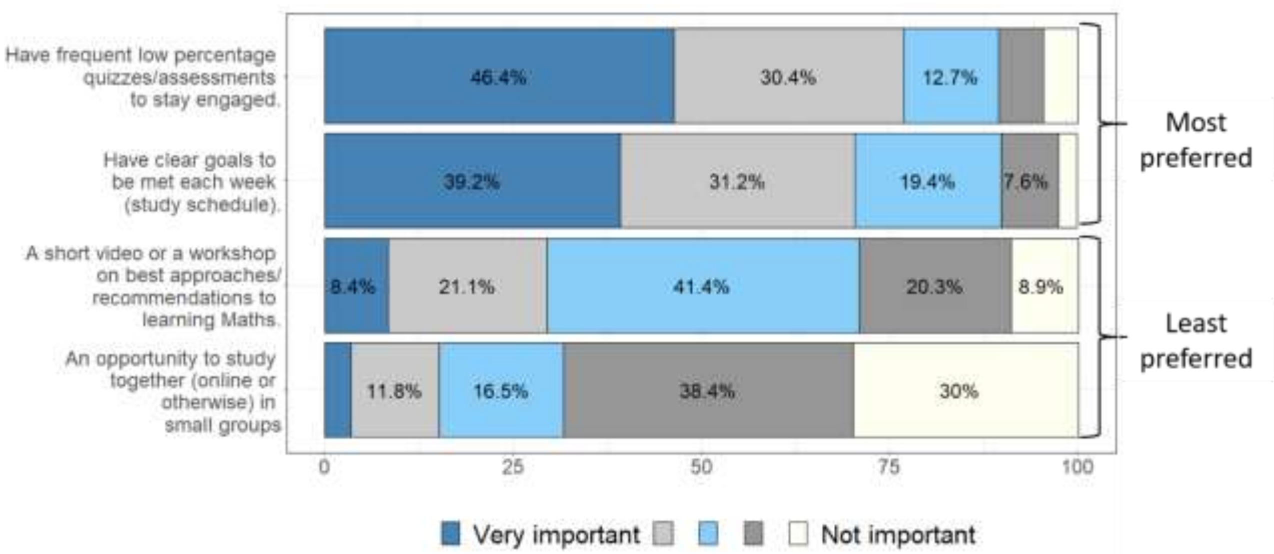

Figure 6. Students' views on most helpful learning supports, ranked in terms of importance (n = 222), with frequent low percentage quizzes/assessments and having clearly identified goals to be met each week as most helpful ($p < 0.001$).

3.5. Students' preferences for digital maths learning resources

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

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

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

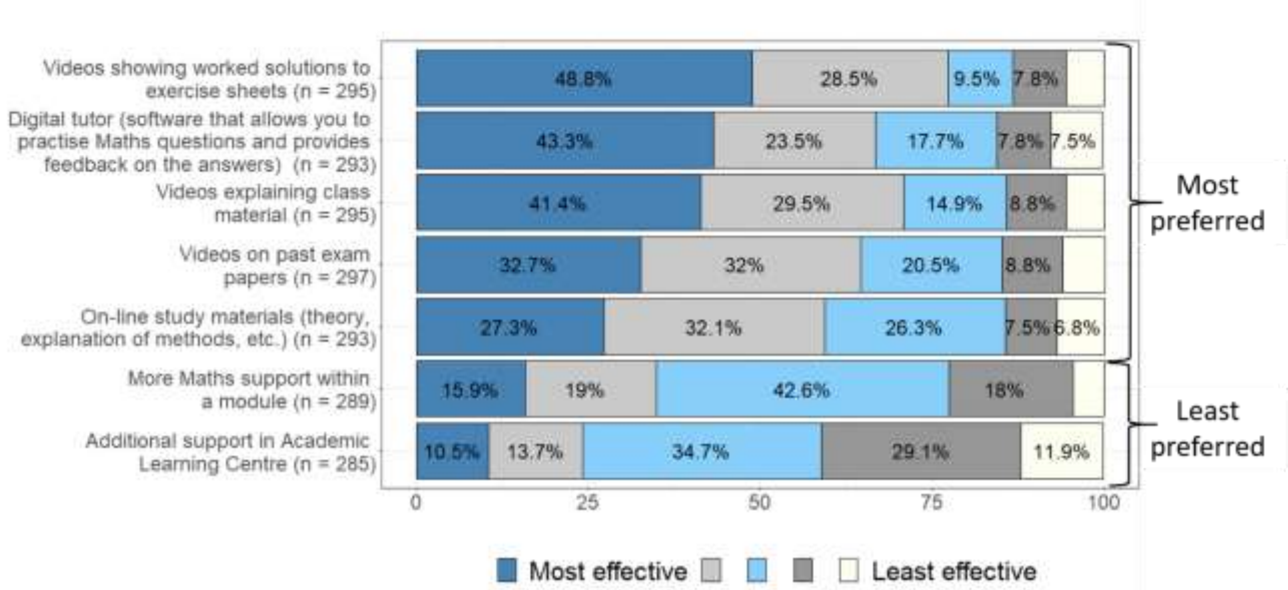

Figure 7. Digital resources rated in terms of effectiveness. Students' most preferred options were learning resources involving videos, along with a digital tutor ($p < 0.001$).

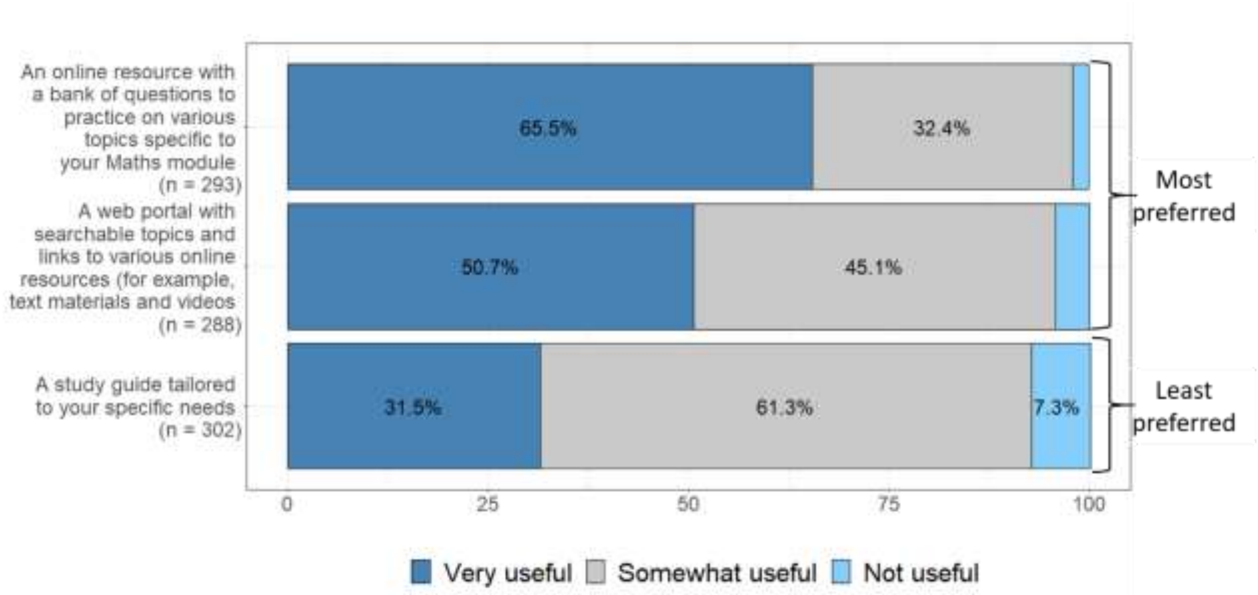

Figure 8. Digital resources rated in terms of usefulness. Students' most preferred options were resources containing a bank of questions and a web portal with searchable topics ($p < 0.001$).

4. Conclusions

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

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

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

5. Acknowledgements

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6. Ethical approval

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

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Appendix. Questionnaire

Q1 Do you find maths difficult?

- Yes
- No

Q2 When choosing your degree course did you realise a maths module was going to be compulsory?

1. Yes
2. No

Q3 Before entering college did you expect maths at third level to be …

1. Similar level to Leaving Cert maths
2. A small bit harder than Leaving Cert maths
3. A considerable step up from Leaving Cert maths

Q4 After entering college I found the level of maths.

1. Similar to Leaving Cert maths
2. Somewhat harder than Leaving Cert maths
3. A considerable step up from Leaving Cert maths

Q5 Which one of the following statements do you agree most with? *Choose one.*

1. I find remote learning more suited to maths than other modules.
2. I find remote learning the same for maths as for other modules.
3. I find remote learning less suited to maths than other modules.

Q6 Which of the following resources do you use for your maths study?
Choose as many as apply.

1. Materials provided by the module lecturer (for example, notes, videos, links, etc.)
2. Textbooks
3. Internet
4. Academic Learning Centre
5. Maths Online
6. Group study (for example, PALs Group study (using WhatsApp, social media, etc.)
7. Other (please specify)

Q7 What do you dislike most about Maths?
Choose one

1. Nothing
2. Need to think and understand rather than learn off
3. Need to practice to master methods etc.
4. Too difficult
5. Doesn’t make sense
6. Don’t know why I have to do it
7. I don’t like numbers
8. Other (please specify)

Q8 On average, how much time per week did you spend working independently* on your maths module? *Choose one*.
* Working independently relates to any work additional to lectures (either live and/or pre-recorded) and tutorials/labs.

- None
- One hour a week
- Two hours a week

- Three or more hours a week

Q9 In relation to learning maths remotely, what would be most helpful to your learning?
Please rank in order of importance (1 is VERY important and 5 is NOT important).
- Have clear goals to be met each week (study schedule).
- Have frequent low percentage quizzes/assessments to stay engaged.
- A short video or a workshop on best approaches/recommendations to learning Maths.
- An online meeting with 3rd/4th year students explaining do's and don'ts of learning Maths at MTU.
- An opportunity to study together (online or otherwise) in small groups.

Q10 What would be the most effective resources to help you master your maths at MTU?
Rate on the scale of 1 to 5, where 1 is not effective and 5 is very effective
- Videos on past exam papers
- Digital tutor (software that allows you to practice maths questions and provides feedback on the answers)
- Videos showing worked solutions to exercise sheets
- Videos explaining class material
- More maths support within a module
- Additional support tutorials in Academic Learning Centre
- On-line study materials (theory, explanation of methods etc.)

Q11 How would you rate the following digital resources in terms of their usefulness to you?
Each item rated on the scale: not useful, somewhat useful, very useful.
- A study guide tailored to your specific needs
- An online resource with banks of questions to practice on various topics specific to your maths module
- A MTU web portal with searchable topics and links to various online resources such as text materials and videos

CASE STUDY

Digital Resources for Targeted Mathematics Support

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Abstract

SPIRIT Maths (Students' Perceptions Informing and Redefining Innovative Teaching of Mathematics in Higher Education) is a project that was established in Munster Technological University (MTU) to investigate students' attitudes towards mathematics and to explore a more student-centred development of mathematics resources. One of the aims of the project was to create a collection of student-preferred digital materials with a view to improving student engagement, building students' confidence in mathematics and helping students to succeed in their mathematics modules.

The findings of a survey disseminated to first year students in MTU indicated that students would be most likely to use the resources if they were geared towards their specific module; to maximise impact, resources were developed for two modules, one in Engineering and one in Business, that are each taken by large numbers of students. The resources were integrated on the learning management system and are available to all MTU students taking a mathematics module. Three interlinked digital resources were developed: (1) a series of interactive self-assessment questions, (2) corresponding videos showing worked solutions and (3) an associated bank of practice questions developed using a digital tutor to provide instant feedback. It is hoped that the complementary resources will facilitate student learning through a combination of active learning, explicit instruction and the ready availability of the resources.

This article describes these resources and how they were developed, and outlines how these are being promoted to students. We also report on the feedback received from a small number of students who tested the resources and discuss how to measure student engagement with the resources.

Keywords: digital resources, mathematics and statistics support, student perspective, learning technology, online mathematics support.

1. Introduction

Munster Technological University, one of Ireland's newest Higher Education Institutions, was established on the 1st January 2021 from a merger of Cork Institute of Technology and Institute of Technology Tralee. The Department of Mathematics in MTU is primarily a service department and plays a key role in almost every programme in MTU. Out of 3,169 first year students in the academic year 2020/2021, 2,260 (71.3%) took at least one mathematics or statistics module. While mathematics is clearly a fundamental aspect of many programmes, it is often perceived as difficult and can present an obstacle to students from other disciplines. For example, up to 40% of first year students on some programmes failed a mathematics module at their first attempt. To address this, the SPIRIT Maths project sought students' insights and preferences in relation to their study of mathematics and created resources based on these findings.

As part of the SPIRIT Maths project, two surveys (for students who enrolled pre and post COVID-19) were disseminated to over 1,600 first year MTU students in June 2020 and February 2021. These surveys invited students to share their experiences, perceptions and attitudes towards mathematics. Comparison of the results from the two instances of the survey revealed no statistically significant differences, so the responses from the two surveys were combined. Any references to survey results for the remainder of this paper therefore refer to results from the combined data. When participants were asked to rate a selection of resources to help them to master their mathematics modules, "Videos on past exam papers", "Digital tutor" (software allowing students to practise mathematics questions and receive feedback) and "Videos showing worked solutions to exercise sheets" were each rated as 5 (most effective) by 33.3%, 42.3% and 49.5% of respondents respectively (n = 312, 309, 309 where n refers to the number of respondents who ranked each of the given resources). Furthermore, when asked to rate the usefulness of specific digital resources (as one of "Not useful", "Somewhat useful" and "Very useful"), 72.9% of respondents rated an online bank of practice questions specific to their mathematics modules as "Very useful", while 51.8% of respondents rated a web portal with searchable topics and links to online resources such as text material and videos as "Very useful". The findings of the survey informed the development of the digital resources which we describe below. For further details on the SPIRIT Maths survey, see Lishchynska et al. (2022).

The remainder of this paper is structured into five sections. In Section 2 we present the design objectives and features of the resources, in Section 3 we discuss how the resources are integrated into the online learning environment at MTU, in Section 4 we report student feedback following resource testing and in Section 5 we consider how to monitor student engagement with the resources and discuss the main points to consider for future resource development.

2. SPIRIT Maths Resources

2.1. Design Objectives and Implementation

Informed by the results of the SPIRIT Maths student survey, and the resource developers' teaching experience, the SPIRIT Maths resources were designed to satisfy four key requirements: the resources should: (1) be time efficient from the student's perspective, (2) be tailored to the student cohort, (3) facilitate active learning and (4) be easy for the student to navigate and access relevant materials. Considering these requirements, three interlinked digital resources were developed: a series of interactive self-assessment questions, corresponding videos showing worked solutions and an associated bank of practice questions (see Figure 1). The three interlinked resources were developed for two first year mathematics modules at MTU, one delivered on a business programme and the other on an engineering programme. Both modules are taught to a large number of students (approximately 500 students combined), and both modules suffer from high failure rates. The resources were piloted by a small group of student volunteers and the feedback gathered was used to further improve the resources. We discuss the features of each resource and their implementation below and highlight how, together, they satisfy the four design objectives.

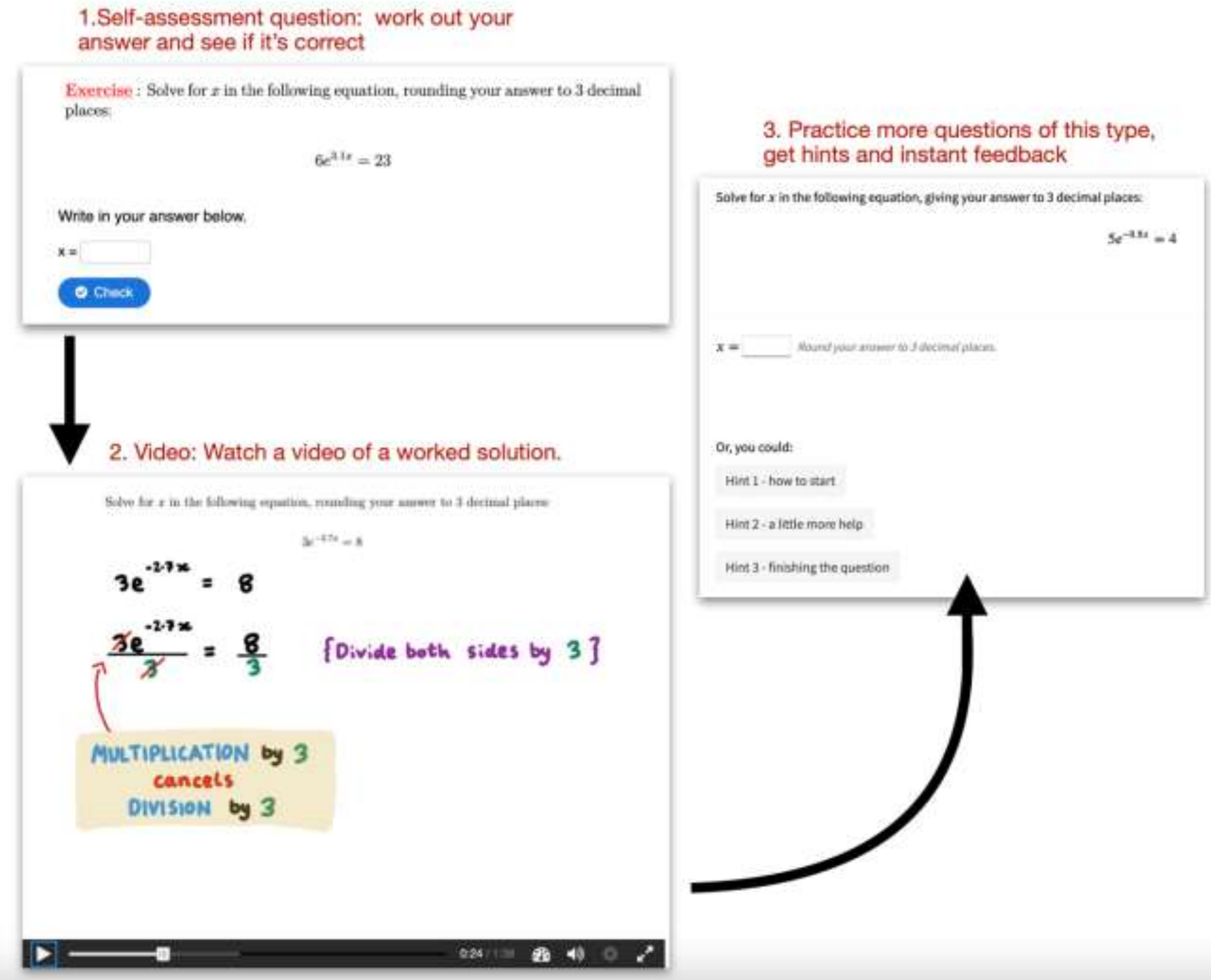

Figure 1. An example of the three interlinked digital resources to support student learning.

2.2. H5P self-test questions

H5P is a software tool which can be used to create interactive web content. It integrates easily with most of the common learning management systems, including Canvas, the system used in MTU. H5P was used to write an initial self-test question based on exercise sheets or past exam papers where the student can test their existing knowledge. The "Fill in the Blanks" content option allows the user to enter their answer, which can then be verified by clicking the "Check" button. Reports of submitted answers are available to the lecturer; monitoring these can provide valuable feedback showing where exactly the students are going wrong (see Figure 2). If the student correctly solves the question and is comfortable with the content, they can then focus on other topics that they are less comfortable with. As well as the benefits associated with time management, the H5P self-test questions also engage the user with the material from the start; students are required to actively solve a problem rather than absorb information passively. The benefits of active learning are widely acknowledged (Prince, 2004; Freeman, et al., 2014), and in addition to this, an incorrect answer provides strong motivation to focus on the accompanying video.

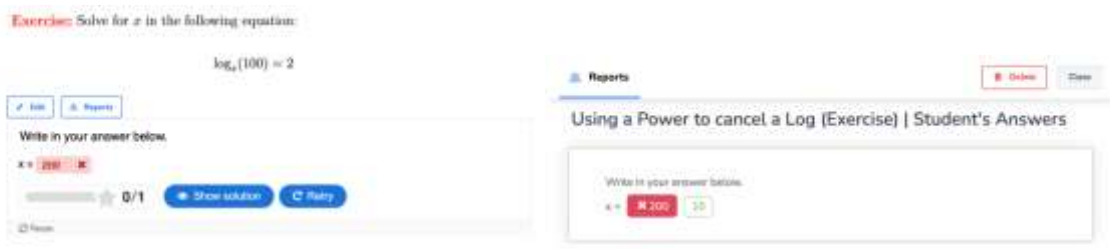

Figure 2. An example of one of the H5P self-test questions (left) and the lecturer's view of the submitted response (right).

2.3. Videos

Each H5P self-test question is followed by a video providing explicit instruction on how to answer the question. In a study analysing 6.9 million video-watching sessions (of which 2.8 million were related to a statistics course), Guo, Kim and Rubin (2014) found that "video length was by far the most significant indicator of engagement" with recorded video content, and recommend videos of less than 6 minutes in length to maximise student engagement. The use of shorter videos to increase the likelihood of viewers watching the full video in a single sitting was also recommended by Nielsen (2020), following analysis of the use of video recordings in a flipped classroom course in engineering mathematics. Videos created in the SPIRIT Maths project were therefore kept short with most of them shorter than 5 minutes, and focused only on the key problem-solving steps, with a view to facilitating both engagement and time efficiency.

There are numerous short videos freely available online covering a wide range of topics in mathematics. Two popular examples include Khan Academy (Khan, 2022) and the videos from "3Blue1Brown" (Sanderson, 2022). However, rather than providing links to existing videos, lecturers created their own videos from scratch. The advantages of this are threefold; (1) videos can be tailored to course specific content; (2) according to the student survey, materials provided by the module lecturer were the most frequently used resources during remote delivery (Lishchynska, et al., 2022); (3) there is evidence that instructor generated videos can improve student learning (Hegeman, 2015). Lecturers creating the videos were given discretion in terms of the style of production, with some videos taking the format of a full-screen video showing the solution being handwritten by the lecturer, accompanied by a narrated explanation while others were designed as silent animated videos in which all problem-solving steps were written on screen. Students had an option to adjust the playback speed to a slower pace if they needed more time to process the steps.

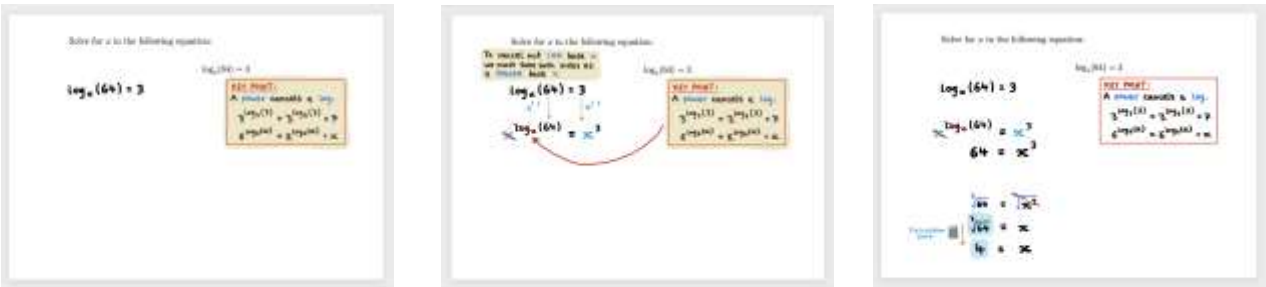

Figure 3. Images from one of the short, animated videos.

2.4. Numbas questions

Accompanying each H5P question and worked video solution is a bank of Numbas practice questions, accessed via a link below or beside the video. Numbas is an e-assessment tool that provides users with instant feedback and allows for a variety of question formats. Each Numbas question was created to match the corresponding H5P question and video solution, with the same wording, but with randomly generated numbers that change each time the question is generated.

The questions are structured to allow students to work at their own pace with a series of supports available depending on individual need. Students are initially invited to try the question themselves and enter their answer. If their answer is correct, they have the option of trying further questions by selecting “Try another question like this one” at the end of the question. If their answer is incorrect, or if they are unsure how to start the question, students can select “Reveal answers” to see a full solution to the question before trying a new question of the same type. For some questions, as well as the full solution, students have the option of selecting one or more hints to help guide them through the question (see Figure 4). After each hint, students can continue with the question themselves or request a further hint. Both the hints and full solution emulate the corresponding worked video solution.

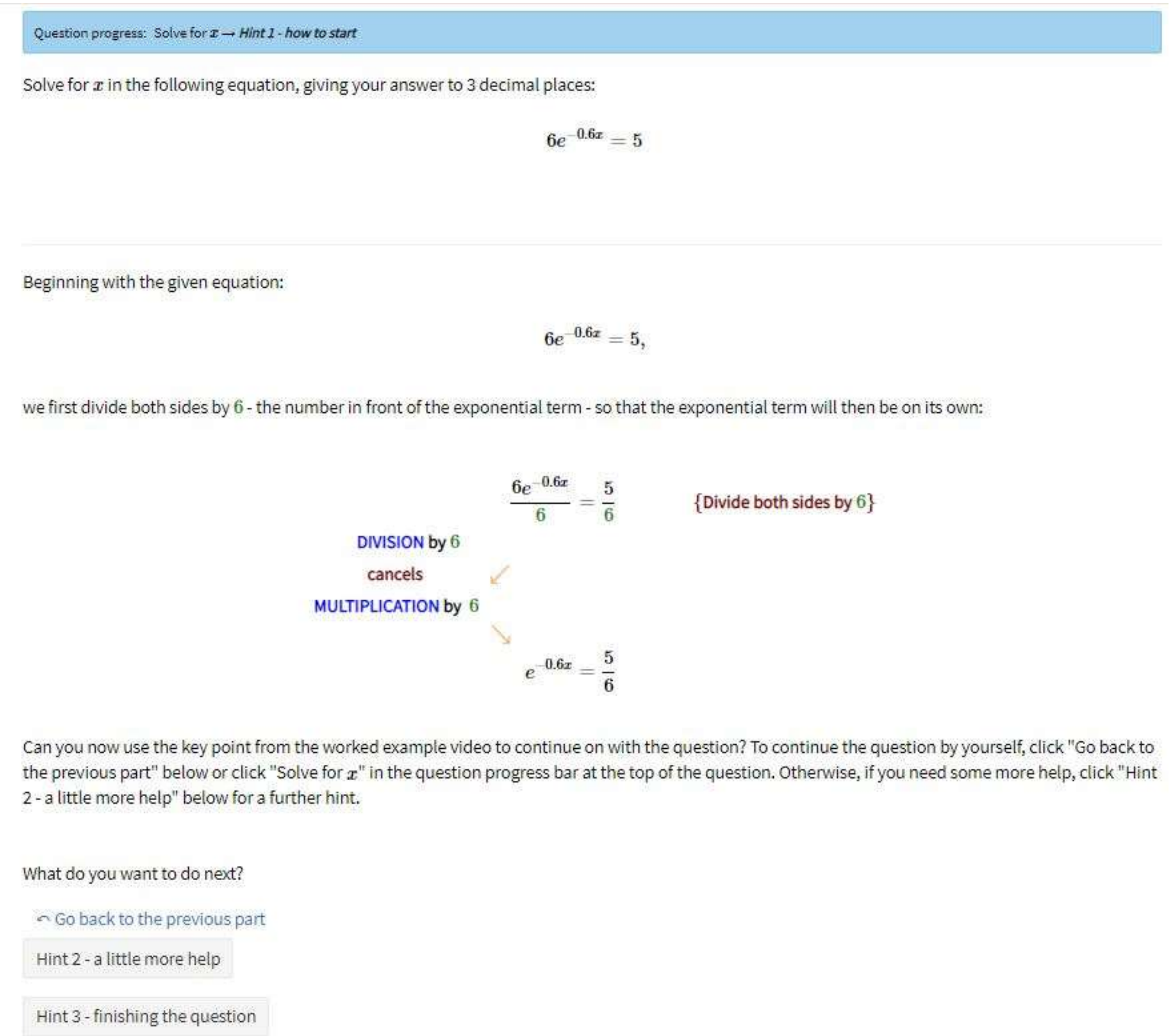

Figure 4. Students can access step-by-step hints to help guide them through the question.

In addition to providing worked solutions and hints, Numbas can also be set up to provide feedback to address misconceptions and catch common errors. If a student enters an incorrect answer that indicates the answer was arrived at due to a particular misconception, then specific feedback can be provided, explaining why the answer is incorrect and how to obtain the correct answer (see Figure 5).

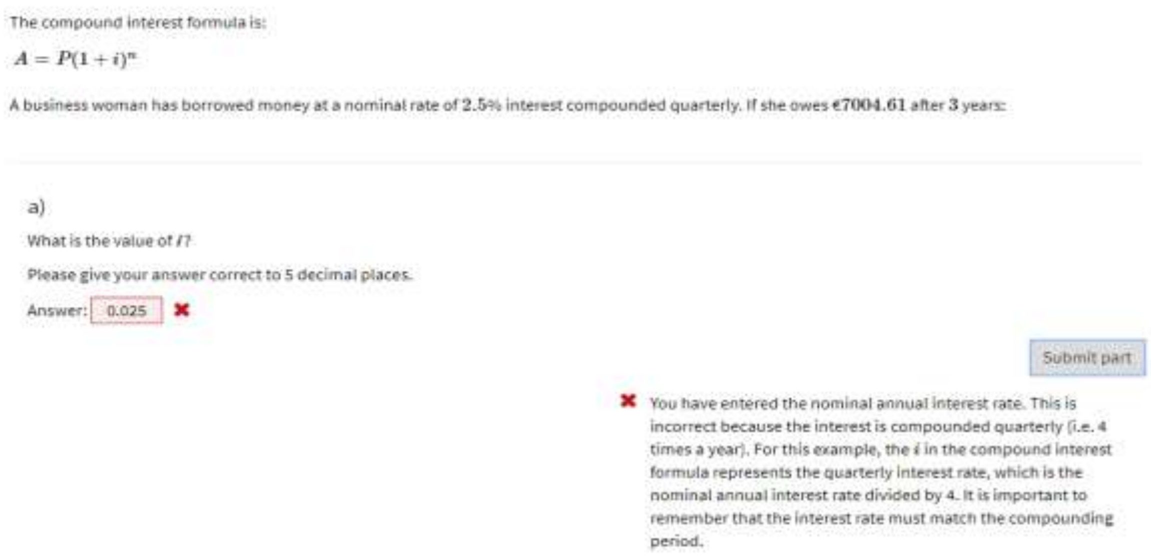

Figure 5. Specific feedback is provided to address common misconceptions.

The inclusion of practice Numbas questions facilitates student learning through: (1) formative feedback which enables students to gauge their own understanding of the material, (2) explicit instruction in the form of step-by-step solutions, (3) scaffolding by breaking down questions into parts with optional hints, (4) catching common misconceptions by providing specific feedback for common incorrect answers and (5) encouraging flexible thinking by providing students with problems that seem different on the surface but have the same underlying structure.

2.5. H5P or Numbas?

The initial self-assessment questions were developed using H5P while the banks of practice questions were created using Numbas. Both systems serve a similar purpose in the project – providing an interactive platform for students to test their knowledge of mathematical concepts. When initially developing the resources, the team was keen to utilise individual resource developers' own knowledge and familiarity with specific tools, in order to maximise the potential of the systems used and also to avoid the additional investment of time associated with learning a new system. As the project evolved, various differences between the two systems emerged. Questions developed using both H5P and Numbas are easily embedded into a page on learning management systems such as Canvas, with little difference in terms of presentation or usability. However, Numbas proved significantly more flexible in terms of the types of student response that could be accepted as well as offering a wider range of question styles, including the option of randomising variables if required and providing customised feedback. On the other hand, H5P does not have as steep a learning curve as Numbas and H5P questions have a slightly more attractive interface when embedded into a page. The specific types of question and answer required and whether the option to provide multiple questions using different randomised variables is desired might therefore inform a potential resource developer's choice of system.

3. Online learning at MTU

The SPIRIT Maths resources are integrated within Canvas via “Maths Online”, a specialised Canvas module developed by the mathematics support centre in MTU. This module serves as a hub for all things maths support related; students can book one-to-one help sessions with lecturers, attend topic specific workshops and access a wealth of additional maths materials. All students taking a mathematics module are automatically enrolled in the Maths Online module; in 2020/2021 approximately 3,500 students were enrolled. The resources on Maths Online are organised by module code/name, allowing students to quickly identify exactly which materials are relevant to them. The SPIRIT Maths resources are hosted within this existing structure, making the materials readily accessible to students. In addition to being able to access the resources by searching for a topic within their module, students can also access the resources through embedded links within the pdf files of past exam papers. By accessing a single pdf file, the student therefore has the solutions available at their fingertips if needed. Whether they need the guidance of the full video or just want to check their answers, all the student needs to do is click the link next to the part of the question they are working on (see Figure 6).

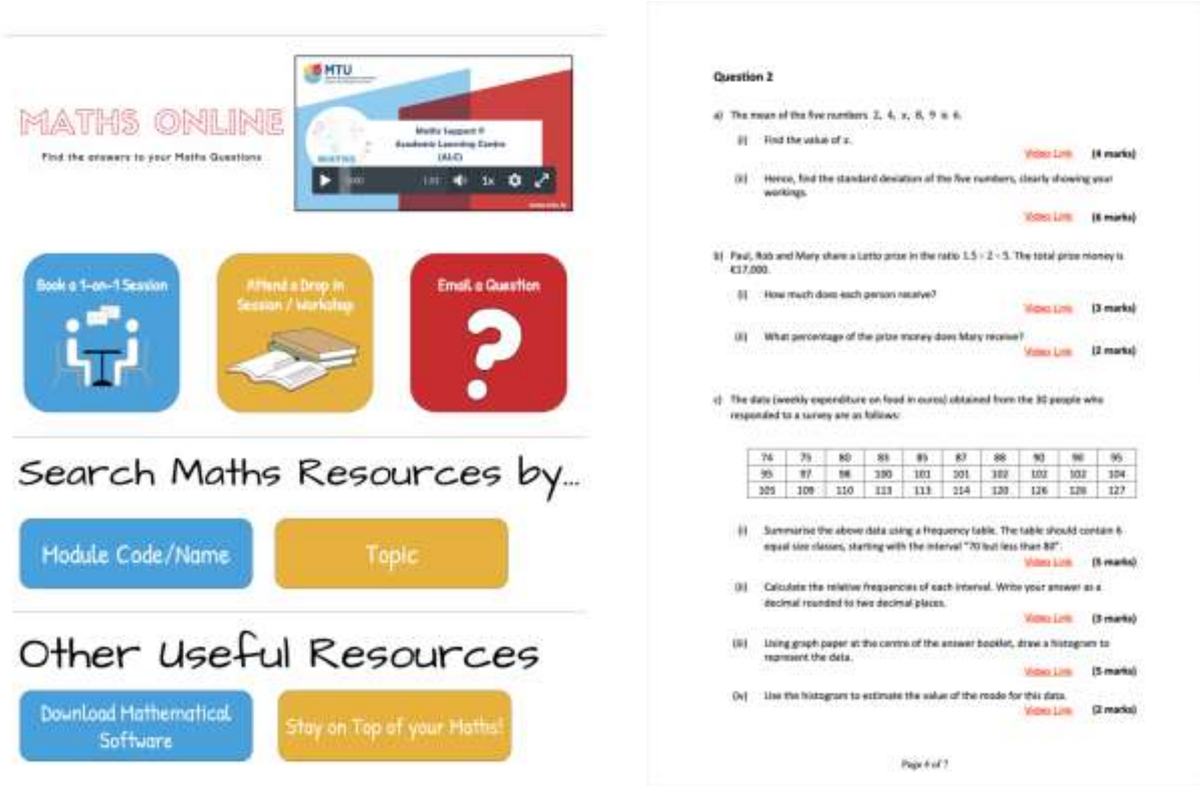

Figure 6. Students can access the resources by searching under Module Code/Name or Topic or by clicking on video links embedded in past exam papers.

4. Feedback

The first version of the resources was piloted by five volunteer students in semester two of the 2020/2021 academic year and feedback was gathered via an online survey and short follow up interview. Following initial feedback, the resources were updated and additional feedback was gathered from a further five students over the summer. The second round of feedback was a slightly longer survey that included additional questions regarding alternative layouts for the resources. All volunteers were asked to spend 1-2 hours testing the resources and were compensated for their time.

The surveys contained both qualitative and quantitative information. The quantitative information has been summarised directly and the main themes emerging from the qualitative data have been summarised following the guidance of Wellington (2000). The general response to the resources was very positive with an overall rating of 4.3 out of 5 (with a score of 5 being the most useful). The videos were identified as being the most useful resource with an overall rating of 4.6 out of 5. The clear explanations provided by the videos, the ability to rewatch solutions, to control the pace of learning and have immediate access to a solution were identified as the most useful aspects of the videos. Other positive aspects of the resources in general included: linking to similar practice questions in Numbas, instant feedback and having the resources in the one place.

The most common negative feedback was in relation to rounding issues in the H5P and Numbas questions, which highlights the importance of stating the accuracy required for each question and ensuring that the range of accepted answers reflects this. While some learners may have the knowledge to overcome small differences in answers, others could find this confusing and off-putting. More than anything, the feedback process highlighted how important it is to incorporate feedback into the creation of digital resources, from the point of view of content, layout and navigation. A striking example of this emerged during the interviews; one of the students had not noticed the links to the Numbas questions on the page. Finally, when asked about improvements to the resources, the following ideas were suggested: link the resources to lectures so the students can access them as they progress through the module; provide a tutorial or tooltip guide on how to use the resources; and incorporate a chatbox style function to allow students to ask a question and receive a response from a lecturer.

5. Conclusions and Future Work

In response to student preferences and considering the online learning environment at MTU, three interlinked digital resources were developed as an aid to independent learning. The resources scaffold self-directed learning in three complementary ways: by enabling students to gauge their own understanding through self-test questions with instantaneous feedback, by providing explicit instruction using short explanatory videos and by facilitating further practice of similar questions through Numbas.

Early feedback from a small number of students indicates that this format is effective for self-directed learning but it is important to ensure that the resources are working correctly and that students have clear instructions on how to use them. Those last two points may seem obvious but the feedback highlighted how issues that may seem small to one learner can be extremely confusing and frustrating to another. These small issues can easily be addressed in a face-to-face setting but can be overwhelming when encountered online. For ongoing feedback, as the resources are rolled out to students on a large scale, a short user experience survey has been incorporated into the resources pages. This will enable lecturers to fix bugs/errors and improve the resources as issues arise.

During the next phase of the project, we will roll out the resources to all first years taking the targeted business and engineering modules and the scope of the digital resources will be expanded to include material for further mathematics modules within MTU. To ensure that students are aware of the resources and understand how to use them, lecturers will provide links to the materials from the modules' Canvas pages and demonstrate the materials during lectures. Additionally, short instructional videos outlining how to use the resources will be provided on Canvas (see www.spiritmaths.com).

An important consideration for future work is the accessibility and usability of the digital resources. Having sought feedback from the Disability Support Service at MTU, we note that the silent animated videos may not be universally accessible and it is preferable to include both narration and captioning in explanatory videos to allow students to process the information in different ways. In addition to the videos, it is important to have an accompanying written explanation in the form of a pdf or MS Word file that can be downloaded for use with assistive technology. Video content management software such as Screencast-O-matic, and Panopto have incorporated speech captioning into their software using automatic speech recognition software. In our experience, automatic speech recognition software can struggle with captioning mathematics and often needs to be edited. Panopto also offers a human transcribed captioning service at additional cost. Decisions surrounding resource accessibility will need to be made on a case-by-case basis, taking into account the learning management systems and software available at an institution and weighing up longevity and frequency of resource use with financial considerations. In our experience, consulting with the Disability Support Service provided us with advice specific to our institution.

Measuring the impact of resource use on students' mathematical knowledge is difficult but can be approached following previous studies that assess the impact of Mathematics Support Centres (MSCs) on student grades and perceptions of mathematics, see Matthews et al. (2013) for an overview. The impact on student grades has been assessed by analysing either student pass rates or the grades themselves in the context of visits to MSCs. Studies by Dowling and Nolan (2006), Patel and Little (2006), Lee et al. (2008), Pell and Croft (2008) Mac an Bhaird, Morgan and O'Shea (2009) and Jacob and Ní Fhloinn (2019) all found that availing of the supports offered at the MSC had a positive effect on student grades. The study designs varied from comparisons of the pass rates of cohorts using the MSC to those who did not, to more complex analyses using regression models that accounted for other potential influential variables. Due to the observational nature of any data collection, measuring the impact of resource use on students' mathematical knowledge will be affected by a number of confounding variables; highly motivated students may be more likely to make use of the resources, students using these resources may also be making use of other resources, different lecturers have different in-class approaches etc. This issue has been acknowledged by previous studies and the inclusion of a student's performance on past exams may provide a measure of some of the potential confounding variables (e.g. Lee, et al., 2008; Mac an Bhaird, Morgan and O'Shea, 2009; Jacob and Ní Fhloinn, 2019).

Since the digital resources are embedded within Canvas, it will be possible to measure some useful indicators of student engagement with the materials using Canvas Analytics, including which resources were accessed by each student and how often they accessed each resource (see O'Sullivan, Casey and Crowley (2021) for details on how this information can be collected). There is potential to cross-reference individual Canvas Analytics data with end of semester module grades and grades obtained in matriculation examinations; however, issues regarding GDPR will need to be taken into consideration. Given the difficulties associated with quantifying the impact of the resources, it is important to also assess the impact of the resources qualitatively through student feedback (Ní Fhloinn, 2009; Matthews et al., 2013; Ní Fhloinn et al., 2014). Again, since the digital resources are embedded within Canvas it will be possible to gather student feedback through an online questionnaire accessed via the same page as the resources or to simply expand the user experience survey currently offered. The data obtained in such a survey could overcome any GDPR issues faced in obtaining sensitive information, such as student's performance on past exams, as this information could be obtained with the respondent's knowledge and consent. The large sample of basic information obtained using Canvas Analytics would be complemented by the smaller but richer information obtained via student feedback to provide a comprehensive assessment of the impact of the digital resources.

6. Acknowledgements

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CASE STUDY

PeerWise: Students' perceptions of creating questions for their peers

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Abstract

PeerWise (https://peerwise.cs.auckland.ac.nz/) is a system which allows students to create multiple-choice questions for other students, answer questions posed by their peers and then provide feedback (Denny et al, 2008). There is evidence in the literature to show this method of assessment has a positive impact (e.g., Guilding et al. 2021; Fergus et al. 2021; Feeley and Parris 2012), particularly on students' attainment and engagement. In a funded project, we introduced PeerWise into the assessment for a module at Sheffield Hallam University (U.K.) and another at La Trobe University (Australia). In this case study, we give an overview of PeerWise and the activities within the platform, results from our evaluation of the activity, and advice for implementation collected within the project from other practitioners around the world who have experience using PeerWise. Cohesive themes arising from our evaluation and the advice collected are summarised to form recommendations for improved student experience and outcomes, for future implementation of the PeerWise platform by practitioners.

Keywords: PeerWise, student-generated questions, problem posing, peer feedback, assessment.

1. Introduction and background

PeerWise (Denny et al, 2008) is a website (https://peerwise.cs.auckland.ac.nz/) where students can post multiple-choice questions for their peers within a closed course site. When setting questions, students present up to five answers, indicate which answer is correct and provide an explanation. Explanations may include worked solutions to a problem, reasoning for why a particular answer is correct, or reference to module materials. When answering questions written by their peers, students get to see the explanation once they have answered, provide feedback comments, and give two ratings: one for overall quality, as well as a difficulty score. Feedback provided can be of a general nature, or include suggestions for improved clarity of the question or explanation, or suggested corrections. Following feedback, students are able to edit their questions if desired. Students can see all the questions posted on the course site, the difficulty ratings and the feedback. All the activity, including summary pages, can be seen by the instructor accounts connected with the course site.

PeerWise is used in many different disciplines, including Computer Science, Psychology and Physics. Benefits include better exam performance, as reported in the study within Medicine by Guilding et al. (2021). Fergus et al. (2021) saw high student engagement in both formative and summative Chemistry assessment. Overall, as presented by Feeley and Parris (2012) in a Political Science example, more learning can result from the use of PeerWise. In particular, they found that there was a statistically significant association between the number of PeerWise questions answered and a student's change in rank in student performance, from midterm to final exam rank.

Within this case study, we present two examples of assessment that required students to use PeerWise.

1.1.U.K. University – first year module

The assignment at Sheffield Hallam University (SHU) in the first year of BSc Mathematics was a one-off assignment at the end of the module around number and algebra that had two deadlines: one for creating questions (part 1), and another for answering questions and providing feedback (part 2). Within part 1, the students were required to create one question on set theory and the other on binary operations. They had to highlight the correct answer and write an explanation. In part 2, the students answered at least two questions on each of the two topics that their peers had written, and leave feedback. The work was worth 5% of the module mark.

When marking the work after all parts of the assessment had been completed, there were a number of considerations which the students knew about before they undertook the assessment. If a question writer had made an error (e.g., they had marked the wrong answer as correct), this was picked up in the marking stage and the students who answered that particular question were given the credit for what they had done correctly, even if their answer was marked as incorrect on the system. When determining grades, the difficulty of the questions answered were taken into account. When marking the assignment overall (including questions, answers, explanations and feedback), factors such as communication, knowledge and understanding, demonstration of skills, whether the work was beyond expectation of the level, and correctness of answers determined the overall grades.

1.2. Australian University – third year module

Unlike the assignment at SHU, the assessment at La Trobe University (LTU) was ongoing throughout the semester in a third-year statistics capstone module. It contributed 10% towards the final module mark and was structured as follows:

1. 5% for writing one question per week (10 out of 12 weeks)
2. 2.5% for answering at least 25 questions correctly
3. 2.5% for the ‘reputation score’, which is based on question authoring, answering, and rating.

The reputation score is calculated within the PeerWise platform via an algorithm that encourages students to participate early rather than last-minute, and encourages quality and fair contributions. For example, students do not accumulate points simply for providing ratings. Rather, a student will gain a point when another student gives a particular question the same rating as they did. This encourages students to participate early, and also fairly, since unreasonable ratings are less likely to be agreed with by other students. In a similar manner, points are scored on the ‘answering’ component when a student correctly answers a question and another student then selects the same answer. For question authoring, points are scored by the author when other students rate a question either “good”, “very good”, or “excellent”. The reputation score is calculated as a combination of the question authoring, answering, and rating components, and higher scores are awarded to students participating in all three components rather than just one or two areas.

The marking was mainly automated by using the various scores from the PeerWise website. As students are able to provide feedback on their peers’ questions, many errors are corrected without the need for intervention by the lecturer. However, questions were checked to make sure they related to the weekly content. Also, since the reputation score depends on the number of students in the class, this was taken into consideration when using the reputation scores from the website.

2. Methodology

We aimed to evaluate the experiences of students in their use of PeerWise in Mathematics and Statistics in the modules. We were particularly interested in the experience of each stage of the process and any reactions to the visibility of their work. A questionnaire was conducted in classes at both SHU and LTU after the assessment involving PeerWise was carried out. In the modules under consideration (one from each university), all students were invited to take part.

Within the questionnaire, we checked which activities of the assessment they carried out. We asked 4-point scale questions regarding how they found creating questions and providing feedback. These were followed by open questions about anything they gained from each of the stages. They were asked closed questions about the most and least beneficial parts', and open questions about why.

The students were asked about the effect of each of the stages whether they thought their confidence, understanding and ability had increased, decreased or stayed the same. Students were not prompted to interpret confidence, understanding and ability in a specific context; rather, these questions were intended to gain insight into a student's perceived confidence, understanding and ability in the subject material overall. We asked whether it concerned them whether their question would be seen by other students, with the options of 'yes' and 'no'. They were asked whether their questions would have been better, worse or the same quality if they knew they would not have been available to other students and why. The evaluation is presented in Section 3.

Following the assessment and its evaluation, the authors noticed the variety in the strength of questions. In particular, some students stayed close to the taught material, e.g., by asking for definitions. In contrast, some students were able to demonstrate a deep level of understanding by creating entirely new questions where they had taken misconceptions into account. We also noticed the differences in how the two assessments had been done, and some issues (e.g., the amount of time to mark in the approach at SHU).

Student researchers used the list of PeerWise publications (https://peerwise.cs.auckland.ac.nz/docs/publications/) to identify academics who had used PeerWise, and subsequently conducted a short questionnaire which mainly contained open questions asking for advice on using PeerWise for assessment, how to encourage students to write high quality questions and general advice. The information gathered is presented in Section 4. In Section 5, common themes arising from the advice gathered and our own evaluation are summarised, leading to recommendations offered for future implementation in Section 6.

3. Evaluation

Students had the opportunity to fill in questionnaires in both modules. There were 9 and 3 responses from cohorts of 24 and 8 students at SHU and LTU respectively. Figure 1 shows that students generally found PeerWise easy to use, but there was more of a mixed response regarding the difficulty of creating questions.

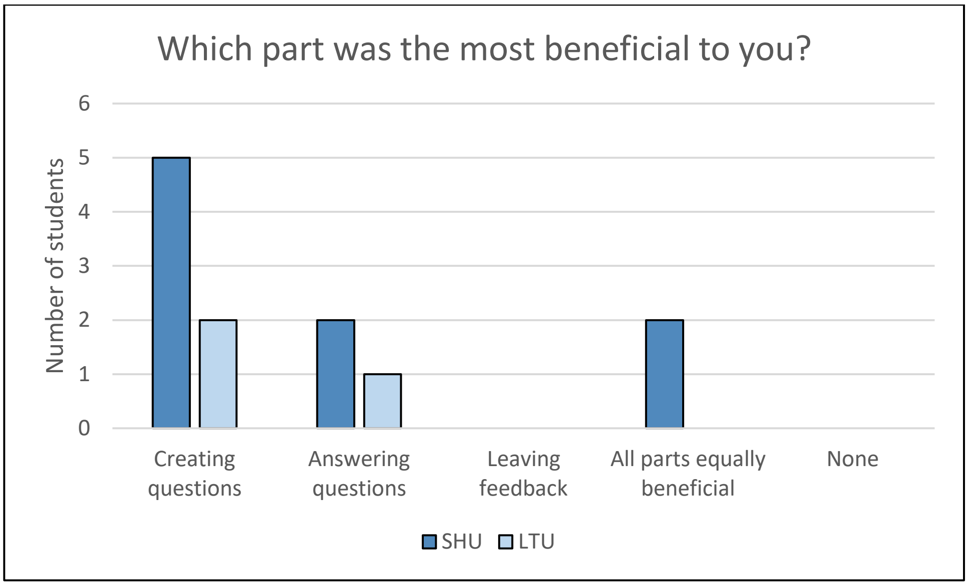

Figure 1. How students generally felt about parts of PeerWise (both SHU and LTU).

When asked what the most beneficial part of the assessment was, the most common response was creating questions. Some students selected answering questions or all parts (Figure 2). No students reported that leaving feedback was the most beneficial part, and no students reported “none”. When asked what part was the least beneficial, leaving feedback featured in the answers (Figure 3). Some students found that all parts were equally beneficial, with one SHU student providing the following comment:

“All parts worked well in different ways.” **(SHU student)**

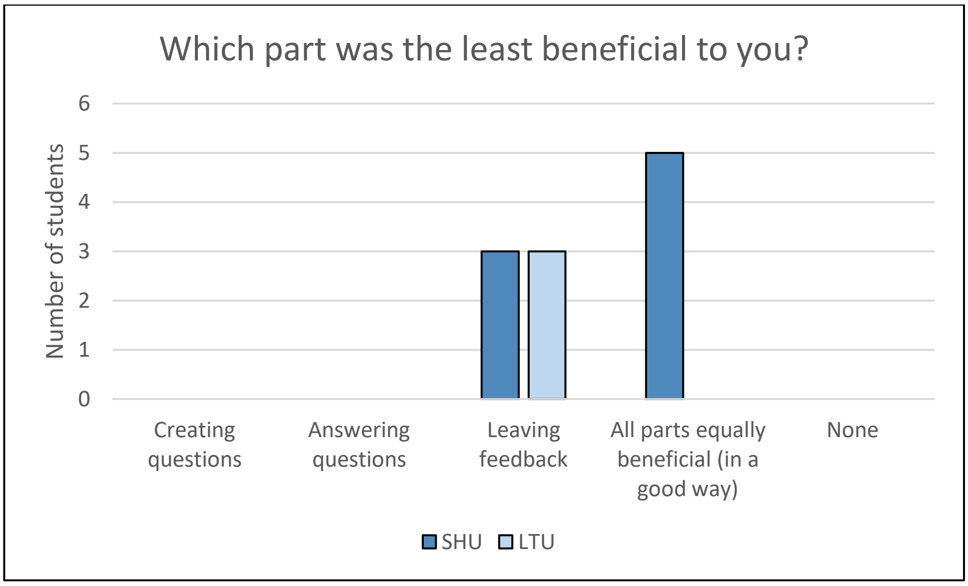

Figure 2. Student views on which parts were the most beneficial (both SHU and LTU).

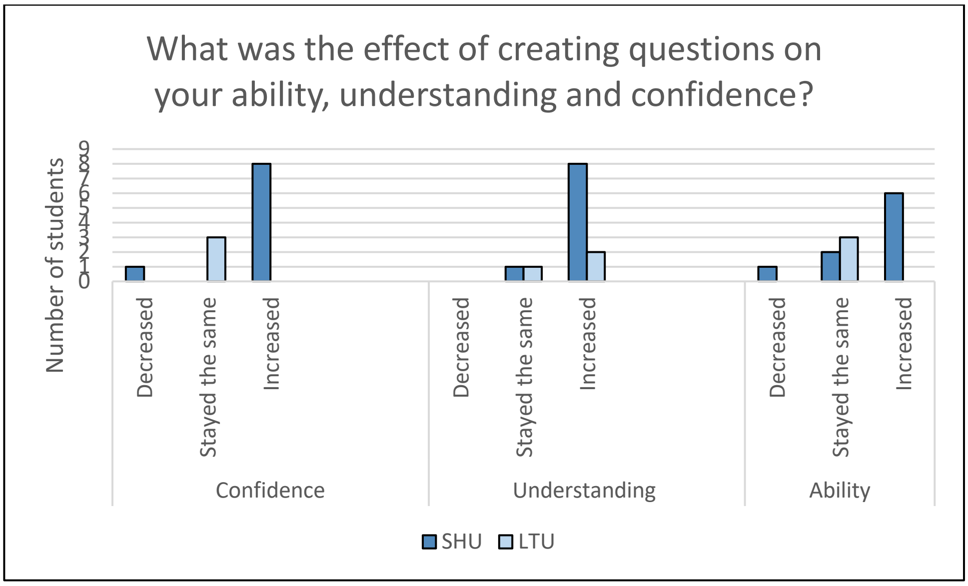

Figure 3. Student views on which parts were the least beneficial (both SHU and LTU).

Creating questions, answering questions and leaving feedback will now be explored in more depth.

3.1. Creating questions

When asked what they gained from creating questions, the most common responses were around engagement with module content (five SHU students). This is perhaps due to topics being selected at SHU that had not been taught for a while. It appeared to be a useful revision exercise. There were some comments about the activity helping with understanding of the module content (three SHU students). Three students (two from LTU and one from SHU) also said they learnt about designing questions in the exercise.

Amongst the students who thought that creating questions was the most beneficial part of the assessment, a couple indicated it was because of the understanding that this brought:

"Creating questions meant I had to develop a better understanding of the content to be able to put it into a question and explain the answer." **(SHU student)**

"Mainly it was coming up with a question answer combo that was unambiguous. That meant that I had to make sure that I understood the concepts surrounding the question I chose." **(LTU student)**

Another LTU student thought creating questions was the most beneficial part due to the revision being required:

"Was a chance to review previous learning and choose the most applicable knowledge to anwser [sic] the question" **(LTU student)**

As reflected in the student comments, Figure 4 shows that creating questions in PeerWise helped increase students' perceived understanding. Some of the SHU students reported that they thought it increased their ability and confidence, but none of the LTU students reported this. It is interesting that one SHU student indicated that creating questions had decreased their ability and confidence.

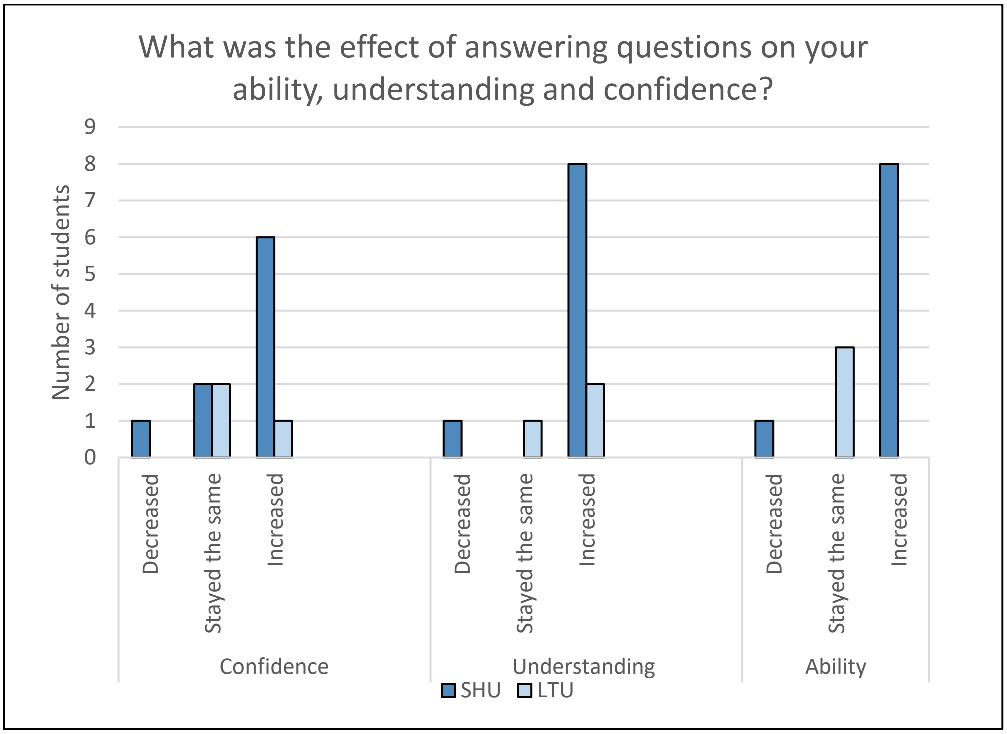

Figure 4. Students' views on the effect of creating PeerWise questions on ability, understanding and confidence (both SHU and LTU).

3.2. Answering questions

When asked whether they had gained anything from answering questions, one SHU student and one LTU student did not provide an answer. The rest of the SHU students said this part was useful for learning and/or revision (eight students) as it tested their understanding. The following student thought this part was the most beneficial part:

"It was the part that revised the subject the most as it asked questions I may not have thought of." **(SHU student)**

The following student highlighted how the mixture of questions was useful:

"Getting a variety of different questions from each student with different levels of difficulty" **(SHU student)**

One of the students also found it reassuring that they were not alone in finding content challenging:

"I saw what I assumed other people considered challenging topics, and felt at ease with myself for finding some of them quite difficult myself." **(SHU student)**

Both LTU students said that answering questions was beneficial for designing questions. The difference in the responses in Figure 5 from the SHU and LTU students can be explained by the way the LTU students regularly created questions following on from recent topics, whereas the SHU students only did this once on topics they had not encountered for a while.

Some students thought that answering question in PeerWise increased their ability, understanding and/or confidence (Figure 5). In the same way as creating questions, students most commonly reported increases in understanding as a result of answering questions. It is again interesting that one SHU student thought that all three factors had decreased because of answering questions.

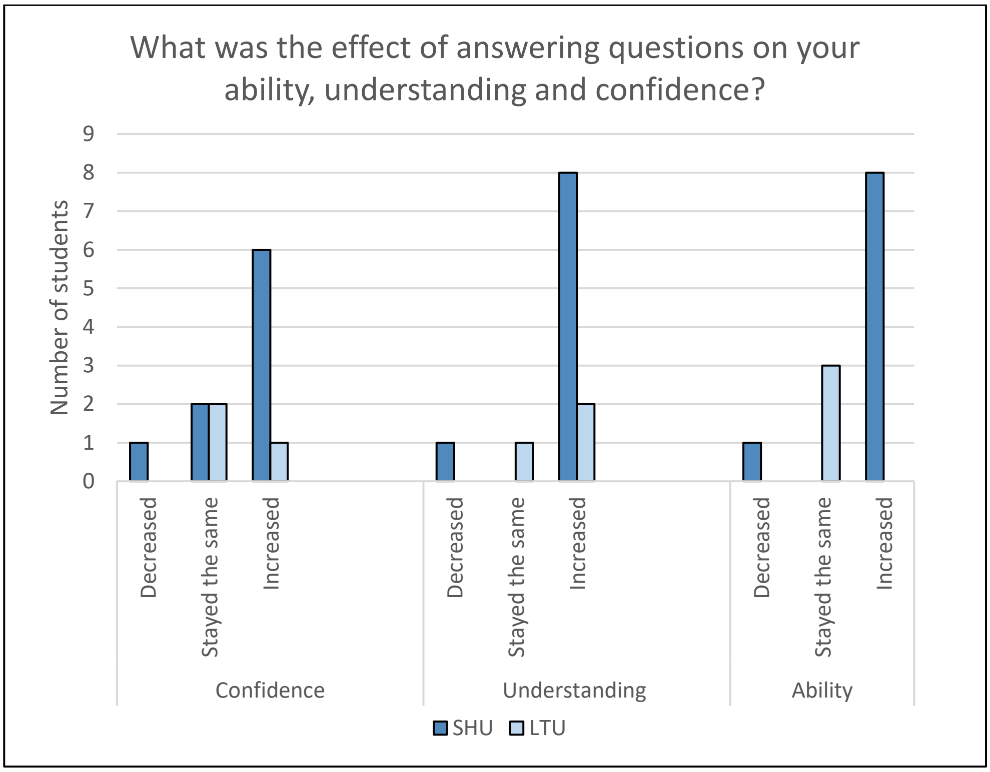

Figure 5. Students' views on the effect of answering PeerWise questions on ability, understanding and confidence (both SHU and LTU).

3.3. Giving feedback

Two SHU students and one LTU student did not provide a comment regarding whether they gained anything from giving feedback. Five SHU students pointed towards being able to reflect on question writing and two referred to learning. On the other hand, the LTU students focussed on the learning community advantages. The comments about what they gained from giving feedback were:

"The feedbacks were mainly for the lol's and the memes. I feel it brought me closer to my fellow students [sic] *though, as it built a sense of camaraderie."* **(LTU student)**

"How much banter people like." **(LTU student)**

The difference between the LTU and SHU responses here could also be partly due to the difference in assessment strategies, particularly surrounding the ongoing (LTU) versus one-off nature (SHU).

When indicating which parts of the assessment they thought were the least beneficial, a couple of students indicated that they thought leaving feedback for others was not helpful for them academically (one SHU student and one LTU student). However, one of these students thought it could have been helpful for others:

"I believe the feedback may have been more useful to the students I was providing it to." **(SHU student)**

The other student thought that leaving feedback was beneficial for enhancing the learning community:

“In an academic sense they were the least beneficial, but they were the most fun and they definitely gave us something to talk about and bond over” **(LTU student)**

The LTU students thought their ability, understanding and confidence stayed the same as the result of giving feedback (Figure 6). Although this was a common response amongst the SHU students, some of them thought that their ability, understanding, and/or confidence increased because of providing feedback.

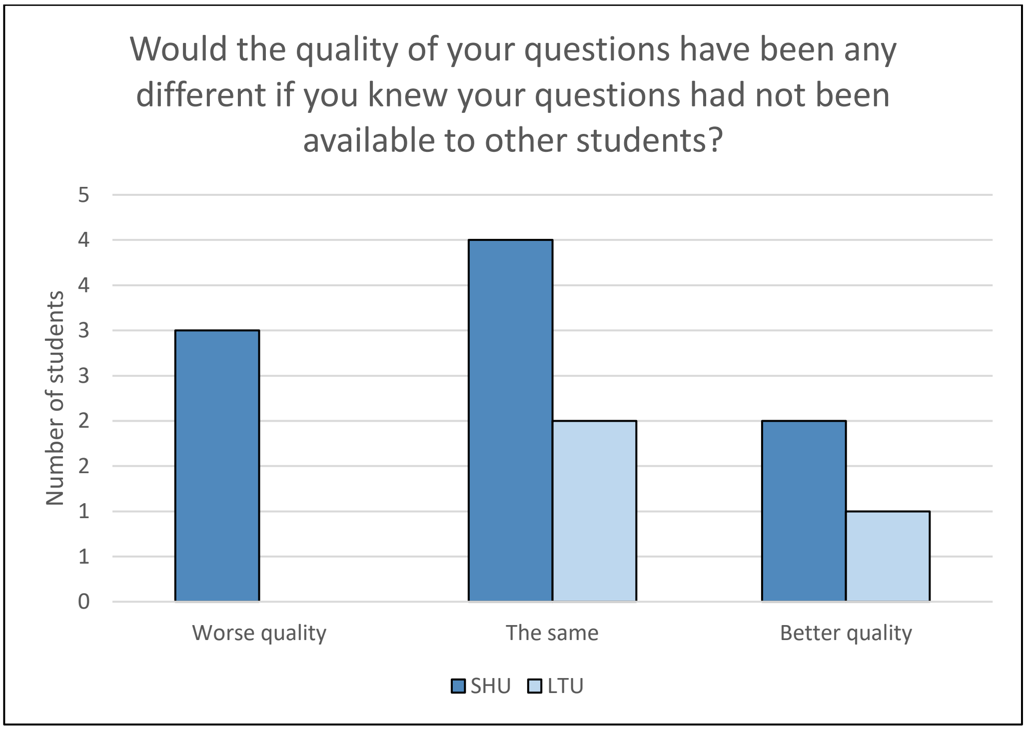

Figure 6. Students’ views on the effect of providing feedback on PeerWise questions on ability, understanding and confidence (both SHU and LTU).

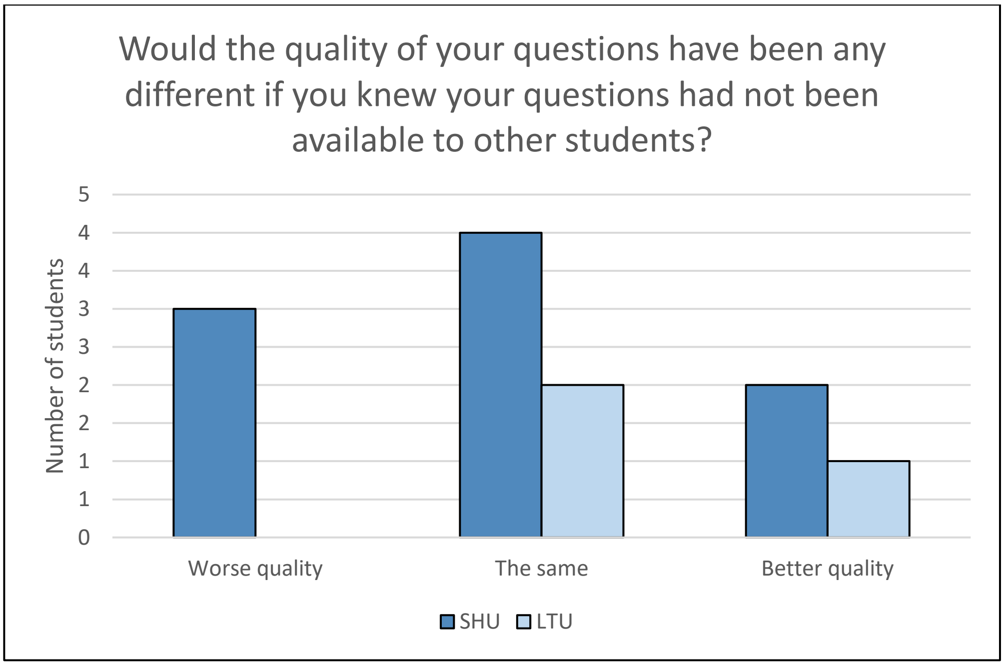

Figure 7. Student views on whether the quality of their questions would have been different if their questions had not been available to other students (both SHU and LTU).

3.4. Visibility and quality of questions

At SHU, two out of nine students were concerned that their questions would have been seen by other students, whereas seven were not. At LTU, none of the students were concerned about this.

When asked whether the quality of their questions would have been different if their questions had not been visible to other students, the most common answer was that they would have been the same (Figure 7). One SHU student, who provided this response, indicated that their focus was mostly on the marks:

"My grade is the most important thing so my work should not change based on who sees it because it should be consistent" **(SHU student)**

Amongst students who said their questions were either better or worse, there were reactions to the pressure of knowing their questions would be visible to other students. The following student had a positive response to pressure and said that their question would have been of a worse quality if their questions had not been seen by others:

"There comes a pressure not to look silly when presenting work to others especially people you know, friends, teachers, classmates." **(SHU student)**

There were a couple of students who had negative responses to the pressure, which meant they thought their question would have been better had it not been visible to other students. This is due to worries about other students and the fear of visibly making mistakes.

"Less stress to write questions, probably would have put a bit more effort or made them harder so others wouldn't worry too much about them." **(LTU student)**

"The idea of someone answering a difficult question I wrote (that might've been wrong) was potentially embarrassing." **(SHU student)**

4. Advice

Following our own experience of using PeerWise for assessment, we gathered advice from practitioners across the world regarding using PeerWise.

4.1. Encouraging students to write high quality questions

We collected examples on how students can be encouraged to write high quality questions. One indicator of a 'high quality question' is that it encourages higher-order thinking (Bloom, 1956), as discussed by Scully (2017) in relation to the creation of multiple-choice questions (MCQs). As compared with knowledge recall, for example, questions that encourage higher order thinking require a greater depth of understanding from both the question writer and the question answerer, thus fostering greater learning. High quality MCQs also avoid flaws such as grammatical clues, vague terms, implausible distractors, and the presence of less than or more than one correct answer (Tarrang and Ware, 2008).

As we learnt from other educators, approaches to encourage the creation of high quality questions included running workshops to help students with creating and critiquing questions (**Delyse Leadbeatter, Dentistry, The University of Sydney**), providing writing guides (**Adam Persky, Pharmacy, University of North Carolina at Chapel Hill**), giving exemplars of different quality questions, explanations and feedback (**Suzanne Fergus, Chemistry Education, Learning &**

Teaching, University of Hertfordshire), and providing advice on question writing (**Philip Smith, Medicine, Cardiff University**). We were also told about the following approaches:

"During in-class polling, I often highlight the type of question and why I am using it…We provide links to two websites with advice on question design."
Susan Howitt, Biology, Australian National University

"Encourage students to actively review/critique each other's questions and give them opportunity to edit their questions prior to teacher harvest the questions for marking."
Ky-Anh Nguyen, Oral Microbiology, University of Sydney

4.2. The use of PeerWise for assessment

Regarding the use of PeerWise for assessment, a couple of educators recommended working with the students when introducing a PeerWise assessment:

"Co-design a quality assessment tool with students"
Delyse Leadbeatter, Dentistry, The University of Sydney

"The mark scheme was shared and discussed with students in the PeerWise workshop that took place to introduce the tool."
Suzanne Fergus, Chemistry Education, Learning & Teaching, University of Hertfordshire

Other advice included providing clear instructions (**Denis Duret, Veterinary Science, University of Liverpool**), possibly having a PeerWise activity *"with open book in a set time slot"* (**Anonymous, Educational and Developmental Psychology, Monash University**) and using PeerWise for formative assessment with large groups (**Suzanne Fergus, Chemistry Education, Learning & Teaching, University of Hertfordshire**).

4.3. General advice

General advice about PeerWise also featured comments about student involvement. Suggestions included the following:

"Important to fully discuss/negotiate with students before commencing! Ownership with each class."
Anonymous, Educational and Developmental Psychology, Monash University

"We now get students to conduct the introduction to PeerWise as this gives the whole thing more credibility. Also students enjoy being course administrators and looking in on student questions to leave comments and help."
Philip Smith, Medicine, Cardiff University

Other advice included spending time helping students in areas such as giving feedback (**Delyse Leadbeatter, Dentistry, The University of Sydney)** and the following:

"Students felt overwhelmed if there are too many questions to be reviewed for a given period of time"
Ky-Anh Nguyen, Oral Microbiology, University of Sydney

"Provide some questions initially to get the ball rolling"
Denis Duret, Veterinary Science, University of Liverpool

We will use this advice when using PeerWise in the future.

5. Discussion

It is noted that the number of responses to the student survey gives a limited picture of the student experience. However, the responses still gave an insight, especially into the differences in results between the SHU and LTU modules. The evaluation within this case study indicates that overall PeerWise generally had a positive impact on the learning experience of students in both modules. For example, several students thought that their understanding had improved because they used PeerWise, and some thought their ability and/or confidence increased.

The most prominent theme arising from SHU students' qualitative comments was related to PeerWise being a useful tool for re-visiting material. This highlights one of the advantages of the assessment approach adopted at SHU where, as a one-off assessment, students were asked to write and answer questions on topics that had not been taught for a while. For SHU students, the activity appeared to be a useful revision exercise. By contrast, the most prominent themes arising amongst LTU students were related to the positive impact on their ability to write clear questions, which in turn helped increase their understanding, and the learning community that the activity helped to foster. This highlights one of the advantages of the ongoing nature of the assessment approach which was adopted at LTU.

Also of interest was the diversity of student reactions towards the fact that their questions would be visible to other students. While some students reported that the quality of their questions was not impacted, some other students reported either a positive or negative impact. This finding indicates that future work to further explore student perceptions as they relate to visibility of questions would be of interest.

Much of the advice presented in Section 4 was consistent with the student feedback and our own implementation and perceptions of the activity. For instance, several students commented that through engaging with the activity, they gained skills related to designing questions, indicating that this was a new skill for them. This supports the advice from practitioners that teaching students how to write high quality questions in the initial stages would provide useful scaffolding for this activity. Providing clear instructions was also highlighted in the practitioners' advice. In our own experience, we found this to be a useful practice also, so that students knew what was expected of them and were able to gain as much as possible from the activity.

From our experience, how to use PeerWise for assessment is a question that requires careful consideration. Two methods were presented in this case study, both of which had advantages and disadvantages as discussed. Furthermore, while one method involved manual marking and thus facilitated a more rigorous marking scheme with a higher focus on question quality, the other involved automated marking but with less capacity for detailed evaluation of question quality. While manual marking may be considered a preferred option in terms of quality of the assessment, the feasibility of doing so at large scale may come into question. One practitioner offered an alternative solution for large cohorts, which was to use PeerWise for formative assessment only and as such, the benefits of learning would still be available to students without the need for formal marking to occur.

It was also observed that, in general, the student perception was that providing feedback was the least beneficial part of the activity. However, some studies have shown that providing quality peer feedback to other students can have a positive impact on one's own academic performance (e.g., Li and Steckleberg, 2010). It would therefore be useful to help students understand the benefits of providing feedback to others, particularly in terms of the benefits to their own learning. This sentiment was echoed in the gathered advice, and the suggested methods could be used to help with this, such as workshops to critique feedback, providing exemplar comments and creating guides.

6. Recommendations for future implementation

The common themes arising from the evaluation within this case study and the practitioners' advice provide some useful conclusions. These can be offered as recommendations for future implementation in order to improve the student experience while using PeerWise, as well as student outcomes. First, it is recommended that at the initial stages of implementing PeerWise in a module, support is provided to students on how to write high quality questions. Second, it is recommended that the benefits of providing feedback to others, particularly for one's own learning, is communicated. Suggested methods for implementation of these recommendations include workshops, exemplar questions and comments, and creating guides. Third, it is recommended that clear instructions be provided to students to facilitate a positive and beneficial student experience. Fourth, it is recommended that careful thought be given to the assessment strategy. While there are a number of options in this regard, including manual, automated, or no marking (formative only), consideration may be given to the class size, weight of the assessment, and desired outcomes.

7. Funding

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8. Acknowledgements

The authors are grateful to the students who filled in the survey, which enabled us to evaluate the assessment. The authors also wish to thank the practitioners from across the world who kindly offered their advice as summarised in Section 4.

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SHORT UPDATE

maths e.g. as a learning resource

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Abstract

This update describes the use of the "*maths e.g.*" question database in enhancing any sort of learning material by easily including specific 'Try one yourself' links to any of the over 5000 individual (randomised) questions or allowing student selection from the numerous topics/sub-topics that span the school/university interface and selected service mathematics content. A new question type is also presented to facilitate the (partial) testing of more theoretical material.

Keywords: learning resource, service mathematics, e-assessment, feedback.

1. Introduction

Since 2000 we have been developing the *maths e.g.* e-assessment system at: https://www.mathcentre.ac.uk:8081/mathseg/ for casual use (no sign up required) and a teachers' interface at: https://www.mathcentre.ac.uk:8081/mathsegteacher/teacher.jsp where (after you sign up) tests may be composed by teachers from the 5000 or so question spaces, in a manner similar to shopping on Amazon (but entirely free).

In common with most other e-assessment systems such as Stack, Numbas, Dewis and Webworks, *maths e.g.* uses **question spaces** that encode the algebraic and pedagogic structure of each question which is then realised at runtime by choosing randomised parameters (numbers, words, scenarios). Thus, each question space generates thousands or millions of questions seen by students, thereby allowing virtually unlimited practice. If a student goes wrong, feedback is given with the question's choice of parameters carried through into all features of the feedback (wording, equations using MathML and diagrams using SVG), see Greenhow (2015). This represents a rich learning environment and, being a standard web page, works accessibly on all browsers, PC, Mac or smart phone, using browser-native zoom and translate capabilities and a "Fonts and colours" link to allow a student's display choices to be implemented.

Whilst I make no claims for the efficacy of *maths e.g*. as an e-assessment package, still less present evidence or comparisons with other systems, the experience of remote teaching last year during Covid restrictions suggests *maths e.g*. could be a useful addition to the students' learning, as follows.

2. Embedding resources in curriculum delivery

Last year I sat weekly in-term *maths e.g.* tests, primarily to keep remotely-learning, and possibly assessment-driven, students on task; to assess students I did not need so many marks. Moreover, continual testing did run the risk of downplaying their engagement in the underlying theory, which with no marks associated with it, "didn't count" in the eyes of those students who would benefit most from mastering it. With a return to 'normality', a sensible balance might be to embed e-assessment formatively within such theory, thus breathing life into what they can perceive as otherwise dry material, followed by just two or three in-term e-assessments and a traditional exam. I have no hard evidence that this will work, but anecdotally students do attempt questions, then very actively engage with the feedback, learn how to do a particular question and then follow it with generalising what they have learned in conjunction with the theory they now see the need for. On running a new realisation of a question, I have observed that students initially treat it as completely new, starting from scratch, and then say “Hang on, I have done this question before.” This is where we want students to be, i.e., able to do all questions of that class. The flipped approach of example-to-theory may help, especially as students can self-test their newfound understanding by running another question, or several, before moving on. Without such examples, students may move on anyway and fail to learn much. *maths e.g.* now provides a trivially-easy way to access questions and feedback outside of formal tests and doesn’t require student login, so can be also used for pre-sessional revision or schools outreach material without falling foul of privacy issues.

The interface is based around a tree structure currently comprising 29 main topics and numerous subtopics spanning GCSE, A level and year 1 undergraduate mathematics and some mathematically-oriented topics from Economics, Biosciences, Chemistry and Health. Whilst familiarity with this tree structure is educational in itself, one should not simply point students at the above links and hope they will engage. Even for keen students, it will not always be clear where to find questions: for example, an integration involving partial fractions could be in algebra or integration. This difficulty will be compounded for students tackling new subject areas and, especially, expending effort in answering questions they may, or may not, need. Thus, teachers will need to direct them: I think this is best done by embedding links to individual questions or whole sub-topics into any of your (existing) learning resources that supports web links (word, power point, pdfs, other web pages etc). For an individual question, just run any question and add the link to the url at the top of the question window to your resource. For a topic or subtopic, note its pid number (displayed top right when a topic is selected in the student interface) and edit the following link: https://www.mathcentre.ac.uk:8081/mathseg/topic.jsp?pid=114 (the 114 at the end links to Differentiation\Chain rule\Natural logarithms as shown in Figure 1). It’s as easy as that.

Screenshot of the *maths e.g.* student interface and selected sub-topic.

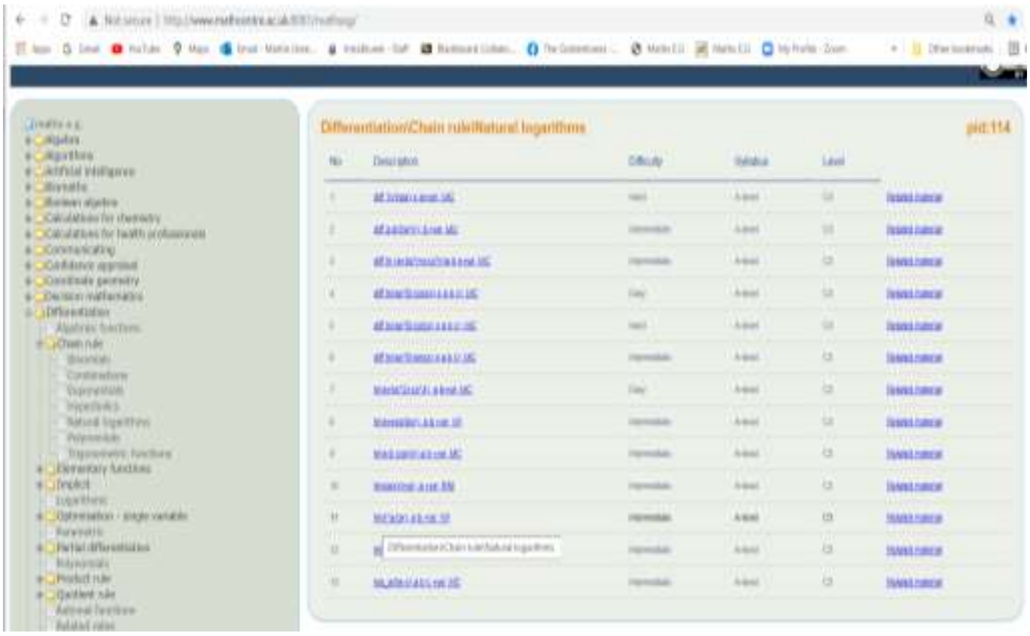

Figure 1. Part of the topic tree expanded on the left and questions in the selected topic on the right, showing pid 114.

It will not have escaped you that *maths e.g.* is a potentially-useful source of questions, generally 'reverse engineered' so that the answers come out nicely, that can be used in traditional assessments and exams. Just take what you want. If you want to re-author any question in any other e-assessment package, or any learning package such as a scripted web page, take a look at the Javascript code using View Source and take what you want. Some questions use global functions which I can provide on request. If you do use *maths e.g.* in this way, please make whatever you create publicly available for all.

3. A new question type

It is obvious that e-assessment can only form part of the student's journey and is limited in addressing our overarching aim of getting students to be able to 'do mathematics'. This undoubtedly involves moving away from standard questions to at least being able to mathematically model, make approximations and find approximate or limiting-case solutions, implement suitable computer packages or numerical methods, make conjectures (and hopefully prove them), make generalisations and extensions, interpret results and finally effectively communicate to others at an appropriate level. Such lofty aims will fail unless students have done the groundwork. e-assessment is an excellent way to provide the necessary fluency they will need to be able to use an array of techniques and tools in unstructured tasks.

There are many different question types available to help students master algorithms and procedures needed in basic algebra and calculus for example, but I have found these difficult to implement effectively in definition-based or analysis-type questions. For the latter, true/false questions are useful and versatile, but for the former I have needed to develop list-based questions, as in Figure 2. Both will be included in the next *maths e.g.* update, but on paper it is not obvious how the question in Figure 2 was randomised. In fact, all correct and any number of incorrect (but feasible) statements are held in arrays from which the code randomly chooses a number (usually between 5 and 8) of statements to display (again in a randomised order). Given that the functionality of the question is independent of these arrays or question topic, the author only really needs to focus on creating incorrect statements. Feedback for such definition-based questions is currently limited to just stating the correct answers, but could be extended to give counter-examples showing why chosen incorrect statements are wrong. Another extension could be to replace the word **must** in the question wording with **must not** or **may** but this has not been attempted yet.

Clearly this question type needs evaluating by collecting student views and success rates. Indeed, a reviewer states: *It seems that more natural input (from student's perspective) would be achieved via checkboxes* and this is a good point. However, for partial credit, the marking scheme becomes complicated: should one reward students for identifying correct choices AND not selecting incorrect choices, and penalise them for not selecting correct choices AND selecting incorrect choices? This could result in negative marks which students generally do not understand and think is unfair. At least for now, the question is marked dichotomously as a mastery question where the response must be fully correct and in the correct syntax (although spurious white spaces are removed before marking). Insisting on syntax may seem picky, but such discipline may help students when later writing their own computer code.

Screenshot of a list question.

In this example Declan is considering using the Intermediate Value Theorem (IVT) on a function f(x) to infer that for some value, c, then

if u is any number between f(a) and f(b), then there is some c in the interval (a,b) such that f(c) = u.

Which of the following properties **must** the function have in order to apply the IVT theorem?

Given such properties, and any others necessary for the IVT to be applied, which, if any, properties below hold for *c*?

You may assume a < b

1. The function is negative in the closed interval [a,b]

2. c is in the closed interval [a,b]

3. The function f(x) is piecewise continuous on the open interval (a,b)

4. The value(s) of c cannot be determined from IVT theorem

5. The domain of the function f(x) contains the closed interval [a,b]

6. f(a) > f(c)

7. The function f(x) is differentiable on the closed interval [a,b]

8. The function f(x) is continuous on the open interval (a,b) but not necessarily on the closed interval [a,b]

A =

Important: You must select all properties that apply to the question and nothing else

Input your answer string in the form of a sequence of increasing numbers e.g. 1,3,9 without spaces, separating each property number with a comma and with no full stop at the end

If you think none of the above properties apply, input *none*

Figure 2. A question to test student understanding of the necessary conditions for the IVT.

4. Reference

Greenhow, M., 2015. Effective computer-aided assessment of mathematics; principles, practice and results. *Teaching Mathematics and its Applications*, 34(3), pp.117-137. https://doi.org/10.1093/teamat/hrv012

RESOURCE REVIEW

Accessible teaching with GNU TeXmacs

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Abstract

In this article I give a brief overview of some of the challenges in creating accessible documents for STEM education, as well as why and how GNU TeXmacs can be used to address some of these.

Keywords: accessibility, HTML, software, WYSIWYG.

1. Introduction

Equal access to education is an ideal that is supported by many governments and organisations and is enshrined in international treaties (Right to Education Initiative, 2022). Discriminated groups and society in general stand to gain from giving more opportunities to contribute to a wider group of individuals. It is, therefore, not surprising that legislation is put in place to improve equal access to education (HM Government, 2021). Such regulations stipulate that new educational materials have to meet accessibility requirements or, if this is not yet the case, that they should do so in the near future. Such accessibility means, roughly speaking, that the way in which information is transferred should not be an obstacle to the processing of that information.

In practice, this means providing documents in formats and styles that are suitable for users with visual, aural, movement or cognitive disabilities. For example, users with visual disabilities may require a text to be read out to them, while readers with dyslexia can benefit from the use of a concise writing style and a specific layout of the text on the page.

Education in science, technology, engineering and mathematics poses particular challenges in this regard, due to the frequent use of equations, graphs and diagrams that are difficult to convey in a non-visual manner. In the case of plots and diagrams, an accessible format may be a tactile reproduction on embossed paper or an audible representation. For mathematical equations the format may be Nemeth Braille, or HTML with MathJax that can be read out by screen reader software (Cervone, 2012).

2. Screen readers and HTML

We will now focus on users with visual impairment. For these students consuming text can mean that it should be read out loud. Fortunately, this can now be done by computer algorithms called screen readers. For documents with little structure (with a linear flow of text with the occasional heading), these algorithms work quite well. However, the situation becomes more involved when mathematical notation, such as subscripts, superscripts, fractions and square roots, appears. For the screen reader to correctly pronounce such mathematical constructs, they need to be presented in a structured format, so that the software can understand what symbols belong in the numerator and what belongs in the denominator of a fraction, say.

To the author's knowledge, the main methods currently available to provide structured mathematical information to screen readers is either via a tagged PDF or via HTML with MathML. Unfortunately, the popular Chrome browser currently doesn’t support MathML, with some progress recently being made by Igalia (https://mathml.igalia.com/). In the meantime, using MathJax to provide the right output for a variety of browsers and screen readers seems to be the best solution. MathJax also provides other accessibility features, such as the ability to magnify parts of the equation.

3. The problem with LaTeX and possible solutions

The formats in which to present information in an accessible way presents one side of the equation. The other side is how to author such content. Currently a lot of the material used in higher STEM education is produced in LaTeX and output as PDF files. Unfortunately, LaTeX discards any structural information in the source once the document is typeset. The resulting output is basically a set of disconnect characters on a page.

Given the large amount of material already written in LaTeX, a lot of effort has been invested in creating accessible work-flows for it, following different strategies. Once ready, LaTeX3 should be able to produce tagged PDFs (Mittelbach, 2020), but is at least several more years from completion and usable solutions are needed right now. Other methods to create tagged pdfs are complicated to use.

LaTeXML and TeX4ht seem to be the most well-developed methods to create HTML output from LaTeX. Although they work well in many situations, due to the complexity of the LaTeX input, they fail regularly, with error messages that can be hard to decipher. Compilation can also take longer than with standard LaTeX. This is obviously not an ideal solution, as it further complicates the already tedious edit-compile-inspect cycle typical to LaTeX.

Since the complexity of LaTeX hampers its convertibility (Poulain, 2014), another solution is moving to a simpler format other than LaTeX, but closely related to it. For example, PreTeXt and RMarkdown can include equations in LaTeX, but they lack the flexibility of LaTeX. Most importantly, these formats still require authoring in raw text with an edit-compile-inspect cycle. If we need to change our work-flows and switch to a different format, why not change to a method that not only makes use of the document structure to make information accessible to a wider audience, but also makes use of that structure to make the authoring experience more pleasant to the writer?

This is what GNU TeXmacs aims to achieve (van der Hoeven, 2020). It is a true WYSIWYG ("what you see is what you get") editor for technical documents that makes use of the structure of the document to facilitate editing.

The fact that TeXmacs internally uses a format that is quite similar to XML also means that conversion to HTML and MathML are reasonably straightforward, certainly when compared to the conversion from LaTeX.

It should be noted that TeXmacs can not only be used to author new mathematical documents. It also features a converter to import existing LaTeX documents into TeXmacs. Its conversion algorithm is less robust and feature-rich than that of LaTeXML, but it gives a good result on well written LaTeX documents. The result may need manual editing, but in the author's opinion, this is worth it, considering the efficiency gains that can be obtained once using TeXmacs.

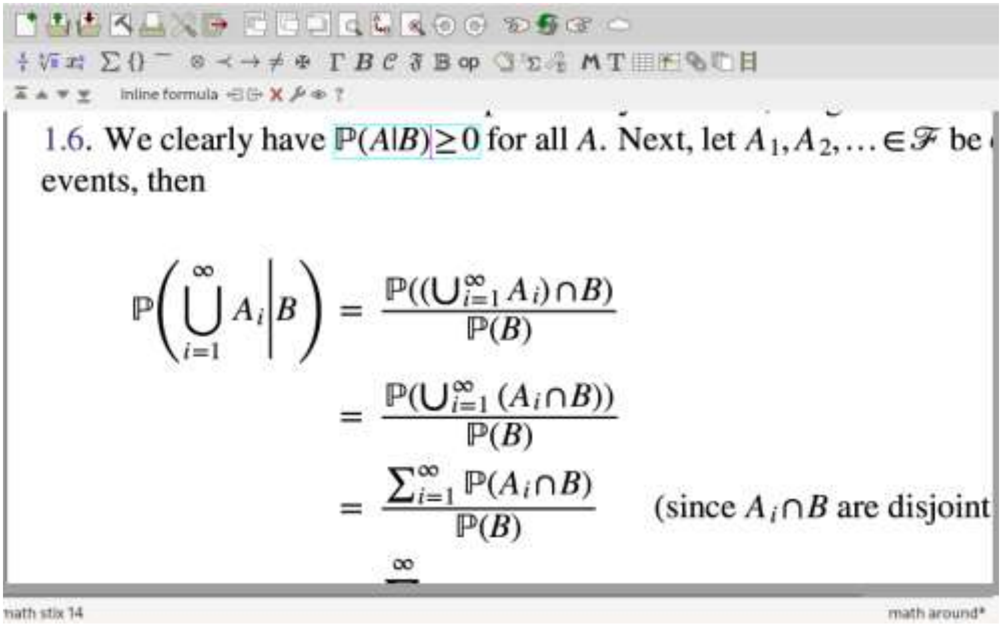

Figure 1. TeXmacs' user interface. Equations can be entered in three different ways: through the toolbars of the graphical user interface, using keyboard shortcuts (e.g. Alt-f for a fraction) or using LaTeX-like commands (e.g. "\frac" for a fraction).

4. Creating accessible documents in TeXmacs

Manuals and tutorials on creating TeXmacs documents can be found on the TeXmacs website. Here we'll only mention the conversion to HTML.

Practically speaking, to output HTML documents with MathJax equations in TeXmacs, go to the "Convert" tab of the "Edit → Preferences" menu. In the "Html" sub-tab, select "Export mathematical formulas as MathJax". Next, from the document you wish to export, select "File → Export → Html". The exported Html can be further styled using CSS, for example to select the font or page margins. A PDF file can similarly be saved via "File → Export → Pdf".

In the author's work-flow for educational documents, both a PDF and HTML version would be created for each item, as some students may still prefer the fixed PDF layout. The files are then attached to items in the University's virtual learning environment (Blackboard). By attaching them we have full control over the rendering of the HTML document, avoiding possible conflicts with Blackboard. Another possibility is to open the HTML file in a text editor and copy/paste the source code into a Blackboard item, although MathJax version 3 seems to be incompatible with Blackboard, so the version should be manually changed to 2 in this case.

From observation in the classroom, both the PDF and HTML formats are used by students, with HTML having the advantage of being better suited for the mobile devices that many students are now using.

TeXmacs can also be useful to create documents suitable for students with other disabilities than visual impairment. For example, the British Dyslexia Association provides guidelines on how to produce dyslexia friendly documents (British Dyslexia Association, 2018). Based on these guidelines, you may want to consider applying the following simple changes from the TeXmacs user interface:

- Go to "Document → Font" and pick a large and well readable font (e.g. Fira Sans or Carlito at 12-14pt size).

- Go to “Document → Paragraph” and choose an appropriately large interline spacing.
- Go to “Document → Colors → Background” and choose a light, but not white, background.
- If necessary, go to “Document → Page → Margins” and adjust the margins, so that about 60-70 characters fit on one line.

Once the above changes have been made, they can be put into a TeXmacs “style file”, which can later be added to other documents with two mouse clicks.

The above style changes will appear in the PDF version of the output, but are not automatically translated to the HTML output. For this, a CSS file can be used. The CSS used by the author is reproduced in the appendix. Users can also adjust the style of a document to their personal preference by using various browser plug-ins.

Inserting alt-text descriptions of images is currently not directly supported from the TeXmacs GUI, but they can be inserted by using the html-attr tag. To create this tag, type \html-attr and press the Return key. Edit the arguments to provide the alt-text: <html-attr|alt|"my alt text"|>. Then, move into the third argument field and press Return again. This will activate the tag. Finally, the image can be inserted into the active tag. The author has published a small plug-in for TeXmacs to simplify this procedure at https://gitlab.act.reading.ac.uk/ss902791/tm-alt-text.

5. Improving accessibility in online sessions

Another way in which the accessibility of STEM education can be improved is by using TeXmacs to deliver live on-line sessions. Previously, the author would use a tablet with a stylus to write equations on a virtual whiteboard. This, however, would occasionally lead to questions to clarify some of the handwritten equations. To increase legibility, it was decided to switch to TeXmacs for on-line teaching. Thanks to its intuitive keyboard short-cuts, the author can enter equations at nearly the same speed as he would write them on a whiteboard. To this end, the Beamer style included in TeXmacs can be used in combination with a large, clear font (e.g. Fira Sans 14pt) to make the equations and text easy to read.

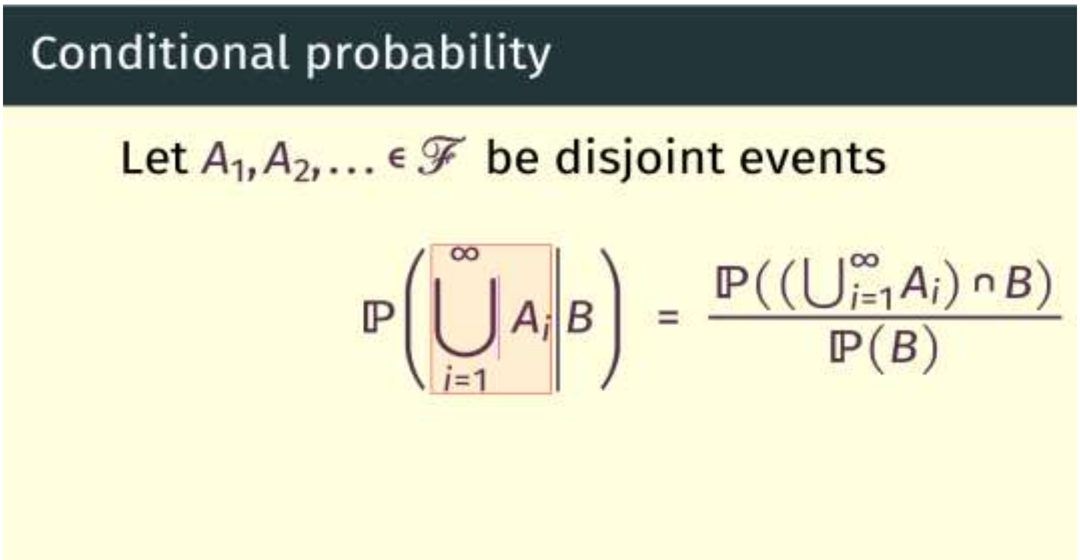

Figure 2. A screenshot showing the use of the Beamer during online teaching sessions.

To start a presentation in TeXmacs, from the user interface:

- Go to “Document → Style” and select “beamer” for TeXmacs' presentation style.
- Go to “Document → Font” and pick a large and well readable font.

After the first on-line session using TeXmacs as a presentation tool, students reacted positively when asked for feedback. A majority preferred this method over the method of drawing on an electronic whiteboard with a stylus.

Using TeXmacs during live sessions has the advantage of producing typeset output which can almost immediately be shared with students. The created content can be copied into a standard (non-beamer) document for some final editing before being converted to PDF and HTML as described above. Another advantage of this approach over other methods is that no additional hardware, such as high-resolution web-cams or styli, is needed. A disadvantage is that creating complicated diagrams requires some practice and is slower than drawing with a stylus.

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7. Appendix: dyslexia friendly CSS

```
html {
    background-color: #fdffe2;
    border: 0px;
    padding: 0px;
    margin: 0px;
}

body {
    font-size: 32px;
    font-family: 'Arial', 'Linux Biolinum', 'Belleza', 'Optima';
    text-align: justify;
    border: 0px;
    padding: 1em;
    margin: 0px;
    margin-left: auto;
    margin-right: auto;
    max-width: 45em;
    line-height: 2.0
}

/*  Add a scroll bar to long equations */
mjx-container {
  display: inline-grid;
  overflow-x: auto;
  overflow-y: hidden;
  max-width: 100%;
}

/* Some equations are put in tables, so add a scroll bar */
table {
    display: block;
    overflow-x: auto;
    white-space: nowrap;
}
```

RESEARCH ARTICLE

Blended Tutorials: Blended Synchronous Learning in Mathematics

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Abstract

A *blended* tutorial is a single learning event which gives students the opportunity of attending face-to-face or online. This article reports the findings of a scholarship of teaching and learning project conducted at The Open University, and considers the barriers and opportunities to using blended tutorials to support distance learning. Two pilot blended tutorials were carried out on the honours mathematics module M337 *Complex Analysis*, and the results of the evaluation are presented. Using qualitative data from practitioner reflections, lesson observations and semi-structured student interviews, this project uses thematic analysis to identify barriers and opportunities to using blended tutorials. Particular emphasis is given to the unique challenges in learning mathematics, and in the distance learning context of The Open University. The report concludes with recommendations for the design of blended tutorials, and recommendations for future research.

Keywords: blended, hybrid, synchronous, synchromodal, tutorials.

1. Background and Literature Review

By *blended tutorials*, we refer to *blended synchronous learning*, where a single synchronous learning event is held simultaneously as a face-to-face event and an online event. Other terms used in the literature are *synchromodal learning* (Bell et al., 2014), *Here or There (HOT) Instruction* (Zydney et al., 2018), and *synchronous hybrid learning* (Raes et al., 2020).

Historically in The Open University (OU), tutorials have typically taken place as *either* face-to-face events, *or* online events. This project explores the research questions:

1. What are the barriers and opportunities to offering blended tutorials in the context of an honours OU mathematics module, M337 Complex Analysis?
2. How should practitioners design a blended tutorial for a distance context?
3. What specific challenges to a blended approach are present in a mathematics context?

In partial answer to Questions 1 and 2, Bower et al. (2015) conduct a cross-case analysis of design and implementation factors in blended synchronous learning, and offer a “Blended Synchronous Learning Design Framework”. Aspects of this framework were used in our design of blended tutorials; however, the OU context presents additional institutional and logistical challenges not covered by this framework. For example, the geographical spread of our students and tutors adds institutional challenges, and the fact that study centres are typically not equipped with OU equipment presents logistical challenges.

Although Bower et al. (2015) do consider a case of blended synchronous learning in a statistics class, there is, in general, a gap in the literature on the unique challenges that mathematics faces in a blended environment. For example, it is well known that rendering mathematical symbols in synchronous web environments (such as Adobe Connect) can be challenging. Smith and Ferguson (2004) report the difficulty in communicating diagrams and mathematical notation, while Loch and McDonald (2007) point to the awkwardness of being restricted to typed communication, which requires either mathematical typesetting skills or the use of embedded image files. Hodges and Hunger (2011) offer shared electronic whiteboards as a solution to what they see as a “lack of dynamism” (p.42), and this is the approach we have taken.

2. Methodology

2.1. Evaluation strategy

We planned two blended tutorials to take place during the 2019/2020 presentation of M337 *Complex Analysis*, and designed an evaluation strategy that would explore the barriers and opportunities of blended tuition in a distance context.

We gathered perspectives from three sources:

- The *practitioner* perspective – through our own reflections;
- The *outside expert* perspective – through observations of the blended tutorials by experienced Associate Lecturers (ALs) on M337;
- The *student* perspective – through semi-structured interviews with attendees of blended tutorials.

Both of the authors are experienced teaching practitioners on M337. To gain a more objective perspective, however, we recruited two experienced ALs on M337 to conduct observations – one for each blended tutorial. For the student perspective, we invited students to take part in semi-structured telephone interviews, where students were asked about their experiences of the blended tutorials.

All three sources of qualitative data were subjected to thematic analysis, the results of which will be discussed in the Findings section below.

2.2. Technological setup

Technological worries dominated the early stages of planning the blended tutorials. We decided that both project leaders would facilitate each session – Andrew in the room as the lead facilitator, and Colin facilitating the online environment from home. If the connection between face-to-face and online environments proved impossible to maintain, then Andrew would be still be able to continue the tutorial with the face-to-face students, and Colin would still be able to continue the tutorials with the online students.

To enable a shared visual space for both face-to-face and online students, Andrew used a Microsoft Surface Pro with a stylus pen for handwritten annotation. This was connected to an overhead data projector, so that students in the room would see what was being written on the Surface behind Andrew’s head (see Figure 1). At the same time, Andrew’s screen was shared via Adobe Connect screen sharing, so that online students would see the same view (see Figure 2).

Figure 1. A photo of the blended tutorial from the face-to-face students’ perspective

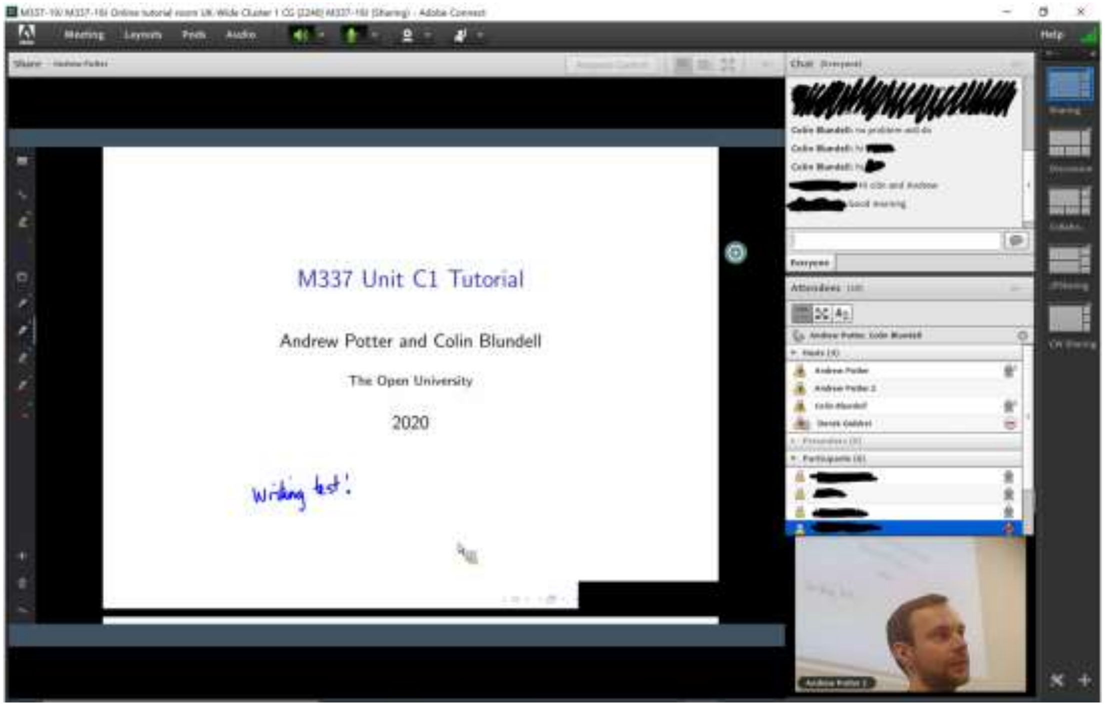

Figure 2. A screenshot of the blended tutorial from the online students’ perspective

2.3. Pedagogical approach

We adopted a largely tutor-led approach to the pedagogical design of the sessions. Andrew was concerned that other approaches might not work because of the technological setup. The only ways to communicate between the face-to-face students and the online students were (by audio) through the conferencing microphone/speaker and (visually) through the shared screen, both of which were near to Andrew only. As such, Andrew felt that the only way to proceed was for both tutors to act as facilitators across both modes. Critical reflection on this approach will be found in the Findings section below.

The format of each tutorial was designed as an examples class with the opportunity for whole-class discussion. Students who signed up to the tutorial received by email a problem sheet one week in advance. The tutor then led the students through the problems, using tutorial slides with the questions and various teaching points pre-prepared on them, and writing solutions to the problems by hand on blank spaces left on the slides. Students were encouraged to ask and answer questions throughout to stimulate discussion.

2.4. Participation in numbers

All students on the 2019/2020 presentation of M337 (around 200 students) were invited to attend the blended tutorials. To make sure that no students felt disadvantaged by the experimental nature of this pilot scheme, we were very clear to students that these tutorials were *additional* to the usual tutorial programme.

On a typical presentation, students have the option of attending around 30 online sessions spread across the year, and around 3-5 face-to-face tutorials are offered in each of the following locations: London, Reading, Leeds, Birmingham and Cambridge. The addition of the blended tutorials provided 2 extra sessions based in Edinburgh.

The attendance numbers per tutorial were:

- 11 January 2020: 8 face-to-face students, 16 online students, 52 students watched recording;
- 29 February 2020: 3 face-to-face students, 15 online students, 28 students watched recording.

In total, 14 students attended both tutorials live (3 face-to-face, 8 online, and 3 one of each). Of these, 4 watched (some of) both recordings, and a further 5 watched (some of) one recording.

From all students who had some interaction with at least one blended tutorial, 28 were identified by the University's Student Research Project Panel as approachable for interview, and 7 students consented to be interviewed. Of these, 2 attended both face-to-face, 1 attended one face-to-face and the other online, 3 attended both online, and 1 attended one face-to-face and listened to the recording of the other. Thus, although a response rate of 25% (7 out of 28 respondents) would appear disappointing at first, we were able to interview 6 out of the 14 students who attended both events live (43% response rate).

3. Findings

The thematic analysis of our practitioner reflections, lesson observations, and student interviews drew out the following five themes, which we will consider in turn:

- Two different worlds
- Blended pedagogy
- Audio communication

- Visual communication
- Organisational issues

3.1. Two different worlds

Student interviewees reported that the tutorial “felt like a normal tutorial” – whether they had attended face-to-face or online. Indeed, one online attendee did not realise that there had been students who attended face-to-face! In that sense, the blended tutorials seemed to replicate the style of tutorial that students were used to. We acknowledge that student comfort does not always lead to student learning! However, in a distance context, where tutorials are optional and students can often lack confidence from learning in isolation, a greater emphasis is placed on ensuring a comfortable learning environment.

One AL observer remarked that, at several points, there was a rich discussion happening ‘here’ (in the room) and also ‘there’ (in the text chat of Adobe Connect), but there was not much discussion or interaction *across the boundary of the two modes*. This seemed to confirm the students’ observation that there was not much difference from what they were used to.

For both of us as practitioners, this gave rise to the reflection that this was probably due to the way in which we had set ourselves up as gatekeepers of each mode. Students would have to get through us, the tutors, in order to communicate across the modes. This had not been our intention in designing the sessions, and gives rise to the question of whether a truly blended experience is possible. Can the experiences of face-to-face and online students ever be truly equivalent?

Student interviewees reported an *acceptance* that the experience for online students was fundamentally different to the experience for face-to-face students. This was not considered to be positive nor negative, with each of the options for attendance bringing benefits that the other lacked. Online students talked of the convenience of attending from home, the benefits of recording, and the relative security of being ‘unseen’ passive observers. Face-to-face students, on the other hand, enjoyed the opportunity to meet tutors in person, ask questions dynamically, see body language, and meet other students. Perhaps a better question for future research is: is there any benefit at all to attempting to make the experiences equivalent?

3.2. Blended pedagogy

As mentioned above, we adopted a largely tutor-led pedagogy in the design of the blended tutorials, motivated primarily by Andrew’s technological worries. This appears to be an example, noted by Cornelius (2014), of practitioner anxiety in technology-enhanced learning leading to a “retreat towards teacher-led approaches” (p.261).

For the student interviewees, the tutor-led approach was not seen to be a negative, with face-to-face students in particular valuing the opportunity to engage in rich discussions about the material, despite the approach. Two online students reported a very minor increase in interaction from what they would expect, with one student saying it was good to be able to hear student questions. However, many of the face-to-face students reported issues of not wanting to disrupt “the flow” of the tutorial, which suggests an excessive tutor-led approach inhibiting interaction. One face-to-face student didn’t want to “interrupt” or “derail the tutorial” with tangential questions; another face-to-face student didn’t want to “waste other students’ time”, and be seen by other students as “showing off”. One face-to-face student also reported that the recording made them a little bit self-conscious, not being accustomed to being recorded in a face-to-face tutorial.

One AL observer also commented on the pacing of the tutorial. Audio interruptions, sound checks, reporting across modes and technical breakdowns all served to slow the pacing down somewhat. However, when asked about it, students in both modes either reported that they didn't notice a difference, or that it was a positive to keep things slower. One student reported, for example, that in online tutorials, she often finds it difficult to type quickly enough to be able to ask a question, and often the moment passes before she has a chance to ask it.

Bower et al. (2015) report that blended synchronous learning can often place considerable extra cognitive effort on the practitioner, and this is certainly confirmed by Andrew's experience, who was exhausted after each tutorial! Bower et al. (2015) also recommend that pedagogy be given first consideration in learning design, and in retrospect, both Andrew and Colin would be keen to embed more of a student-led approach from the beginning. Colin, in particular, would be keen to experiment in future with more student-led pedagogy in a blended environment, giving students more of the work to do.

3.3. Audio communication

Many of the student interviewees in both modes talked about minor audio issues during the tutorials. However, none of the interviewees reported that this seriously diminished the student experience – "I'm used to it" was a common response. This caused Andrew and Colin to reflect that perhaps they had spent too much time worrying about technological issues, and that the students were more resilient to technical glitches than anticipated.

One face-to-face student made the observation that, as the number of attendees grows, the problems associated with turn-taking, and the potential for audio lag and talking over one another also increase, and so inhibited him from wanting to contribute too much. Another student (online) said that he prefers speaking, but since no one else does, he doesn't contribute. This suggests greater care is needed in facilitating audio interaction in a blended environment.

Because of the positioning of the conferencing speaker/microphone near to Andrew, one online student (who is hearing impaired) reported that he couldn't really hear any of the face-to-face student contributions, but could hear Andrew. Although care had been taken to ensure accessibility of the blended tutorials, this was an unanticipated issue, and would require careful consideration in future blended sessions.

An unintended positive consequence of audio communication emerged when Andrew accidentally left the conferencing microphone open during a ten-minute coffee break. One online interviewee reported that she found listening to the informal chatter which was captured between the students comforting. During this time, they chatted about future module choice, which parts of the module they found difficult, and other informal topics. The online student reported that this made her feel part of a community of learners that she had not before experienced.

3.4. Visual communication

Because not much use of a webcam was made, online student interviewees commented that it was difficult to discern meaning without the visual cues present in normal speech. This accords with Price et al. (2007), who report student frustrations due to the lack of "paralinguistic cues". When asked about the use of the webcam in the second tutorial, one online student said it was good to see the human side. However, another online student remarked, "It was nice to see [Andrew], but it didn't really add much." A third online student said that it was, in fact, a bit distracting because the video was not synced to the audio.

Students and practitioners alike agreed that the shared screen was vital to a mathematics tutorial, and being able to see what Andrew was writing was crucial to understanding. However, this meant that visual space was at a premium, both for online and face-to-face students. For online students, having the text chat was important for communication, but it came at the expense of being able to see what was going on in the room. Even if webcam use was extended, the size of the window would be so small as to have been useless. On the other hand, students in the room had no access to the text chat, because it would have been too small to read on the projected screen. As such, they relied on Andrew and Colin to relay any salient questions or comments from the text chat. For this reason, one of the AL observers recommended that face-to-face attendees be invited to bring a laptop so they could access the text chat if they wished.

3.5. Organisational issues

A key question for both Andrew and Colin was whether a blended tutorial be facilitated by a single tutor only. A key benefit of blended tutorials ought to be that it obviates the need for two separate sessions, optimising practitioner time and student choice. In the context of the COVID-19 pandemic, there is also a benefit of allowing greater flexibility in the mode of delivery, as institutions wrestle with closures and social distancing guidelines.

At the first tutorial, Andrew relied on Colin to mediate the text chat, but at the second tutorial, he had a second machine set up so he could see the text chat directly and so had more autonomy. This led us to speculate that the role of the online tutor did not need to be a tutor at all, but could, for example, be a student monitor.

When asked about whether they would support blended tutorials being used in the future, students demonstrated a nuanced understanding of the resourcing constraints that the university faces in tutorial provision. However, it was clear that the face-to-face students were particularly keen to preserve as many face-to-face opportunities as possible, and the online students were keen to have as many tutorials (in whatever medium) as possible. If blended tutorials allow for a greater number of tutorials (and face-to-face opportunities), then students appeared to be in favour.

4. Conclusion and recommendations

The five themes we have explored give the main barriers and opportunities to using blended tutorials, based on the practitioner perspective, the outside expert perspective, and the student perspective. On the whole, all three groups of stakeholders were positive about the future of blended tutorials, showing that more research into this area is needed. We conclude this section of the report with some recommendations, which seek to answer all of the research questions posed in the Background and Literature Review section.

- Blended tutorials offer a tremendous opportunity to **maximise face-to-face opportunities** for students, and **increase the number of tutorials** for all students.
- The design of blended tutorials needs to place **pedagogy** and **accessibility** first, before any technological considerations.
- Blended tutorials **do not need to offer equivalent experiences** to face-to-face and online students – students are aware of the advantages of each mode and **value the choice**.
- **Leave the microphone on** during coffee breaks – the vicarious consumption of natural, spontaneous interactions offers online students a key benefit over online tutorials.
- Allow face-to-face students the opportunity to participate in **text chat** (a key benefit of blended tutorials for face-to-face students), and allow online students the opportunity to participate in **audio chat**. Consider the use of **polling systems** as a simple way to facilitate participation across both modes.

- For blended synchronous learning in **mathematics** specifically, having a **shared visual space** is vital.
- An opportunity for blended tutorials is that it has the potential to optimise practitioner time, by negating the need for separate face-to-face and online sessions to reap the benefits of both. More research needs to be done into **facilitating blended tutorials with a single practitioner**, perhaps with the help of a **student online monitor**.
- More research needs to be done into **facilitating student-led pedagogies** in a blended environment where **visual and audio space are both at a premium**. An easy first step would be to explore the use of collaborative **group work**, using wholly face-to-face groups and wholly online groups.

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CASE STUDY

The effect of scheduling on attendance at synchronous online support tutorials in mathematics

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Abstract

Optional synchronous online support (SOS) tutorials play a key role in student success. However, with the additional pressures of external commitments on students are the "traditional times" of offering study support the optimal times?

Following on from the trends in increased availability of mathematical support (Grove et al 2019) we have piloted a model that focusses on providing different SOS tutorials based on, time of day, study speed and study programme.

The results of this pilot show, that whilst traditional times still attract the highest attendance, by offering a variety of SOS tutorials overall engagement can be significantly increased.

Keywords: synchronous, online, support, maths, timing.

1. Introduction and background of online mathematics support

The Open University has been supporting mathematics students using synchronous online support (SOS) tutorials since 2007, with our first extensive trial in 2008 (Mestal et al., 2011) and regular online support sessions run since 2009. During the trial, students and staff rated online tutorials as convenient with a good overall learning experience. Around this time, other universities were also exploring online mathematics support, with a trial at the University of Northampton (Rice, 2012), and a pilot for a shared online statistical support service between Birmingham City University, De Monfort University and University of Sunderland (Owen et al., 2011). A trial of synchronous chat and electronic ink was held by University of Southern Queensland as part of their distance tuition (Loch et al., 2007).

Online support continued to be of interest within the mathematics support community, with the 4th Irish Workshop on mathematics learning support concentrating on the use of online technology (Ni Fhloinn, 2010). Three Universities preparing to form the Technological University for Dublin prototyped a virtual mathematics learning support drop-in service (Breen et al., 2016). Whilst the preference of both staff and students was for mostly in person support it was decided to trial a virtual drop-in service where students at one institution could be supported by staff at another organisation. Overall, the students were positive towards the concept of the virtual drop-in service, however in practice, technical issues such as feedback and slow internet connection affected the trials. Even with these issues, the advantages of online support were seen by students and staff where feedback on the trial included as advantages "it will help people learn or ask questions easier who are shy or ashamed to do so in class" and "… the virtual drop-in gives a larger scope of time and geographic location".

Offering of SOS at university level has continued, with a 2018 survey of the extent and uptake of mathematics support at higher universities in England and Wales (Grove et al., 2019) noting that 18 out of 78 universities that responded to the survey saying they had mathematics support stated they were also using technology to offer online real-time support to learners. It however noted, the provision was very limited with 12 out of the 18 institutions offering less than 1 hour per week.

A further survey (Mac et al,. 2020) looked at the Mathematics Support Centres' online presence in Ireland and the UK in 2018, 33 responses were received. Of the 33 institutions, only 8 provided sessions using a virtual classroom, one respondent praised its usefulness for out-of-hours support for students with full time jobs.

The provision of mathematics support is now widespread (Grove et al., 2019), however the number of students that avail themselves of any support is still relatively low. A study at Loughborough University (Symons et al., 2008) suggested that over 90% of students that failed a first-year mathematics module had rarely accessed the support offered. The survey noted that the most common reason given for non-use was lack of awareness of the location and facilities offered at the centre. A survey at the National University of Ireland Maynooth (Grehan et al., 2011) also cited the main reason of non-engagement with mathematics support was fear. However, in the Open University trial (Mestal et al., 2011) one of the key reasons stated for not attending SOS was an inconvenient time.

In March 2020, due to the Coronavirus pandemic, the requirement for SOS in mathematics became increasingly important. A report into the changes in mathematics and statistics support practices due to Covid-19 (Hodds, 2020) analysed results of a survey conducted that aimed to take a snapshot of what was being offered now by mathematics support centres compared to before the pandemic started. Of those that answered the survey only 21 institutions were offering some form of synchronous online support before the pandemic, whereas after the pandemic 50 institutions were offering synchronous online support of some form. The survey also determined that over 72% of institutions are intending to continue providing SOS once the pandemic is over.

With the offering of SOS more prevalent, considering the optimal timing of support for students becomes increasingly important to maximise engagement. This paper will examine a pilot within the Open University's Mathematics and Statistics programme and establish what effect holding SOS tutorials at different times of day had on attendance and whether there was benefit in offering SOS tutorials tailored to specific groups of students.

2. History of SOS tutorials for a first level mathematics module

The effects of scheduling tutorials have been piloted on a first level mathematics module at the Open University, MST124: Essential Mathematics 1 (MST124) which covers the basic range of mathematic skills required for a degree in Mathematics, Physic and many other STEM subjects. There is a cohort of approximately 2000-2300 registered students for each presentation of the module which starts in October. The module is delivered via a blend of printed and online teaching material and students can access moderated peer support via online forums.

Each student is assigned a support tutor, who in turn looks after approximately 20 students in a tutor group. The tutor has historically given support only to students within their own tutor group, via telephone, written correspondence and face-to-face (FTF) support tutorials. More recently the support, to their own tutor group, was given via electronic methods, email and text, telephone, FTF tutorials and SOS tutorials. Attendance at FTF and SOS tutorials is optional.

Since 2015, tutor groups have been grouped further into clusters and SOS tutorials were made available to all students within a cluster, rather than just the tutor's own group. A cluster is a grouping designed to enable a more diverse and flexible delivery of SOS tuition within an extended learning community. For MST124 there are 9 clusters, which are based on the location of tutor and student and are reviewed annually to ensure a similar number of tutor groups in each cluster. The allocation of tutorial support between FTF and SOS tutorials is made on a cluster basis and can result in a significant difference in the number of SOS tutorials between clusters. During 2017/18 there were 371 SOS tutorials run and on average 6 students attended a tutorial. The number of SOS tutorials varied between each cluster with the lowest being 10 SOS tutorials and the most 70.

Each tutorial is based on a specific topic. The functions topic is studied at the beginning of November and there are a total of 28 SOS tutorials organised to support the topic, during the presentation 2017/18, 22 of them were run on a midweek evening, 3 were run during a midweek day and 3 were run at the weekend. On 6 dates more than one of the midweek evening tutorials ran in parallel, whilst students could not have attended more than one tutorial on each date, this is a duplication of tutor work. The weekend and daytime tutorials would only have been available to students in the relevant cluster and so for many students the only option of an SOS tutorial time was a weekday evening.

Attendance at SOS tutorials is recommended, but optional, with the largest proportion of students attending SOS tutorials at the start of the module and the number of attendees reducing as the module progresses. 316 students attended a SOS tutorial on functions, which is 14.5% of registered students. The number of students attending the last SOS tutorial which covers complex numbers, run at the end of April, reduced to just 90 students, which is 5.2% of registered students. Figure 1 looks at the total number of attendees at SOS tutorials on functions and shows even when there is an option to attend tutorials at a different time of day, attendance at these tutorials has been limited and the average number of students attending low. This will affect the ability to build communities of practice (Wenger-Trayner et al., 2015) and extended learning communities within their own clusters. This could be due to the limited number of students that have access to these tutorials and the limited times at which they are offered.

The total and average number of students attending a tutorial on functions in 2017/18

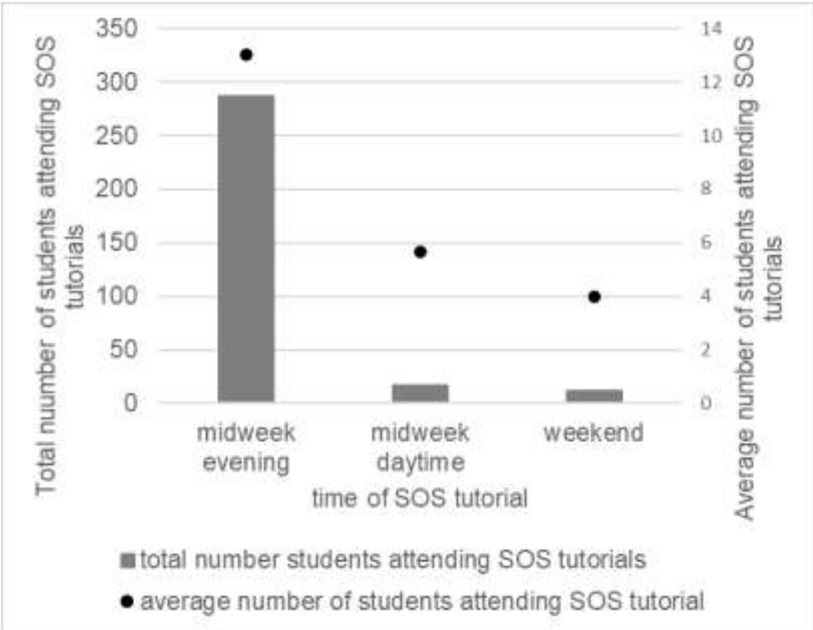


Figure 1: Number of students attending SOS tutorials for functions

3. Initial pilot offering tutorials to whole cohort

To mitigate some of the disparity between the cluster SOS tutorials, a programme of UK-wide SOS tutorials available to all students on MST124 was organised as a pilot for the 2018/19 presentation. The pilot ran a set of SOS tutorials, one to cover each topic of the assessed teaching material, scheduled to run at a date that fitted with the MST124 study timetable, which suggests when each topic should be studied by a student studying only MST124. The dates of the tutorials were listed on the module website and an email containing the programme was sent to all registered students in October 2018. The number of students that attended the first few tutorials was encouragingly high (Figure 2), although they reduced as the presentation progressed, good attendance was maintained, with a total of 305 attendees across all tutorials and on average 24 students attending a tutorial. The number of unique students that viewed the recording of each tutorial was also high with 277 unique students viewing at least one SOS tutorial, which equates to 15% of initially registered students.

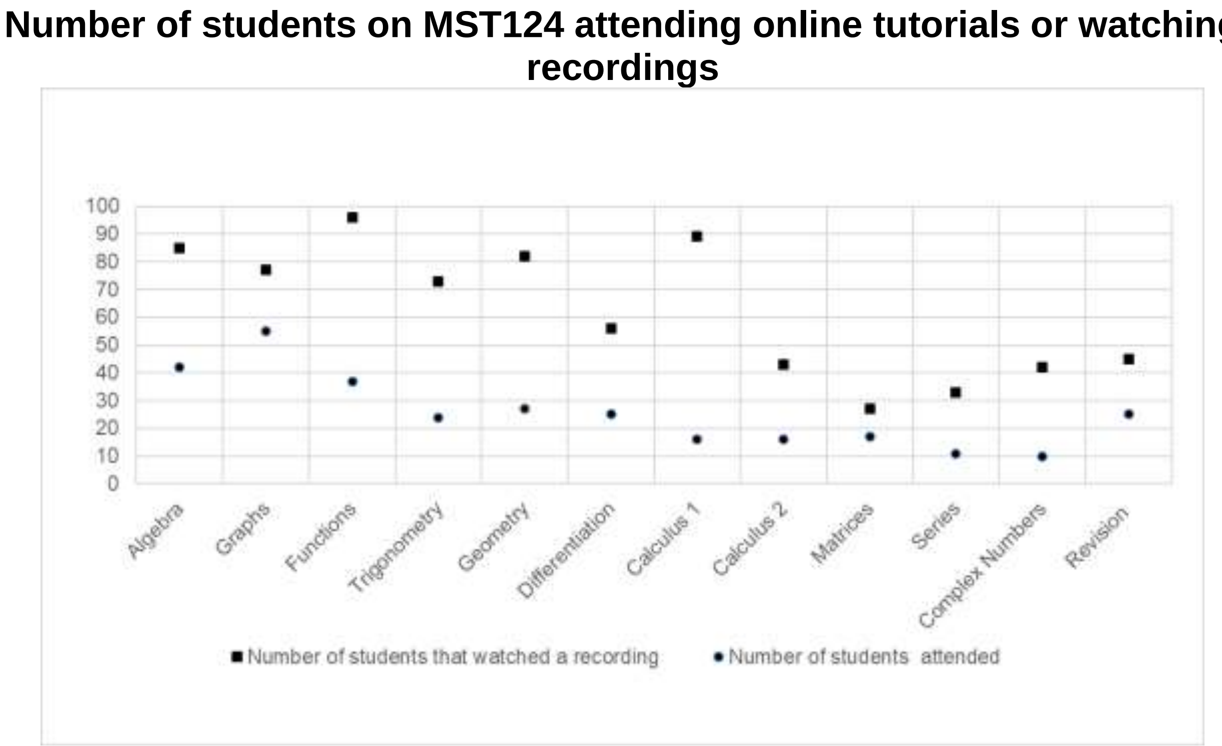


Figure 2: Number of students attending SOS tutorials and watching the recordings

4. Scheduling of SOS tutorials from 2019/20 onwards

With an encouraging pilot, for 2019/20 we extended the pilot further, organising several different programmes of tutorials, available to the whole cohort of MST124 students. Students could attend the tutorial that suited their method of study and availability. Many Open University students study part-time, concentrating on one module at a time, with other commitments taking up significant time during the week, to facilitate these students, we organised several programmes to run at different times throughout the week, so there should be a tutorial available at a suitable time. However, some of our students also study at a higher intensity, studying several modules in parallel. In general, these students follow one of two patterns of study, either they study MST124 and MST125: Essential Mathematics 2 (MST125) in parallel, or they study MST124 and M140: Introducing Statistics (M140) in parallel. On each of these higher intensity study patterns, students study topics at a slightly different time to the MST124 study timetable and so tutorial programmes that follow each of these patterns were offered.

With a proportion of our students living outside of the UK, a programme of tutorials at a time for students living outside of the UK was also run. These was timed to start at 12pm, GMT, which equated to morning in USA and evening in Asia, the timing of the historic cluster mid-week evening SOS tutorial was generally during the middle of the night for our oversees students.

Finally, we were aware that some students study at a quicker rate than our MST124 study timetable and some student study at a slower rate, tutorial programmes for both study speeds were also offered.

This resulted in the following tutorial programmes of whole cohort SOS tutorials (WT) being offered during 2019/20:

Tutorials at different times of the week:

1. Mid-week evening tutorials.
2. Mid-week daytime tutorials.
3. Saturday all-day tutorials.
4. Sunday morning tutorials.
5. Sunday evening tutorials.

Specialist tutorials:

1. Tutorials at a time suitable for students studying outside of the UK.
2. Tutorials for students studying MST124 and MST125 in parallel.
3. Tutorials for students studying MST124 and M140 in parallel.
4. Tutorials run in advance of the MST124 study timetable.
5. Tutorials for students working at a slower rate than the MST124 study timetable.

Each programme offered a variety of tutorials throughout the presentation however due to availability some did not offer a tutorial for every topic.

With the increase in the number of WT available to all students, there is a corresponding reduction in cluster SOS tutorials (CT) (see Table 1) however, in general the creation of the diverse tutorial programmes has increased the total number of SOS tutorials and in total they have increased from 345 in 2018/19 to 362 in 2019/20.

Table 1: Comparing the number of SOS tutorials

	CT		WT		Total	
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20
Algebra	30	21	1	8	31	29
Graphs	26	22	1	9	27	31
Functions	33	25	1	10	34	35
Trigonometry	25	18	1	8	26	26
Geometry	26	21	1	10	27	31
Differentiation	32	22	1	6	33	28
Calculus 1	25	21	1	8	26	29
Calculus 2	29	22	1	10	30	32
Matrices	12	10	1	3	13	13
Series	31	23	1	9	32	32
Complex numbers	34	28	1	10	35	38
Revision	30	26	1	7	31	33

Throughout the year, the WT were advertised by a fortnightly email to all registered students studying MST124 and a calendar of WT scheduled for the next fortnight was posted on the internet. The email was deliberately informal, discussing the approximate progression that students should have been made by that point in time and encouraging students to either attend a synchronous or watch an asynchronous tutorial.

5. The effect of scheduling on SOS tutorials

Table 2 shows the number of attendees at each tutorial which ran at different times of the week. The Midweek evening tutorial still appeared to be the most popular with our part time students, however, Sunday evening tutorials have also proved very popular with nearly as many students attending as the midweek evening option. Other programmes have proven more popular, for some specific SOS tutorials, for example the all-day tutorial run on a Saturday, for Functions, Trigonometry, Geometry and Differentiation were more popular than the equivalent midweek evening tutorials. Also, more students chose to attend revision tutorials at the weekend than during the week, which could indicate a change in study pattern for revision.

The total number of attendees at each programme are given in Figure 3, which show on average more people attended the midweek evening tutorials.

Overall, more students attended tutorials on a Sunday evening and almost as many students attended SOS tutorials on a Saturday, this is partly explained due to a number of missing tutorials on the midweek evening tutorial programme. Equally, although the overall attendance for the Sunday morning SOS tutorials is low, due to the number run, there is still a high average number of attendees indicating some benefit of SOS tutorials run at this time.

Table 2: Number of students at tutorials run at different times throughout the week 2019/20

	Midweek evening tutorial	Midweek daytime tutorial	Saturday all-day tutorial	Sunday morning tutorial	Sunday evening tutorial
Algebra	52	33	14		49
Graphs	37	16	13	23	35
Functions	36	32	41	31	31
Trigonometry	37	16	40		31
Geometry	34	10	32	18	26
Differentiation		7	22		14
Calculus 1		18	5	19	24
Calculus 2	28	11	5	5	23
Matrices			9		
Series	22	10	9		13
Complex numbers	16	18	5	17	16
Revision	19	16	21	45	28

Total number of students and average number of students at WT run at different times of the week 2019/20

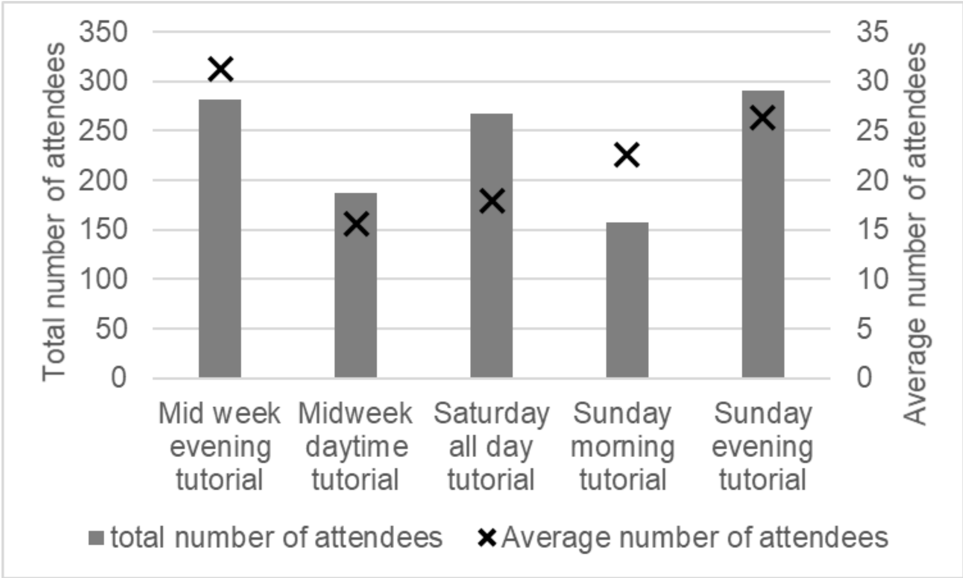


Figure 3: Total and average attendees of WT run at different times throughout the week 2019/20

Table 3: Number of students at specialist SOS tutorials 2019/20

	Students outside of the UK	Students studying on MST124 and M140	Students studying MST124 and MST125	Run in advance	Run at a slower rate
Algebra	24	33	36	68	
Graphs	21	40	41	43	
Functions	18	49	29	30	29
Trigonometry	33		30	26	12
Geometry	12	19	25	15	18
Differentiation		9	12		6
Calculus 1	13	17		16	19
Calculus 2	9	13	8	17	3
Matrices				18	15
Series	10	9	13	5	21
Complex numbers	7	17	11	14	7
Revision	7		19		

Table 3 gives the number of attendees at each of the specialist tutorial programmes. It can be seen that initially tutorials run in advance of the MST124 study timetable are the most popular of all programmes, however by Functions, other programmes are more popular, this may suggest an initial fast pace of study for some of students, reduces within a few months to the expected speed of study. The tutorial programmes for students studying two modules in parallel remains popular for the whole module, however like all programmes the number of students attending decreases as the module progresses.

The same set of tutorial programmes were offered to the whole cohort in 2020/21 and Table 4 shows a similar pattern of popularity with the midweek evening tutorials being the most popular.

Table 4: Number of students attending SOS tutorials at different times of the week 2020/21

	Midweek evening tutorial	Midweek daytime tutorial	Saturday all-day tutorial	Sunday morning tutorial	Sunday evening tutorial
Algebra	121	49	16	84	71
Graphs	73	18	15	46	50
Functions	66	39	32	34	56
Trigonometry	45	16	16	17	49
Geometry	54	28	22	27	25
Differentiation	41	33	12	11	16
Calculus 1	36	28	21	19	43
Calculus 2	23	14	21	13	26
Matrices and Series	24	12	14	9	24
Complex numbers	19	24	6	11	16
Revision	24	18	22	27	25

Table 5: Number of students attending specialist SOS tutorials 2020/21

	Students outside of the UK	Students studying on MST124 and M140	Students studying MST124 and MST125	Run in advance	Run at a slower rate
Algebra	22	35	91	143	
Graphs	0	69	55	98	
Functions	55	48	48	64	31
Trigonometry	36	25	37	35	20
Geometry	28	28	25	35	22
Differentiation	20	19	17	46	16
Calculus 1	31	32	28	31	29
Calculus 2	25	29	21	19	13
Matrices and Series	24	24	15	33	16
Complex numbers	16	14	22	22	12
Revision	28	16	17	25	28

However, again there are several Sunday evening tutorials that are more popular, and even, towards the end of the module, a midweek daytime tutorial on Complex numbers is the most popular. Equally both the Sunday revision tutorials prove more popular than the midweek evening tutorial. Table 5 again shows that the tutorials run in advance of the MST124 study timetable are most popular at the start of the module, however it follows a different pattern to 2019/20 and remains almost consistently the most popular of specialist tutorial programme for the whole presentation.

Feedback from students on how useful they found the tutorial programme was gained via an open question placed on the module forum asking for comments. No negative comments were received, and the following is a sample of some of the positive comments:

Student 1: "The times I find most valuable are the ones later in the evening as I work full time during the day and this allows me to put my little one to bed."

Student 2: "I live in Los Angeles, so I am grateful for the evening classes, as I can make those live. Also appreciate the recorded tutorials for future revision or in case I have to miss a tutorial I wanted to attend. Love the variety that various tutors bring to the table."

Student 3: "Spoiled for choice would be the term that comes to mind. It's brilliant to have so many choices and there is a slight variance in teaching methods so can pick whatever works best for you."

6. Conclusions and observations

Alongside the programmes of WT, the CT have continued. The number provided reduced for 2019/20, however as can be seen in Figure 4 the average attendance remained roughly constant.

Before March 2020 FTF tutorials were also run at various locations in each cluster. Whilst this paper does not discuss attendance at FTF tutorials it can be seen in Figure 5, the average attendance has also remain roughly constant, even after the introduction of the WT. The number of overall FTF tutorials is lower in 2019/20 as they were all cancelled from March onwards due to the Coronavirus pandemic, no FTF tutorials were run in 2020/21.

Looking at the number of students attending SOS tutorials for functions (both WT and CT), at the beginning of November (Table 6) it can be seen that the average number of students decreases slightly between 2017/18 and 2018/19, however the percentage of cohort that attended was similar, due to a smaller cohort in 2018/19. When the WT are introduced, both the average attendance at the tutorials and the percentage of cohort that attended significantly increase (Figure 6).

Even as the module progresses and the number of students attending tutorials decreases overall (Table 7) there is still a significant increase in the average number of students attending a SOS tutorial on Complex Numbers at the end of April and the percentage of register students attending has more than doubled between 2018/19 and 2019/20 (Figure 7).

For 2020/21, no FTF tutorials were run, and so there was a corresponding increase in CT. There was also an increase in average attendance, some of which could be accounted for by the lack of FTF tutorials, but could also be attributed to the change in student's commitments due to the Coronavirus pandemic, which started at the end of March 2020. This is further evidenced in the increase in average attendance at WT, as shown in Figure 8, which shows an increase in the average attendance for all programmes apart from Saturday all-day tutorials., which has remained almost constant.

The number of CT run in each presentation and their average attendance

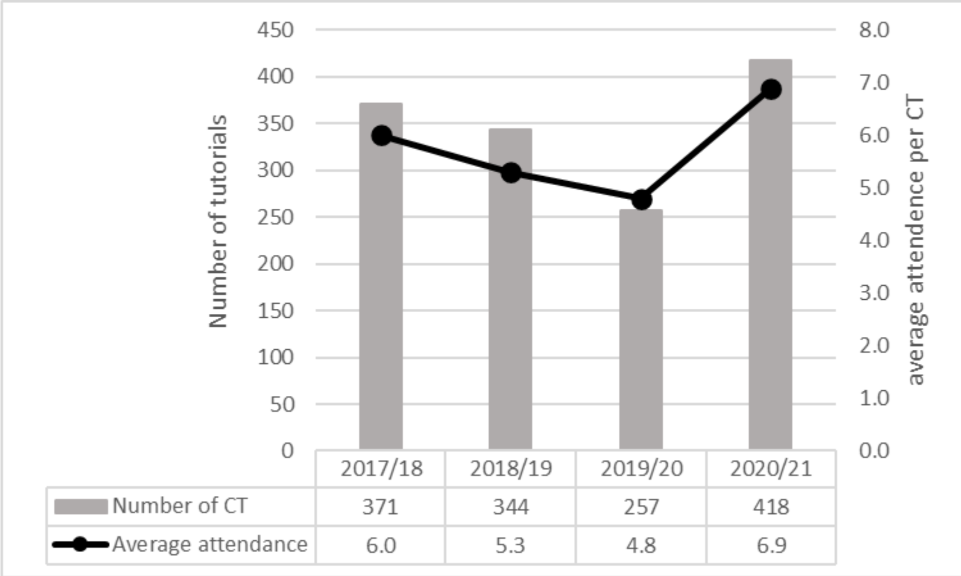


Figure 4: Average attendance at CT

The number of FT tutorials run in each presentation and their average attendance

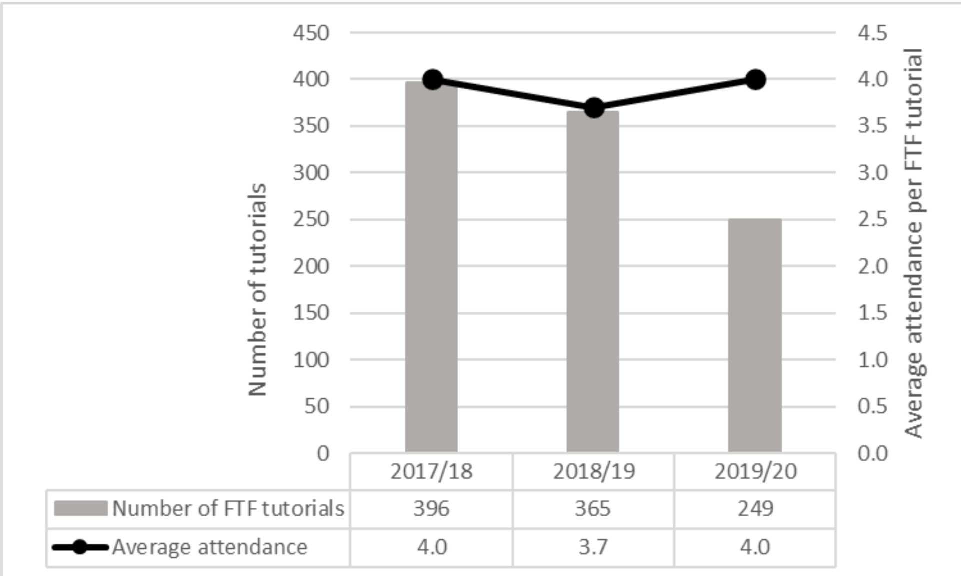


Figure 5: Average attendance at FTF tutorials

Table 6: Attendance at SOS tutorials on functions

	2017/18	2018/19	2019/20	2020/21
Number of students attending a tutorial	316	272	482	825
Number of tutorials	28	34	35	47
Average attendance	11.3	8.0	13.8	17.6
Percentage of registered students	14.5%	14.3%	24.4%	37.3%

Attendance at SOS tutorials on Functions

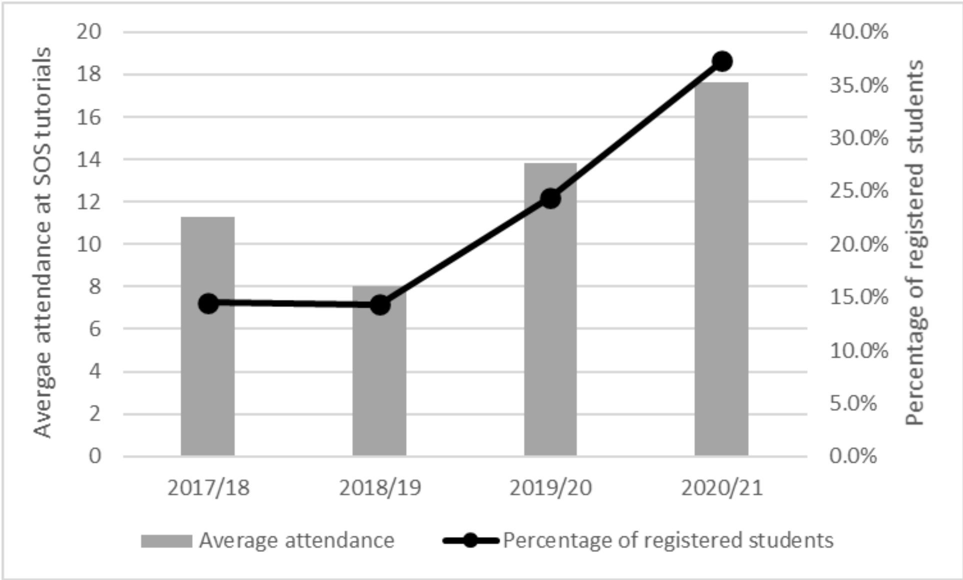


Figure 6: Attendance at SOS tutorials on functions

Table 7: Attendance at SOS tutorials on complex numbers

	2017/18	2018/19	2019/20	2020/21
Number of students attending a tutorial	90	92	202	291
Number of tutorials	29	36	38	46
Average attendance	3.1	2.6	5.3	6.3
Percentage of registered students	5.2%	6.1%	12.9%	15.8%

Attendance at SOS tutorials on Complex numbers

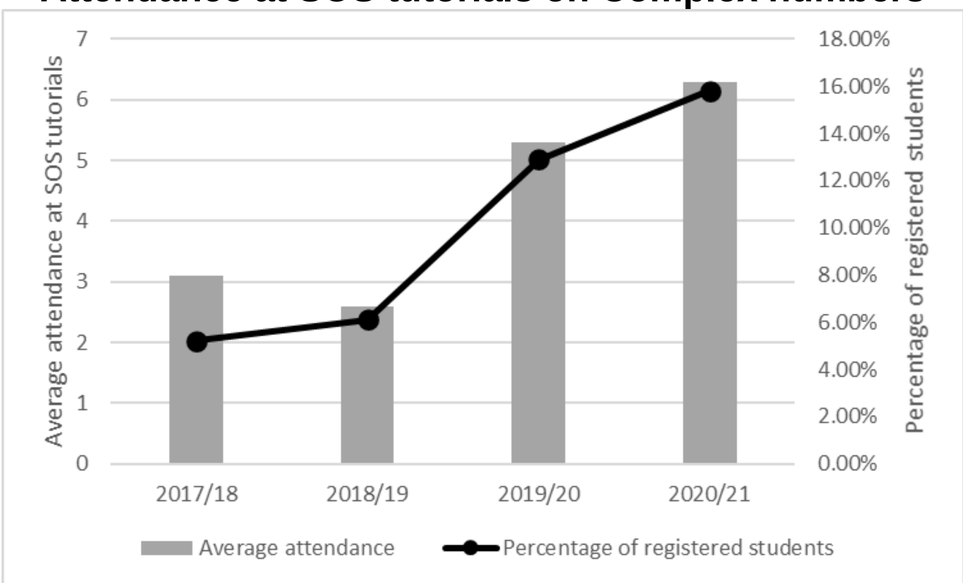
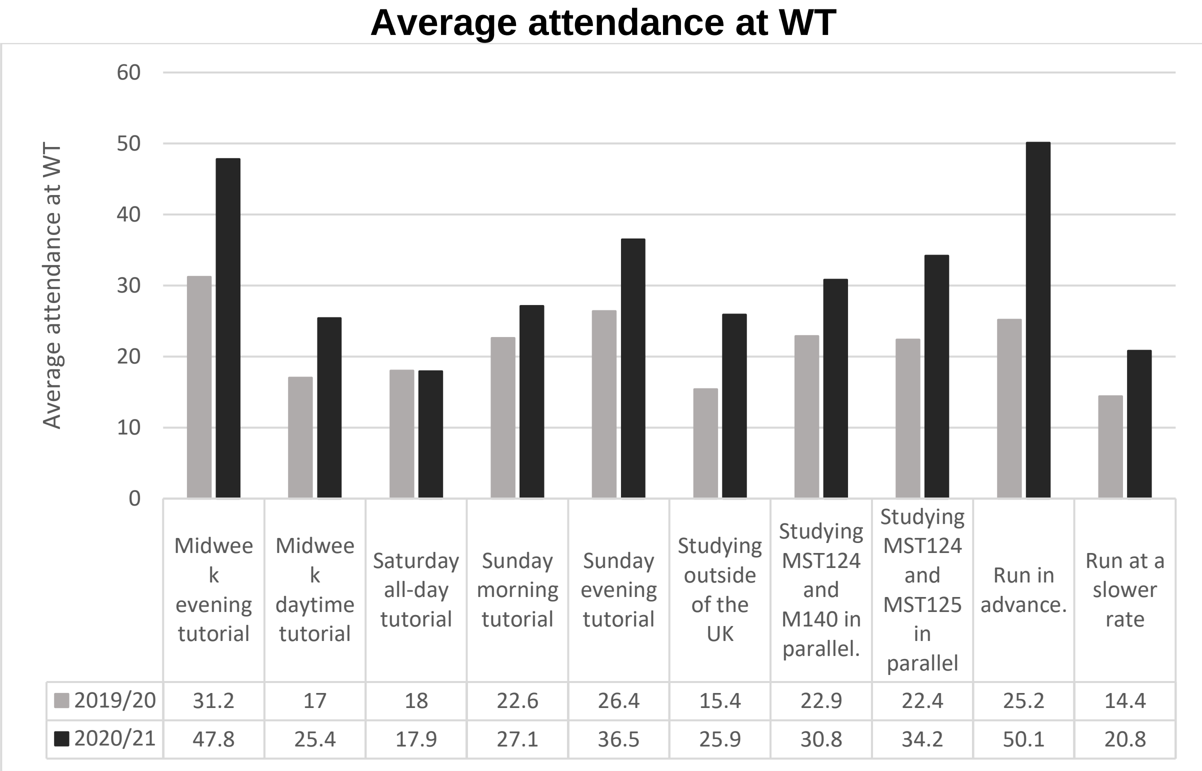


Figure 7: Attendance at SOS tutorials on complex numbers



	Midweek evening tutorial	Midweek daytime tutorial	Saturday all-day tutorial	Sunday morning tutorial	Sunday evening tutorial	Studying outside of the UK	Studying MST124 and M140 in parallel.	Studying MST124 and MST125 in parallel	Run in advance.	Run at a slower rate
2019/20	31.2	17	18	22.6	26.4	15.4	22.9	22.4	25.2	14.4
2020/21	47.8	25.4	17.9	27.1	36.5	25.9	30.8	34.2	50.1	20.8

Figure 8: Average attendance at WT

Some of the largest increases in average attendance are in Tutorials run in advance of the MST124 study timetable, Midweek evening tutorials, Tutorials run at a slower rate than the MST124 study calendar and Tutorials run for students studying MST124 and MST125 in parallel, which all run on weekday evenings, this could relate to the reduction in external evening commitments of our students during the pandemic. The smallest increases in average tutorial attendance are for Saturday all day tutorials and Sunday morning tutorials, which may indicate the weekend commitments of our students remained similar both before and during the pandemic.

Therefore, in conclusion, by increasing the times when tutorials are offered and the type of specialist tutorials, we can significantly increase the number of students that attend SOS tutorials. Our most popular SOS tutorials were still run during a midweek evening, however there is also significant interest for tutorials run at other times, in particular, Sunday evenings and also the study habits of students seem to change for revision periods, where weekend tutorials increase in popularity.

The programme of tutorials has now been expanded by the inclusion of more specialist tutorials, such as post assignment reviews where a small group of students who have struggled with the assignment are invited to an interactive tutorial where the assignment is reviewed in detail, and drop-in clinics, where there is no predetermined structure for the tutorial, and it is completely dictated by the needs of the attendees.

Whilst the data relates to part time distance learning students, analogies can still be drawn with more traditional support at universities, particularly given the findings in *A report into the changes in Mathematics and Statistics support practices due to Covid-19* (Hodds, 2020) which indicates that many institutions will continue to offer online support on a permanent basis. MST124 is a key service teaching module, whose cohort is made up of students studying mathematics, physics, computing, economics and other degrees. Our students benefit from a variety of support which included not only SOS tutorials, but FTF tutorials when available. A face-to-face teaching university may benefit from the addition of a number of online support tutorials for their large service teaching modules at different times and with different focuses.

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RESEARCH ARTICLE

Investigating the relationship between mathematics anxiety, mathematical resilience and mathematics support engagement: an analysis of demographic and cohort factors

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Abstract

Engagement with mathematics support has been of interest for several years, particularly because some students who may benefit from using support do not avail themselves of it. It has been suggested that these students may be those who are mathematics anxious; they may have had previous negative learning experiences with mathematics and thus demonstrate avoidance behaviours such as procrastination and not seeking help. In this paper, the results of mathematical resilience (MR) and anxiety questionnaires (MA) will be investigated. This investigation is conducted at the level of the whole cohort of students and also broken down by a range of demographic features. Consideration is also given to whether there is any relationship between student mathematics anxiety and resilience on the one hand and whether or not they engage with mathematics and statistics support services on the other.

The analysis reveals a weak negative correlation between MA and MR at whole cohort level. In terms of demographic characteristics, students on courses with no mathematics A-level entry requirement were significantly more mathematics anxious than those on courses with a mathematics A-level entry-requirement. They were also less mathematically resilient. Female students, non-Asian students, mature students and disabled students, on average, also had higher MA scores, whilst female students and mature students were also significantly less mathematically resilient.

Keywords: mathematics anxiety, demographics, mathematics resilience, entry-requirements, mathematics support.

1. Introduction

Mathematics anxiety (MA) is defined to be, “a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in … ordinary life and academic situations” (Richardson and Suinn, 1972; p.551). It is a debilitating disorder that can arise from previous negative experiences with mathematics and may in fact be worsened due to the method by which mathematics is taught in UK secondary schools, which has been likened to a form of “cognitive abuse” (Johnston-Wilder and Lee, 2010). Students with MA may avoid mathematics because the brain sees mathematics as a traumatic situation and a fight or flight response is triggered. The emotional response in the brain increases with the severity of the mathematics anxiety and this causes stronger responses in the more anxious students (Marshall et al., 2017). When the brain is in this state, it is unable to think logically and therefore cannot process mathematics effectively, meaning that attempting to learn whilst in this state may not be worthwhile. This shows that avoidance of mathematics or procrastination is potentially an automatic response in students, rather than it being their fault. When students are unable to avoid mathematics, they may end up using self-sabotaging behaviours such as not studying regularly or not seeking help where necessary.

Identifying MA as an obstacle to effective learning in students is potentially the first step towards overcoming it (Uusimaki and Kidman, 2004). Teaching students to become mathematically resilient (MR) (having a positive affective stance to mathematics), can further assist students in tackling mathematics anxiety and students can become effective learners. Lee and Johnston-Wilder (2014) describes MR as being a 3- dimensional construct, with dimensions of growth, value and struggle, with mathematically resilient students believing that:

1. Anyone can learn mathematics; and

2. There is value in learning mathematics; and

3. Struggle is a normal part of learning.

As noted above, where mathematically anxious students cannot avoid mathematics, they may sometimes adopt self-sabotaging behaviours such as not seeking help when it is needed. This may be reflected in their unwillingness to engage with mathematics and statistics support (MSS) services. MSS aims to provide support to all students, but the support offered is on a voluntary basis. Students have to take the initiative to engage with the support on offer. Therefore, this research aims to understand the extent to which MA and MR play a part in engagement with MSS.

Since MA can lead to avoidance behaviours, it is interesting to explore whether levels of MA differ with course of study. It is also beneficial to understand whether MA is more prevalent in specific demographic groups so that, if there is evidence of this, future work can be focussed on tailoring interventions towards lowering MA levels in these demographic groups.

2. Methodology

There are a number of published scales for measuring MA (e.g., Hopko et al., 2003; Núñez-Peña, Guilera, and Suárez-Pellicioni, 2014) and one key scale for measuring MR. In this study, Kooken et al.'s (2013) mathematical resilience questionnaire (retrieved from Johnston-Wilder et al., 2014) and Betz's (1978) mathematics anxiety questionnaire were used to determine respondents' anxiety and resilience level. These scales have been previously used in studies of MA and MR amongst higher education students (Johnston-Wilder et al, 2014). The MR scale ($\alpha = 0.856$) has three subscales (Value: 8 items ($\alpha = 0.841$; Struggle: 8 items $\alpha = 0.762$; Growth: 7 items $\alpha = 0.751$), whilst the MA questionnaire has 10 items ($\alpha = 0.910$). In both the MA and MR scale, respondents are asked to indicate their level of agreement with each item using a 5-point Likert scale (strongly disagree through to strongly agree). Some items are positively worded whilst others are negatively worded (when scoring negatively worded questions the order is reversed to ensure consistency). Sample items are shown below:

MA (positively worded) I usually don't worry about my ability to solve maths problems

MA (negatively worded) My mind goes blank and I am unable to think clearly when working on mathematics

MR (value subscale) Maths is very helpful no matter what I decide to study

MR (struggle subscale) Good mathematicians experience difficulties when solving problems

MR (growth subscale) People are either good at maths or they aren't

The questionnaires were distributed primarily through attaching them to diagnostic tests and were answered by students on a variety of courses. These diagnostic tests were delivered to several

Coventry University course cohorts at the start of their studies to ascertain their level of preparedness in mathematics. At the start of semester one, students were sent a link via email to complete the diagnostic test through OnlineSurveys. Upon completion of the diagnostic test, students were prompted to continue and complete the MR and MA questionnaire. This encouragement made clear that participation was voluntary and not linked to the diagnostic assessment they had just completed. It was hoped that this method of data collection could be repeated in semester 2 to recruit new participants. However, due to changing university processes, the questionnaires could not be added to the diagnostic test, so this approach was not possible. As an alternative, the link to the MA and MR questionnaires was added to the post-diagnostic test email sent out to students giving them their personal diagnosis. This gave a significantly lower response rate. Other methods of participant recruitment included advertisement to students attending mathematics and statistics support drop-in sessions, lectures and course noticeboards.

Data on student demographic characteristics was obtained from the University student record system (participants having given permission for this). Whether or not a student engaged with MSS up to and including the end of the 2020-21 academic year was determined from the attendance records of the MSS service.

Ethical approval for the study was given by Coventry University Research Ethics Committee.

3. Results

3.1. Questionnaires

A total of 488 responses were received, with 395 students completing all resilience questions and 409 completing all the anxiety questions. A five-point Likert scale was used for both scales; responses were scored 1 to 5 (strongly disagree to strongly agree) for positively worded items and reverse scored for negatively worded items. A student score for each construct was calculated by determining their mean item score. Consequently, scores range from one to five, with one meaning a student was not mathematics anxious or resilient at all, and five being a student had the highest possible level of mathematics anxiety or mathematical resilience. The descriptive statistics for both scales can be found in Table 1.

Table 1: Descriptive statistics for both the mathematics resilience and mathematics anxiety scale

Questionnaire	N	Median score	Mean score	Minimum	Maximum
Mathematics resilience	395	4.04	4.01	2.13	4.96
Mathematics anxiety	409	3.10	3.11	1	5

The range for the anxiety results is much wider than that of the resilience, where it seems as though scores are more positively skewed, perhaps because a certain level of MR is needed to attend university and study a course which may have some mathematics content. On the other hand, students' anxiety levels here are seen to range from having little to no evidence of mathematics anxiety to the highest possible levels of mathematics anxiety.

3.2. Correlation between MA and MR

Figure 1 shows a scatter plot of mean MR score against mean MA score. MA and MR were found to be weakly negatively correlated, $r = -.221$, $p < .001$.

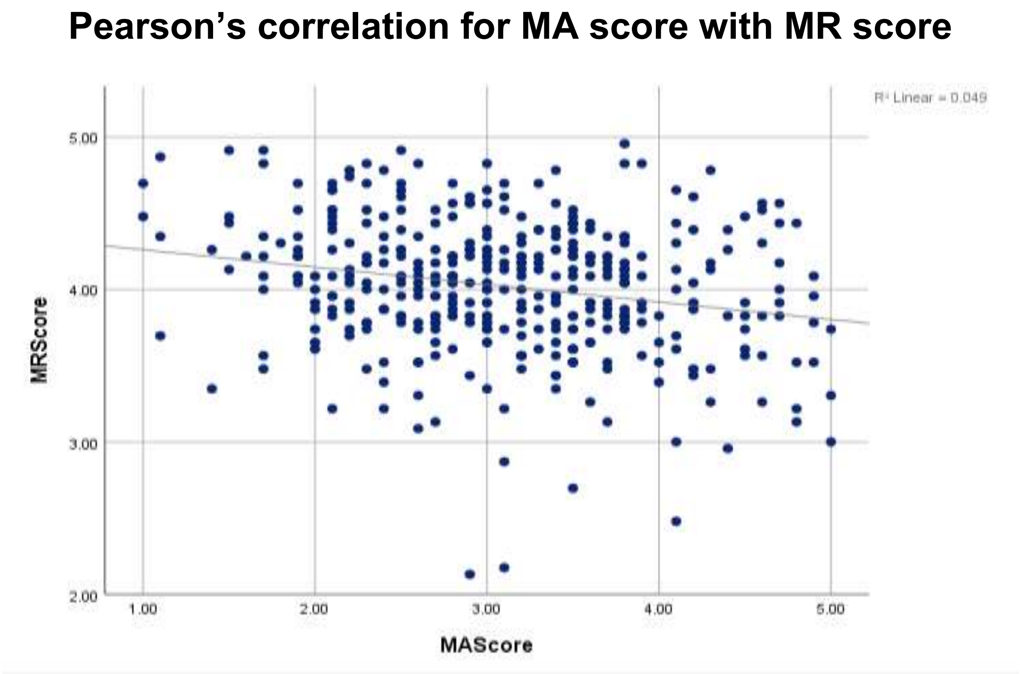

Figure 1: Correlation between students’ average MA and MR score

The relationship between mathematics resilience and anxiety is to be expected (Trigueros et al., 2020), with students displaying elevated levels of mathematics anxiety generally having lower levels of mathematics resilience. There are some outliers, and these may be students that are resilient enough to overcome their anxiety and succeed with the mathematics in their course, whilst students with scores above 4 for MA or below 2 for MR are a cause for concern. This is because a score above 4 for MA would suggest that a student has agreed with most/all of the items, whilst scores below 2 for MR would indicate that a student has disagreed with most of the items (since the response categories were set from “strongly disagree” to “strongly agree”). It is worthwhile to note that no students had an MR score of below 2, though a considerable number did have an MA score above 4 (with three students having the highest possible score of 5).

3.3. MR and MA score by course

Students from several different courses completed the questionnaire. To make analysis by course practical, students were grouped according to their courses’ mathematics entry requirement, as seen in Table 2.

Mechanical engineering and mathematics were examples of courses in the mathematics A-level required group, economics and some other engineering courses were in the mathematics A-level recommended group, whilst biosciences and nursing were classed as no A-level requirement.

Table 2: Number of respondents, and the standard deviation and mean for their resilience score, broken down by course mathematics entry requirements

Course	N	SD	Mean MR
No A-level requirement	222	0.44	3.93
A-level recommended	51	0.38	4.11
A-level required	122	0.40	4.13

The difference in MR between students on courses where A-level mathematics was either recommended or required is minimal. However, there is little larger difference when considering students on courses with no A-level requirement. A one-way ANOVA was performed to compare the effect of course mathematics entry requirements on MR score, which revealed that there was a statistically significant difference requirement between at least two groups ($F(2, 392) = 10.433$, $p < 0.001$). A post-hoc Bonferroni correction found that the mean value of MR was significantly different between no A-level requirement and A level recommended, $p = .017$, 95% C.I. = [-.338, -.024]), and between no A-level requirement and A level required, $p < .001$, 95% C.I. = [-.314, -.086]). There was no statistically significant difference between A-level required and A-level recommended ($p=1.000$) as expected from observing Table 2.

It is important to note here that some students may have an A-level in mathematics (or equivalent) but do not study a course where this is required. Future analysis will investigate the relationship, if any, between students' prior qualifications and their mean MA and MR.

However, when looking at MA in these students, there is a notable difference in mean MA scores between all three groups, as seen in Table 3.

Table 3: Number of respondents, and the standard deviation and mean for their anxiety score, broken down by course mathematics entry requirements

Course	N	SD	Mean MA
No A-level requirement	234	0.87	3.34
A-level recommended	51	0.66	3.01
A-level required	124	0.69	2.72

The Mean MA score for students on courses with no A-level mathematics entry requirement is 23% higher than that for students on course with an A-level mathematics entry requirement.

Though there is more variability in mean MA score when considering students on courses with no mathematics A-level requirement, their mean MA score firmly places these students more in the maths anxious category than students in courses with a required maths A-level, who could be categorised as not very maths anxious at all. A one-way ANOVA found there was a statistically significant difference between at least two groups ($F(2, 406) = 24.624$, $p < 0.001$). A post-hoc Bonferroni correction found that there were significant differences in the mean MA score of two of the three pairs, with the test between no A-level requirement and A level recommended returning p = .027, 95% C.I. = [.027, .619], and between no A-level requirement and A level required returning p < .001, 95% C.I. = [.403, .828]). There was no statistically significant difference between A-level required and A-level recommended (p=.084), perhaps surprisingly since the MA score between the two groups differed by a similar amount to the difference in MA score between no A-level requirement and A-level recommended.

3.4. MA and MR by engagement and demographic characteristics

One purpose of this research is to investigate if levels of MA and MR impact on student engagement with MSS. Another purpose is to explore whether specific demographic groups have higher (or lower) MA and MR levels. Table 4 shows a breakdown of the data by various characteristics (the rows "Visited" and "Not visited" refer to students who attended the mathematics and statistics support drop-in provision at least once during the academic year). For each characteristic shown in Table 4 (engagement, gender, ethnicity, age, disability), t-tests were run with this as the independent variable and, in turn, MA and MR as the dependent variable.

Table 4: Mean MR and MA scores broken down by various characteristics and t-test statistics

Characteristics		N	SD	MR	t	p	N	SD	MA	t	p
Engagement	Visited	37	.42	3.85	-2.39	.017	39	.88	3.28	1.33	.185
	Not visited	374	.42	4.02			389	.84	3.09		
Gender	Male	193	.44	4.08	-3.25	.001	197	.69	2.85	6.12	<.001
	Female	218	.41	3.95			231	.89	3.33		
Ethnicity	Non-white	150	.44	4.02	.424	.672	157	.75	3.00	-2.01	.050
	White	245	.43	4.00			252	.89	3.18		
Age	Mature	157	.47	3.94	-2.80	.005	165	.91	3.29	3.66	<.001
	Non-mature	254	.40	4.06			263	.77	2.99		
Disability status	Disability	64	.49	4.00	-.187	.852	71	.82	3.34	2.55	.011
	No disability	331	.42	4.01			338	.84	3.06		

These results show that, somewhat surprisingly, those that did not engage with MSS were statistically significantly more resilient than those that did visit. Additionally, those that visited were more mathematically anxious than those who did not, though this difference was not significant. We might hypothesise that the reasonably high levels of mathematical resilience amongst the students who did visit (3.85) was helping them offset their moderately elevated levels of mathematics anxiety (3.28) so that they did not succumb to self-sabotaging behaviour such as not seeking help. We might further hypothesise that the almost middle mathematical anxiety score of those who did not visit (3.09) allied with high mathematical resilience (4.02) led to these students not feeling in need of additional support. However, the sample size for those that visited is relatively small (and only about 10% of the sample size of those that did not visit). A larger sample size may be needed for more meaningful results.

The respondent numbers by gender were similar, and it was found that male students were significantly more resilient than female students. A similar trend can be seen in their MA scores, where females are, on average, significantly more mathematics anxious than male students, (although there is more variability in the scores of female students). Since three is the middle score on the range of possible scores for MA (which is one to five), the results in Table 4 show that female students' anxiety is above this middle anxiety level, whilst that of male students is below the middle.

In a first investigation of whether there is a difference in MR and MA scores between students of different ethnicities, all non-white ethnicities were amalgamated into a single category. The MR scores for both groups were remarkably similar and, not surprisingly, the small difference was not statistically significant. This was not the case when comparing the mean MA scores, where non-white students are significantly less maths anxious than white students. To investigate both these findings in more detail, the MR scores of the amalgamated non-white category has been subdivided, as shown in Table 5.

Table 5: Mean resilience and anxiety score broken down by ethnicity

Ethnicity	N	SD	Mean MR	N	SD	Mean MA
South Asian	44	.41	4.03	46	.56	2.91
Asian Chinese/Asian Other	19	.39	4.13	20	.75	2.81
Black	53	.48	4.00	56	.83	3.11
Mixed	21	.33	4.03	22	.69	3.05
Other/unknown	13	.61	3.92	13	1.07	3.11
White	245	.43	4.00	252	.89	3.18

From Table 5, we see that Asian Chinese/Asian Other students are on average more mathematically resilient than any other ethnic group (4.13), whilst South Asian, Black, White, and Mixed students all have an MR score of around 4. Other/unknown students are the least mathematically resilient (3.92), but it should be noted that this was the smallest group (there were only 13 students in this category).

The differences in mean MA are quite revealing. It appears that Asian students overall are less mathematically anxious than all other ethnicity groups. They are the only two groups to have a mean MA score below the middle. To determine whether this result was significant, the data was again aggregated to form two groups: Asian and non-Asian, which can be seen in Table 6.

Table 6: Mean MA scores broken down by ethnicity (Asian and non-Asian)

Ethnicity	N	SD	Mean MA	t(407)	p
Asian	66	.62	2.88	-2.48	.01
Non-Asian	343	.87	3.15		

As hypothesised, Asian students are significantly less maths anxious than non-Asian students, with p=.01.

Returning to Table 4, we see that mature students are significantly less mathematically resilient than young students. However, mature students still have a high MR score (3.94). This may be because mature students have learnt, through experience in the workplace about the value of mathematics (one of the subscales of the resilience construct). We also see that mature students are more anxious than young students and this difference is significant. This is consistent with the findings of Durrani and Tariq (2009) and will not surprise mathematics and statistics support practitioners who frequently encounter mature students expressing their concerns about both not having studied mathematics for many years and also not having been very good at the subject when they were at school. It would appear that the relatively high-level MR of such students allied with their anxiety levels motivates them to seek help (whereas if they had low levels of MR they might avoid MSS).

The final factor investigated was disability. There is virtually no difference in MR scores between students with a declared disability and those without. However, it was found that disabled students were significantly more mathematically anxious than students that are not, with p=0.011. It may be that disabled students are generally more anxious about their education, possibly because of difficulties in the past when accessing the support they needed. It should also be noted that the amalgamation of all types of disability into a single category is unsatisfactory because of the wide range of different types of disability and resulting different experiences of students. However, the small number of students who declared a disability required this amalgamation in order to carry out a meaningful statistical analysis.

4. Statistical modelling

To ascertain what factors influenced MA and MR score when combined, an ANCOVA was conducted. In both cases, MA and MR were added as covariates since it has already been found that a significant negative correlation existed between the two variables.

4.1. Mathematics Resilience

When MR score was considered as the dependent factor, course entry requirements, engagement, and MA score all were shown to have a significant effect. Further statistical detail can be seen in Table 7.

Mathematics A-level required was used as a reference category, and it can be seen that students on a course with no mathematics A-level requirement have significantly lower MR scores than those on a course with a mathematics A-level requirement (which is the reference category for course type). However, the difference between the reference category and the courses with mathematics A-level only being recommended is not statistically significant. Either way, the type of course a student studies does have an effect on students' MR score. Furthermore, after adjusting for the type of course, overall, students that visited the drop-in centre had lower MR scores than those who did not. MA score also returned a significant result, showing that as expected, it provides an explanation for some of the variation in MR score that is not accounted for by the other variables.

Table 7: Beta and p-values for reduced ANCOVA model for MR

Parameter	β	p
No mathematics A-level requirement	-.15	.004
Mathematics A-level recommended	-.018	.802
Visited	-.17	.023
MA Score	-.82	.003

4.2. Mathematics Anxiety

Table 8: Beta and p-values for reduced ANCOVA model for MA

Parameter	β	p
No mathematics A-level requirement	.408	<.001
Mathematics A-level recommended	.278	.034
Disability	.288	.007
Female	.207	.051
MR Score	-.306	.001

The analysis determined that MA was influenced both by course entry requirements and disability, along with MR score. Despite the fact that gender was not a significant predictor of MA score, it was included in the model since it had p=.051 and was observed to have a significant effect on MA when t-tests were performed on the data in Table 4. Its lack of significance in the ANCOVA model suggests that there may be some interaction between it and another variable.

5. Discussion

The correlation between MA and MR indicates that those with higher levels of MA tend to have lower levels of MR. This was initially a concern as it raises the question of how students with low MR scores would overcome their MA enough to access MSS. However, it was found that students who visited had higher levels of MA than those who did not, though this was not a significant result. Therefore, this provides some evidence that raised levels (i.e., above 3) of MA may actually promote engagement with MSS. Further to this, those that visited the centre were significantly more likely to have lower MR scores than those that did not visit, though the MR scores of those who did visit cannot necessarily be classed as low – 3.85 is actually relatively high for an MR score (possible scores range from one to five). Those that have very high MR scores (above 4) may be less inclined to access drop-in support because mathematically resilient students may be more likely to know of, and use, many avenues of support (Lee and Johnston-Wilder, 2017), such as asking their lecturers or working with their peers, rather than having MSS centres as their first port of call. However, the population distribution in this research is skewed heavily towards non-visitors, meaning a larger sample size will be needed if these results are to be reliable.

The results of Section 3 further indicate that the MA score differs significantly for each demographic characteristic considered. On the other hand, MR differs significantly only by gender and age, and not by ethnicity (white and non-white) or disability. Neither gender, ethnicity nor age were found to significantly influence MA or MR scores in the ANCOVA analysis. However, the mathematics entry requirements of the course a student studies did appear to have a significant effect.

MA has been shown to be greater among female students in previous studies (Durrani and Tariq, 2009; Joyce et al., 2006; Mutodi and Ngirande, 2014), thus it is possible that the results for the ANCOVA analysis are being confounded by an interaction with another factor. However, Hembree (1990) found that though female students reported higher levels of MA, it did not result in greater mathematics avoidance behaviours, whereas it did for male students. This result is suggested to be potentially caused by females being more willing to admit their anxiety, and females coping with anxiety better.

It may be that the factor confounding the results for the effect of gender or age on MA and MR in the ANCOVA analysis is the mathematics entry requirements of the course a student studies. Students that responded to the questionnaire were primarily either from engineering or health science courses. Engineering is dominated by male students, whereas adult nursing and biosciences have a mainly female population and also a higher mature student population. Engineering courses also tend to have either a mathematics A-level requirement or it is recommended, which is generally not the case for Health Science courses. In Table 2 and 3, it can be seen that those studying courses where no A-level mathematics is required have higher MA scores and lower MR scores than the students studying either of the other course types. Therefore, it may be possible that there is some interaction between these variables, which further research will focus on.

Asian students had significantly lower MA scores than non-Asian students, which, when looking at the mathematics culture for Asian students, may be expected, particularly East Asian students, where they “see math to be less challenging than their western counterparts who “expect” math to be difficult” (Stankov, 2010). White students had the highest level of MA. No other study that we are aware of has investigated MA scores among different ethnic groups, thus more research will be done in this area to see if these findings can be consolidated, and what may be done to target demographic groups with high MA levels.

Mature students were found to be significantly more mathematics anxious and also had lower MR scores. This may be explained by the time spent away from education, and thus, studying any mathematical content formally.

Students with a disability could have a learning difference, a mental disability or a physical disability, or a combination. For the purpose of the analysis, these students were grouped together, though it is noted that accessibility and providing an inclusive space for these students will not necessarily look the same. There was virtually no difference in the MR score between the two groups of students, though it was found that students with a disability had a significantly higher MA score.

6. Conclusions and future work

This research aimed to determine what factors influenced MA and MR scores in students that responded to an MA and MR questionnaire. Mostly students who did not engage with MSS responded, which gave an interesting insight into the MA and MR scores of non-users of mathematics support.

Course mathematics entry requirements, disability, and MR score appeared to significantly impact the MA score of students, whilst course mathematics entry requirements, engagement with MSS and MA score appeared to significantly impact MR score of students. Gender did not return a p-value below 0.05 for either ANCOVA analysis, despite t-tests showing it did have a significant impact on both MA and MR. This suggests there may be an interaction between gender and another factor, although it has been surmised this factor interaction may be with the mathematics entry requirements of the course a student is studying.

Data collection will continue for the next academic year, with focus placed particularly on finding students who have engaged with mathematics support. Alternative questionnaires will be delivered to statistics students to measure their statistics anxiety, and both mathematics resilience interventions and statistics anxiety interventions will be delivered to students, the success of which will be measured through post-intervention questionnaires.

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RESEARCH ARTICLE

Are students too anxious for statistics anxiety workshops?

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Abstract

Statistics is a widely taught subject in Higher Education but for many students, anxiety about statistics interferes with the learning process. Statistics anxiety workshops to help students understand and reduce statistics anxiety were developed by the authors and in 2020/21 delivered collaboratively and remotely with specific cohorts of students at three institutions. Prior to the workshops, all students within the targeted cohorts were asked to complete a survey which included measures of statistics anxiety, and asked if they were interested in attending the voluntary workshop. This enabled a comparison of the characteristics of groups who were interested or not. The workshops successfully attracted the targeted students, since those attending had higher overall statistics anxiety, software and maths anxiety, and anxiety around learning statistics. However, students with higher help seeking anxiety were less likely to attend.

Keywords: statistics anxiety, higher education, workshop, attendance.

1. Introduction

Statistics anxiety is a situation-specific anxiety which can have a considerable impact on a student's ability to study statistics effectively. It is thought that between 70% and 90% of students have some level of statistics anxiety (Zeidner, 1991; Marshall et al, 2021). Whilst several studies show links between statistics anxiety and performance (Onwuegbuzie et al, 2000; Paechter et al, 2017; Zeidner, 1991), it is more likely this is an indirect effect with anxiety, attitudes and motivational beliefs impacting on learning behaviour and subsequently performance. Anxious students often try to avoid situations that involve engagement with statistics, including attending lectures and asking for help. They are more likely to delay work until just before a deadline, have less perseverance at tasks, and put little effort into learning (Macher et al, 2011). This leads to poorer performance (Macher et al, 2011; Gonzalez, 2016; Macher et al, 2013; Kesici, 2011), reinforcing their view that they cannot learn statistics.

Research into maths and statistics anxiety tends to focus on understanding why students are anxious rather than strategies for reducing anxiety, but Johnston-Wilder and collaborators have identified a two-stage process for reduction of maths anxiety (Johnson-Wilder et al., 2016; Johnston-Wilder and Marshall, 2017). The first stage involves awareness of maths anxiety and developing approaches to overcome triggers followed by the provision of positive teaching experiences. One of the most effective methods for reducing maths anxiety is receiving positive one-to-one support (Núñez-Peña et al., 2015; Johnston-Wilder and Marshall, 2017), as support is tailored to the individual and allows immediate feedback. However, as anxious students may try to avoid mathematical situations, many anxious students do not engage with this additional support. A study by O'Sullivan et al, (2014) estimated 33% of students who are at risk of failing do not seek appropriate support, often citing anxiety as the reason for not doing so.

Marshall et al. (2017) trialled a whole cohort group psycho-educational maths anxiety workshop embedded within a foundation maths course, and found that the workshop had an immediate reduction in maths anxiety in the cohort. However, when the workshop was trialled as an optional University-wide session, attendance was poor and those attending were mostly from disciplines requiring a higher level of maths such as economics or engineering. Research incorporated into the workshop included the impact of anxiety on the brain and learning, reflection on past experiences with maths, addressing negative beliefs, growth mindset (Johnston-Wilder et al, 2015) and learning strategies. One of the first stages for a student to overcome anxiety is to understand what it is and how it affects their learning (Uusimaki and Kidman, 2004). It is also important for students to share past experiences which may have contributed to their anxiety, such as negative experiences with maths, and realising that others feel anxious (Marshall et al., 2017).

Hood and Neumann (2013) used a similar workshop for statistics anxiety which included discussion of concerns about statistics, use of basic statistics within the session, and learning styles. Comparison of those who did and did not attend the voluntary workshop at the end of term showed that amongst attendees, there was an increase in self-efficacy and worth of statistics, and a decrease in fear of statistics teachers. No changes in self-efficacy or worth of statistics were observed amongst non-attendees. However, a drop in statistics anxiety was observed in both attendees and non-attendees, making it harder to distinguish the impact of the workshop from instructional style.

Online learning has meant that facilitators can co-deliver teaching to students from multiple institutions simultaneously, without any restrictions on geographical location. Therefore, the statistics anxiety workshops that this current study reports on were delivered jointly by presenters at UK and Australian institutions in the academic year 2020/2021. While the authors viewed the multi-institution aspect of the workshop as a positive, we acknowledge that students may not have. Students could infer from the registration form that there would be students from other universities attending the session and this could have been a barrier to them attending the workshop.

The statistics anxiety workshop was adapted from the existing maths anxiety workshop developed by Marshall et al. (2017), but incorporated more of the strategies used by statistics support services for addressing anxiety (Johnston-Wilder and Marshall 2017). These strategies include seeking help when needed, peer learning, persistence and recognising progression. An important addition was the framing of the strategies within a case study of a very anxious student who attended statistics support, and was able to overcome statistics anxiety and complete her quantitative research. The aims of the workshop were to increase awareness of statistics anxiety and its impact on learning, and to suggest strategies for students that address their anxiety about statistics. Shorter versions of the self-help resources created by the authors can be freely accessed on the Sheffield Hallam maths and statistics support service (https://maths.shu.ac.uk/mathshelp/Anxious.html). Prior to the main offerings of the workshop reported on in this study, a pilot statistics anxiety workshop was trialled by the researchers at the University of York in February 2020. Despite low attendance, reflections on this face-to-face session informed the workshop presented here. Further adaptations of the workshop were necessary as it had to be delivered online due to the Covid-19 pandemic. These included asking attendees to answer questions or contribute to discussions in the chat function, and facilitating small group discussions in break out rooms where everyone could contribute to a shared online document. This document summarised the main points discussed in the small groups for everyone to view.

Three specific cohorts were offered the opportunity to attend the optional extra-curricular workshop. The cohorts targeted for the intervention were surveyed before and immediately after the workshop, as well as at the end of the year. This paper focuses on identifying whether anxious students are interested in and engage with voluntary statistics anxiety workshops using the pre-workshop survey data.

2. Methods

The pre-workshop survey was sent to first year Psychology students at Sheffield Hallam University (SHU) and the University of Worcester, and second year Biology students at La Trobe University. The survey included scales measuring statistics anxiety, worry or concern about learning statistics, maths anxiety, and interest and value in learning statistics and associated measures. Students were also asked if they were interested in attending a statistics anxiety workshop (see below), and demographic questions such as gender. Scales measuring different dimensions of statistics anxiety were taken or adapted from the Statistical Anxiety Measure - SAM (Earp, 2007), and Statistical Anxiety Rating Scale - STARS (Cruise, Cash and Bolton, 1985; see Appendix for items and Cronbach's alpha for each subscale). Seven-point scales for all anxiety questions were used, with responses ranging from "not at all anxious" to "extremely anxious". Items from the SAM scale representing worry or concern about learning statistics were also used (Cronbach's = 0.841). Maths anxiety was measured using three items from the sources of self-efficacy in maths scale (Usher and Pajares, 2009), on a 9-point scale (Cronbach's = 0.931). Items from subscales of the Motivated Learning Strategies Questionnaire - MLSQ (Pintrich, 1991) were used to measure interest in learning, value of statistics, help seeking, statistics self-efficacy, control of learning and peer learning, all on a seven-point scale ranging from "strongly disagree" to "strongly agree".

Additionally, students' level of interest in attending a workshop was sought. Students initially answered a question in the pre survey, stating their level of interest in a statistics anxiety workshop as "yes", "no", or "maybe". For the UK cohorts (SHU and Worcester), students were then asked to register for the workshop in a separate communication. For the Australian cohort (La Trobe), students were invited to register interest using a poll administered via the Learning Management System (LMS). Students could indicate either "Yes" or "Maybe". For all cohorts, attendance was taken at the workshop and defined as a student who was present halfway through the session, although some students may have left early or arrived later. All students were also asked in the post survey whether they had attended a workshop. Interest was therefore classified as follows. If students attended the workshop, expressed interest via the pre survey or LMS poll, or registered for the workshop, they were recorded as "Yes". Students who answered "Maybe" or "No" in the pre survey or LMS poll were recorded as such. If students did not respond to the pre survey question on whether they were interested in the workshop, did not register or complete the LMS poll, did not attend the workshop, and did not fill in the end of year survey, their interest in the workshop could not be determined and they were recorded as missing for level of interest.

A total of 191 students from SHU (141), La Trobe (32) and Worcester (18) took the pre survey, although La Trobe were not asked about maths anxiety, interest in learning statistics and expectations of their statistics course, and therefore were excluded from some analyses. Directly following the workshop, students were asked to fill in the post survey, which included questions asking for workshop feedback. At the end of their academic year, all students were invited to fill in another questionnaire asking whether they had attended the workshop and if not, what the reasons were. The questionnaire also invited workshop feedback. 67 students took the end of year survey, with 24 of these also completing both pre and post surveys.

During the workshops, attendance was taken at several time points and full attendance was defined as a student who was present halfway through the session, otherwise they were categorised as leaving early. As students had cameras and microphones switched off, we acknowledge that some students may not have actually been engaged but merely logged on to the virtual classroom.

3. Results

3.1. Who is interested?

When asked, most students showed some level of interest in attending a workshop on statistics anxiety, particularly Psychology students (Figure 1).

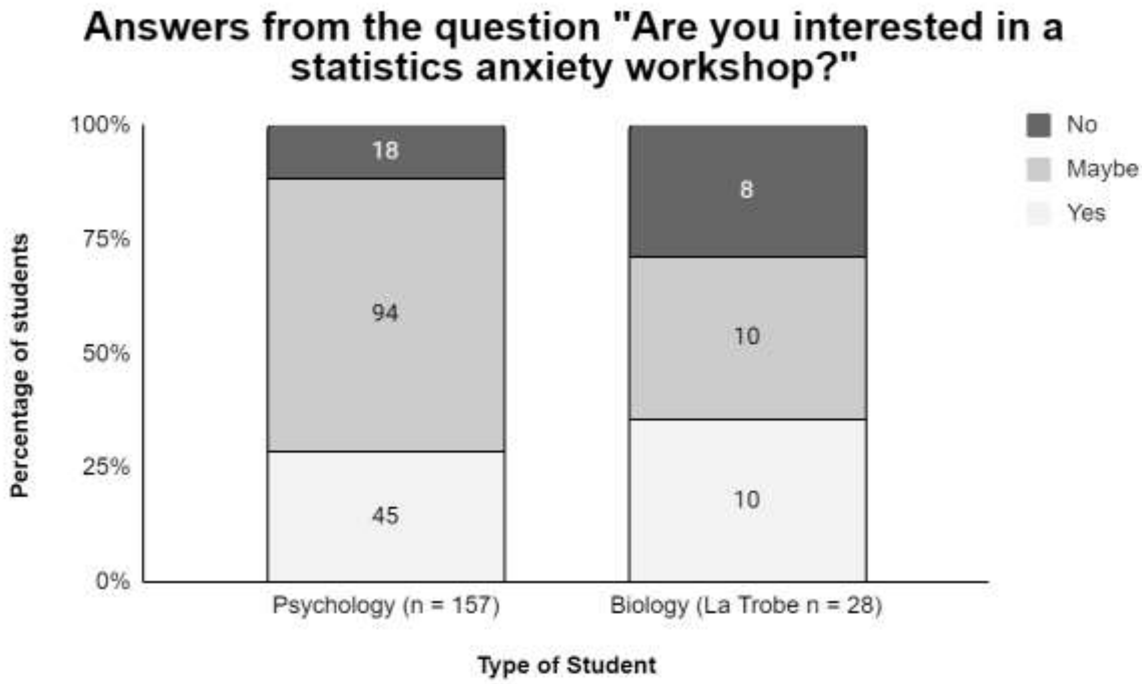

Figure 1: Percentages of students interested in a statistics anxiety workshop

For the UK workshops, 35 (22%) of the students taking the pre survey completed the initial registration form. However, only 16 students went on to choose a workshop date and only 8 actually attended. 47% of the UK students who said “Yes” they were interested, registered. Only 13% of the “Maybe” group and none of the students from the “No” group, registered.

3.2. Are anxious students interested in anxiety workshops?

Inferential statistics were used to test how anxiety differed in students with different levels of interest and engagement in the statistics workshop. To do this, students from all universities were put into five interest categories: those who attended; those who registered to attend in the separate communication or LMS poll but did not; those who said in the pre survey yes they were interested; maybe they were interested; or no they were not interested. The last three categories did not register for or attend the workshop. One-way ANOVAs were used to test the differences among these five groups with a separate one-way ANOVA used for each of the different types of stats anxiety, maths anxiety, concerns and interest measurements.

There were significant differences among the five levels of interest in the workshop for statistics anxiety as measured using the SAM scale (ANOVA, F = 7, $p < 0.001$; Figure 2). While there were no significant differences among those who attended, registered but didn’t attend and those who said yes they were interested, these three groups all have significantly higher levels of statistics task anxiety than students in the not interested group. Despite the not interested group having the lowest average anxiety, there were still students with moderate to high anxiety in this group.

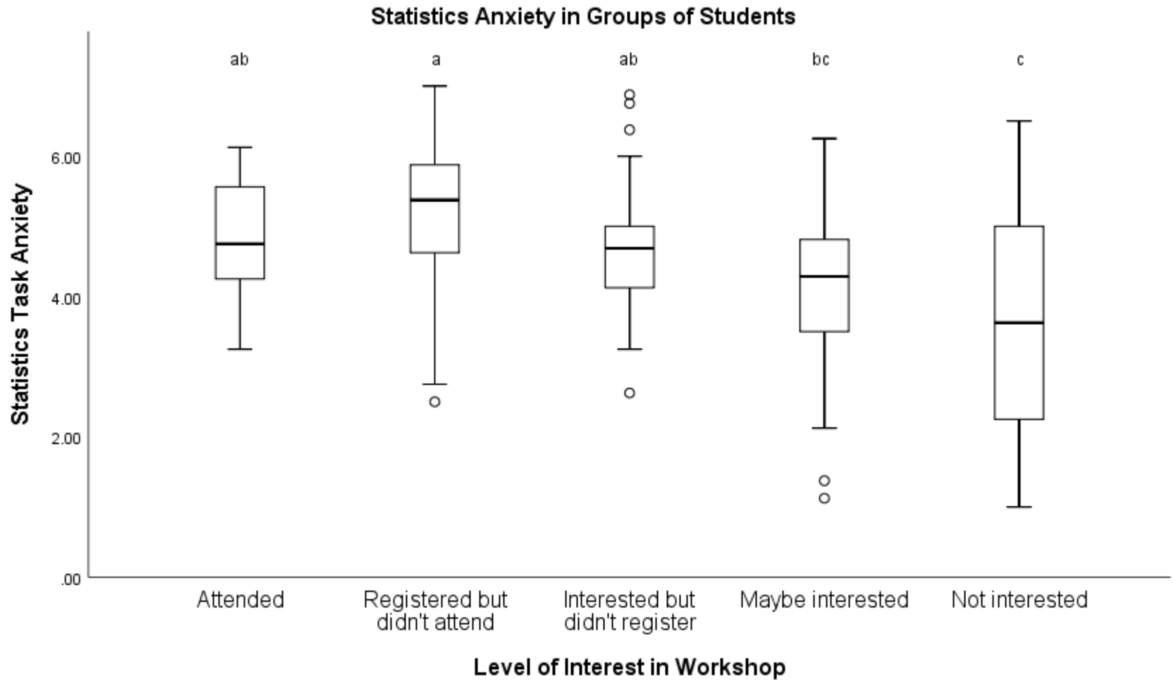

Figure 2: Statistics task anxiety measured using all items of the Statistics Anxiety Measure (SAM) scale, for students with different levels of interest in a statistics anxiety workshop. Groups that share letters are not significantly different from each other.

There were significant differences among the five interest groups for software anxiety (ANOVA, F = 4.5, $p = 0.002$) but not for help seeking anxiety (ANOVA, F = 0.8, $p = 0.525$). Students who were in the "not interested in the workshop" group, had significantly lower levels of software anxiety than those who attended, registered or were interested in the workshop. There were no significant differences among these latter three groups (Figure 3). Whilst the cohorts were generally consistent, help seeking anxiety was highest for those who were not interested in the workshop for UK students but for La Trobe, it was the group who said they were interested but didn't register (data not shown).

To further investigate the characteristics of those who are interested in this type of workshop, groups were tested for differences in other types of anxiety for the UK students only. There were no significant differences for anxiety surrounding working with fellow students online, online lecture and tutorial anxiety, control of learning or employability (ANOVA, F = 0.35, $p = 0.85$, F = 0.68, $p = 0.60$, F = 0.83, $p = 0.51$, F = 0.83, $p = 0.51$ respectively). There were also no significant differences in interest in learning statistics (ANOVA, F = 0.97, $p = 0.425$), however, those who attended had the highest mean level of interest in learning statistics compared to all other groups (Figure 4). Maths anxiety (ANOVA, F = 6.14, $p < 0.001$) and concern about learning statistics (ANOVA, F = 11.1, $p < 0.001$) was significantly higher for both the students who registered but didn't attend group and the group who said they were interested but didn't register, compared to those who said they were maybe or not interested in the workshop (Figure 4). While not statistically significant, the students who ended up attending the workshop had on average lower levels of maths anxiety and concern about learning statistics, than those who only registered to attend or said they were interested but didn't actually attend the workshop (Figure 4).

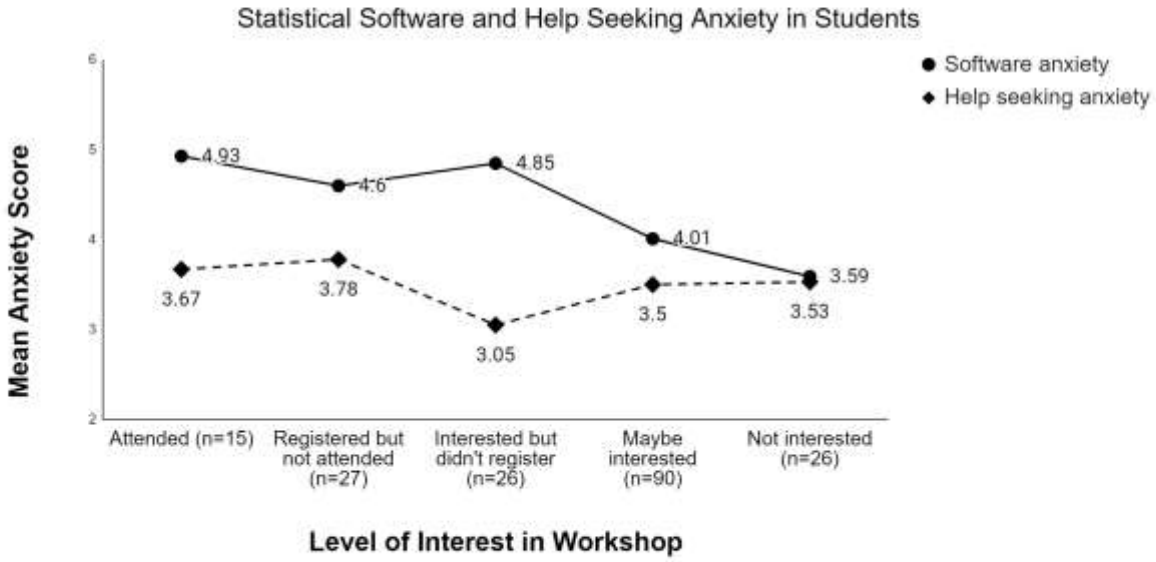

Figure 3: Mean statistics software anxiety and help seeking anxiety by interest in workshop group

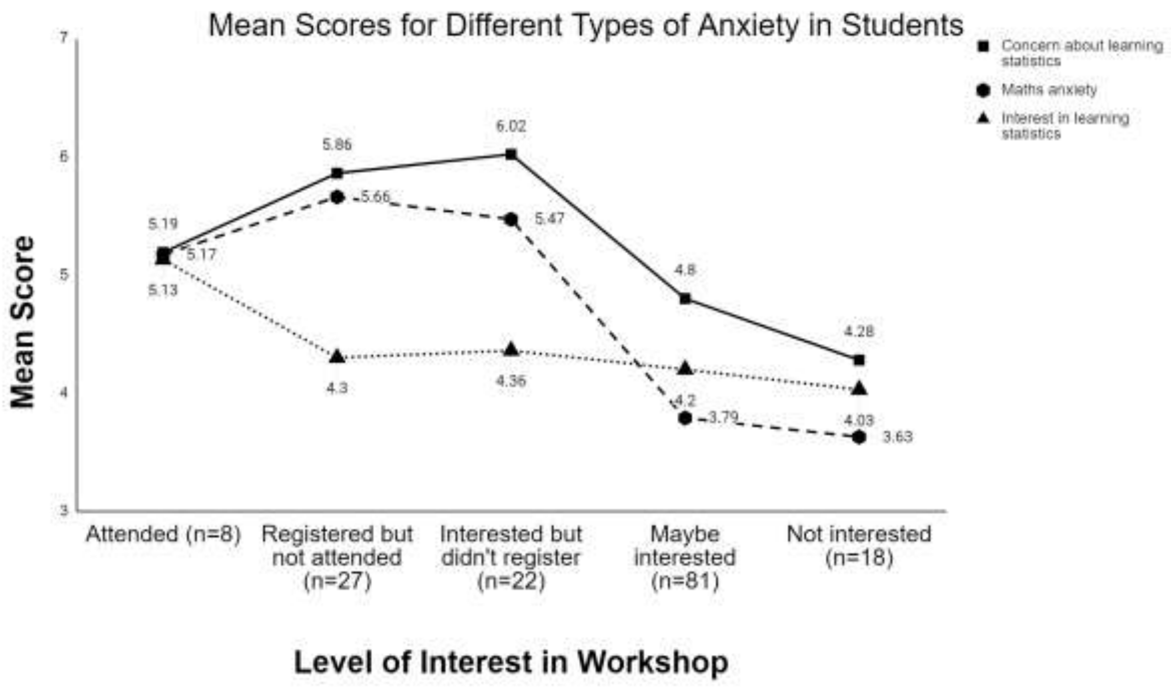

Figure 4: Mean scores for maths anxiety, interest in statistics and worry over learning statistics by workshop interest. Data for UK cohort only. Note that maths anxiety is measured on a 9 point scale whereas all others are on a 7 point scale.

To better understand the type of student who is interested in a workshop, students were reclassified as either interested (attended, registered but didn't attend, interested but didn't register) or not (maybe interested, not interested). Then backward logistic regression was used with interested or not as the binary dependent variable, and the various anxiety measurements as independent variables to identify the more important predictors. The final model, shown in Table 1, shows that those with higher levels of statistics task anxiety, interest in learning statistics, maths anxiety and concern about learning statistics were more likely to be interested in a statistics anxiety workshop. The odds of a student being interested in the workshop are multiplied by 1.9 for each additional point on the statistics task anxiety scale and doubled for concern about learning statistics. Help seeking anxiety has a negative impact after controlling for the other factors, suggesting that if a student's anxiety about statistics is more about a fear of asking for help than maths or interpretation, they are less likely to attend.

Table 1: Final logistic regression model. Response variable is "interested" (attended, registered but didn't attend, interested but didn't register) in workshop or "not" (maybe interested, not interested).

Final backwards logistic regression model	B	P-value	Odds ratio
Statistics task anxiety	0.645	0.026	1.9
Interest in learning statistics	0.397	0.021	1.5
Maths anxiety	0.212	0.08	1.2
Concern about learning statistics	0.673	0.003	2.0
Help seeking anxiety	-0.438	0.01	0.6

The final model correctly predicts 59% of those who were at least interested and 91% of those who were either not or maybe interested. A model that correctly predicts a higher proportion of those interested also contains measures of how relevant students feel statistics is and whether they feel success is related to the effort they put in. Students who do not value the learning of statistics and don't believe they can learn statistics even if they try, are less likely to say they are interested.

3.3. Reasons for not attending

55 students from the UK and La Trobe filled in a multiple-choice question in the end of term survey to indicate why they did not attend the workshop. The most commonly chosen option was being too anxious (35%), followed by not knowing about the workshop (24%), and not being interested in the workshop or not anxious about statistics (24%). Some students chose the option that the time of the workshop was not convenient (18%) [Figure 5].

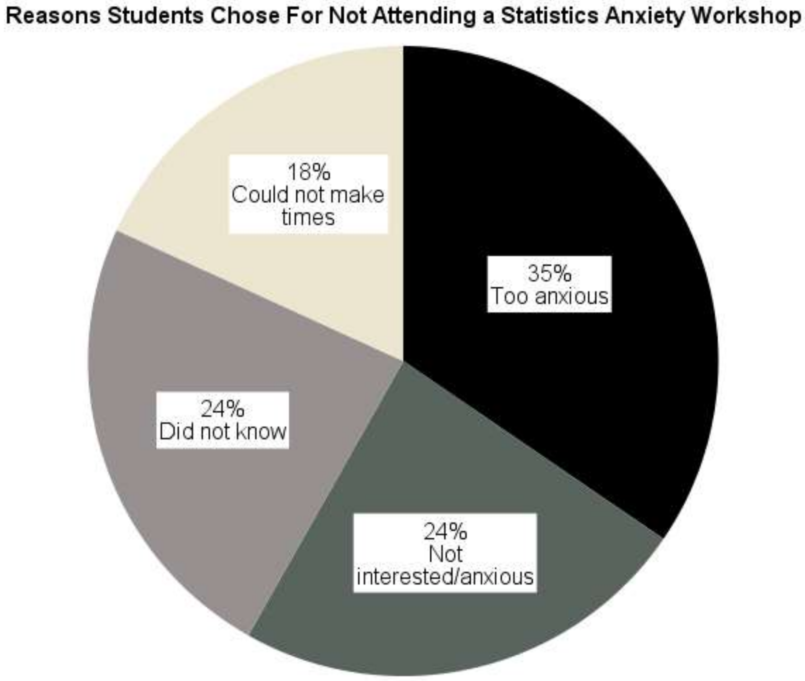

Figure 5: Reasons students chose in the end of year survey for not attending the statistics anxiety workshop.

4. Discussion and Concluding Remarks

In summary, the statistics anxiety workshops are attracting target groups with high statistics task anxiety, software anxiety, maths anxiety and those with concerns about learning statistics. These students are often motivated by interest in learning statistics although it is unclear whether this tends towards intrinsic or extrinsic. The most obvious group the workshops typically failed to attract was the group with high help seeking anxiety. Ironically, this is a group that may greatly benefit from attending the workshop because it has been observed that help seeking anxiety is negatively associated with student performance (Shaker et al, 2021). Initiatives to target this group will therefore need to be researched and take account of their intrinsic/extrinsic motivation for learning the material, since this will impact on the support approach used by staff. In addition, the student's perceived barriers to seeking out and accessing support will need to be determined.

More broadly, findings indicate that strategies in the curriculum to normalise help seeking would be of benefit to students. Attempts in universities to improve help seeking in students include PAL (Peer Assisted Learning; Hager, 2018); a university wide support structure that was scaffolded (Devine et al., 2021) and running convenient sessions where both teaching and learning support staff are available (Hammond et al., 2015). All these initiatives make it easier to access help in the practical sense. However, there are few reported attempts to change the overall cultural attitude towards help-seeking for mathematics or statistics support specifically, though some wider initiatives to scaffold student self-reflection on their approach to learning in Higher Education which include seeking support from others have been developed (Coughlin et al., 2011).

Reasons given by students for not attending the workshop suggest that they did not know about it. Other students said the times of the workshop were not convenient. It could be that advertising more widely, as well as offering more workshops at a variety of times could address this issue. In terms of resourcing, it may be more practical for higher education institutions to offer statistics anxiety workshops as part of a timetabled lecture embedded into the course. As students would be familiar with staff, setting and approach, this would also compliment the workshop content on being comfortable asking for help when needed, so delivering workshops in this way may allow those who are anxious about asking for help to benefit. However, using lecture time in this way can be frustrating for those students who feel they are not anxious about statistics. Alternatively, initiatives to normalise help seeking such as - having academics signpost towards specialist staff and/or peer-support; self-help materials which engage students in study skills but which also address their expectations of the learning process, as well as showing that academics also use the services of skills centres - could be valuable.

Furthermore, the challenge of making help-seeking the norm may be more difficult at some universities than others. Preliminary data from a related project found that the students in a university with higher entry requirements were less likely to seek help compared to a university that required lower grades. While not causational, it is possible that students who are higher achieving may need to address barriers which differ in form and extent before seeking support.

This study suggests then that solutions to addressing the problem of getting students to ask for help when they need it may be in-part drawn from the students' own motivations, needs and expectations, but also influenced by the course design and perceived culture of a higher education institution. Given that organisational culture may be difficult to define, may vary across faculty/discipline and will be difficult to influence in the shorter-term, it is suggested that practical amendments to course design and support, as well as supporting students to explore their approach to their studies, may be the most effective approach in the first instance.

5. Appendix

The items used for each statistics anxiety subscale are given below with Cronbach's alpha.

Individual items	Cronbach's alpha (pre survey)
<u>Online learning</u>	
Watching pre-recorded videos of statistics content	
Attending an online statistics lecture	
Attending an online statistics tutorial	
Working with fellow students in an online class	
Online class anxiety MEAN	0.807
<u>Face to face learning</u>	
Being in a statistics lecture in person on campus	
Attending a statistics tutorial in person on campus	
Working with fellow students in a face to face statistics class	
Face to face anxiety MEAN	0.85
<u>Statistical anxiety measure (Earp, 2007)</u>	
Sitting an exam in person on campus	

Studying statistics generally	
Reading statistical studies	
Calculating probabilities	
Formulating and testing hypotheses	
Developing conclusions based on mathematical solutions	
Interpreting statistics	
Explaining your statistical findings	
Mean Statistics task anxiety (doing statistics)	0.917
Software anxiety	
Inputting/manipulating data in statistical software	
Using statistical software to carry out analyses	
Summarising results from the statistical software output	
Statistical software anxiety (mean)	0.911
Fear of asking for help	
Going to my statistics lecturer for individual help with material I am having difficulty understanding	
Asking a statistics lecturer for help understanding computer output	
Asking a fellow student for help in understanding statistics material	
Anxiety about asking for help (mean)	0.889

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SHORT UPDATE

Language and Discourse in the Learning of Statistical Concepts

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Abstract

Students on Business School courses will require a certain level of numerical ability; therefore, Mathematics and Statistics are important elements of the curriculum (Cottee et. al., 2014). Students often struggle with these quantitative parts of their course and this is sometimes seen as part of a general "Mathematics Problem" that impacts many disciplines including biology, economics, nursing and psychology (Mac an Bhaird and Lawson, 2012). Many students find Statistics in particular a difficult subject as it includes concepts which are complex and even counter-intuitive. For these students the way in which statistical ideas are communicated and specifically the use of language and discourse are of great importance.

This paper reports on ongoing research into the role of language and discourse in teaching and learning Statistics. Included are: Findings from a Pilot Enquiry carried out in 2019; the theoretical background to the research and the challenges presented by the pandemic both for teaching and for the research.

Keywords: statistics education, pedagogic discourse, language codes.

1. The "Mathematics Problem" and the “Statistics Problem"

Business School students in the UK often struggle with the quantitative parts of their courses. This is sometimes seen as part of a general "Mathematics Problem", noted for example in the ‘Roberts Review’ (Roberts, 2002) and in a **sigma** report on Mathematics and Statistics support (Mac an Bhaird and Lawson, D, 2012).

Statistics can be a difficult subject for non-specialists (e.g., Mustafa,1996; Kruppa et. al., 2021; MacDougall, 2021). It includes concepts, particularly those related to the process of hypothesis testing which are complex and even counter-intuitive (e.g., Kapadia, 2013; Babai et. al., 2006). Such concepts may not easily build on students’ existing mathematical understanding which may include limited exposure to Statistics, as Kruppa et. al. (2021) explains: students must “connect the introduced statistical terms within their personal existing networks of largely non-statistical knowledge" There has been considerable research into how students learn Mathematics and Statistics and how that learning can best be supported (e.g., MacGillivray and Croft, 2011). Mathematics and Statistics tend to be considered as a combined discipline however there have been some studies into the specific problems related to learning Statistics, e.g., Garfield & Ben-Zvi (2007) which identifies “common faulty heuristics, biases, and misconceptions found in college students and adults” as a persistent problem.

Communication and discourse play a very important in learning Statistics, as students need to move between the everyday language used for a business problem and the precise mathematical formulation required for a statistical test. There has been considerable research into the role of communication and discourse in education generally (e.g., Illeris, 2018) and Statistics education specifically (e.g., Garfield and Ben-Zvi, 2007). Of particular relevance is Jablonka et. al. (2012) which explored the Mathematical education of first year Engineering undergraduates using Bernstein’s theory of pedagogic discourse (Bernstein, 1981) as elaborated in section 3 below.

2. Pilot Enquiry

A Pilot Enquiry in 2019 using a combination of questionnaires and interviews investigated students' pre-existing abilities and attitudes in Statistics. The population under investigation was all first-year undergraduates of a university business school (approximately 900 students). This included a wide range of degree subjects with various entry requirements. A sample of 32 students completed the questionnaire. A sub-sample of 4 who were broadly representative of the cohort were selected for in-depth interview. The questionnaire used mainly Likert scale questions to determine attitudes followed by open-ended questions to give respondents an opportunity to expand on their answers.

Although the small sample size precluded drawing any definite inferences, some interesting phenomena did emerge which suggest topics for further study. Students varied in the degree to which they saw Mathematics and Statistics as relevant, either in their course (Figure 1) or personally (Figure 2).

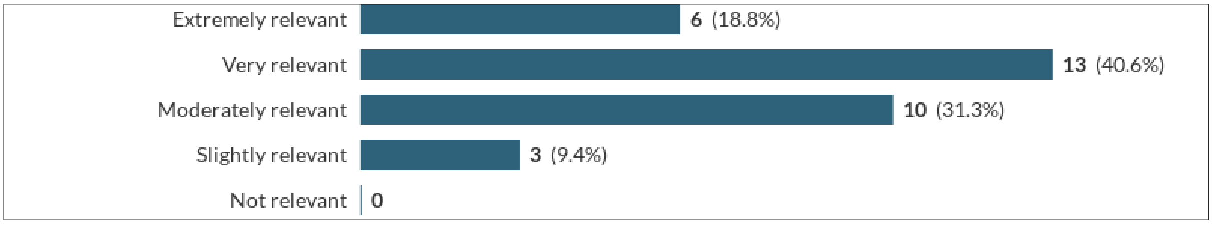

Figure 1. To what extent are Mathematics and Statistics relevant to your course?

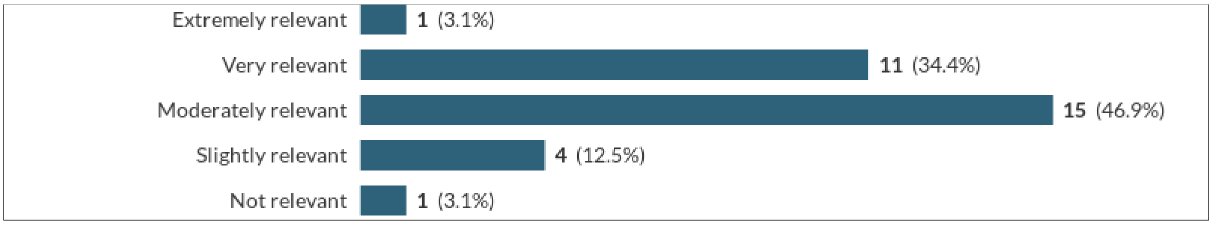

Figure 2. To what extent are Mathematics and Statistics relevant to you personally?

In the open questions and in the in-depth interviews phase it emerged that students differed in their perception of what they considered mathematical or statistical. Some regarded everyday activities as mathematical. Examples cited included: planning the layout of a bathroom; recording and analysing performances in dance competitions; calculating quantities and costs for recipes; and planning a car journey. Others participated in similar activities which included calculating or planning but did not regard these as being strictly mathematical.

Interesting gender differences emerged. On the question "To what extent do you agree with the following statement: Mathematics and Statistics are important only if used for a practical problem?" most male respondents agreed or strongly agreed (56% with 11% neutral) but for females the reverse was true (57% disagreed or strongly disagreed with 19% neutral). However, women students were more likely to cite the previously mentioned everyday uses of Mathematics. It may appear contradictory that most male students see Mathematics as a problem-solving tool but are less likely to perceive everyday problems as being amenable to Mathematics. These findings appear to support the perception of Mathematics as "impersonal, rule-driven, fixed and stereotypically masculine" (Ernest, 1991), perhaps seen (at least by some students) as useful only for well-defined business problems.

Students were asked about their experience of using computer systems in their learning of Mathematics and Statistics. An interesting finding was that students were often unclear about the boundary between a mathematical or statistical technique and the software being used to implement that technique. For example, when learning about correlation and linear regression students may also be learning how to carry out these calculations in Excel. When we discuss the 'tools' used to solve a business problem this could mean a range of things: the method we use (for example a chi-squared test), the symbols and formulae, the software (Excel or SPSS) and the physical computer. In the student's mind the statistical concept would appear to be closely associated with the method or tool used to put into effect the concept.

It was decided to carry out further research into how students construct their knowledge in Statistics, including the way statistical ideas are communicated and where they see the boundaries between Statistics and other disciplines including Business and Computing.

3. Proposed Research

3.1. Overall Aim

The overall aim is to investigate how Business School students learn Statistics. The theoretical framework used will be social constructivism, the idea that students construct statistical and mathematical knowledge from their own experience, individual or social (Cole, 2015). Therefore, the aim can be stated more precisely as "to investigate and model" the *way* in which first year Business School students construct their ideas (individually and socially) and the role of discourse in that construction, using as an example the process of Hypothesis Testing. Hypothesis Testing is used because it incorporates several problematic areas such as conditional probability and inference as well as calculation

In developing a social constructivist model of Business School students' learning of Statistics Bernstein's educational theories will be used as a theoretical lens. This will require precise analysis of the language used in communication statistical ideas. Bernstein sociolinguistic theory of language codes (Bernstein, 1990) will be used to give us a more concrete idea of how statistical knowledge is constructed.

3.2. Theoretical Background

Bernstein's "theory of pedagogic discourse" considers the way discourse (particularly in education) functions in society (Bernstein, 2000). Bernstein viewed "pedagogic discourse" as the means by which notions are structured and reproduced within society. He did not address Statistics specifically, but Bernstein (1990) as cited by Clark (2005) uses the example of Physics which "from its primary location in the universities" is "relocated and refocused it in the secondary school". Bernstein distinguishes between the "message" and the "carrier of the message", i.e., the language and structures. There has been research which has applied Bernstein's theories to undergraduate Mathematics (e.g., Jablonka et. al., 2012; Dowling, 1998), although not specifically to Statistics.

Classification and recognition rules (Bernstein, 1981) are relevant here. Classification refers to 'the degree of boundary maintenance between contents' (Bernstein, 1973) and is concerned with the insulation or boundaries between areas of knowledge and subjects in the curriculum. In the course of their Mathematics education, students move through a range of different mathematical discourses. This can include for example emphasis on informal or formal reasoning; emphasis on practical application or abstract concepts and inductive or deductive reasoning. In the transition from school to university the mathematical knowledge becomes more *strongly classified* (Jablonka et. al., 2012).

Several researchers identify the importance of language and communication in various forms in learning Statistics: Garfield & Ben-Zvi (2007) emphasise the importance of acquiring “Statistical Literacy” as a prerequisite to “Statistical Reasoning and Thinking”. Garfield (1995) advocates a 'corrective-feedback' strategy, encouraging students to explain solutions narratively, as a way to help students overcome their misconceptions. Cakir (2009) sees the importance of ‘conversations’ within small groups of students in the construction of mathematical artefacts. Ernest (2003) sees conversation as a driver in the social construction of knowledge in the classroom but also metaphorically for the historical development of Mathematics.

3.3. Proposed Methodology

An in-depth Case Study will be conducted to investigate conceptual understanding of Statistics over two successive cohorts of the first year of Business School courses and the various ways in which this understanding develops. This will be part action research involving two teaching cycles. The specific methods used for data gathering will be interviews with students, which allow them to “tell their stories”, and classroom observation.

4. Pandemic effect on teaching and research

4.1. Research evidence

Online teaching during the pandemic has changed the way ideas are communicated. It has brought into sharp focus the importance of discourse in a quantitative subject. Walker et. al. (2020) notes that it has some advantages but can be seen as a “*potential panacea which can enable scaled delivery*” but “*the amount of work involved in online teaching and marking is being underestimated*”. There is conflicting evidence on effectiveness of online teaching. Cassibba et. al. (2021) in study of distance teaching of Mathematics in Italian universities notes: “*The problems of adapting ways of teaching to the new e-learning environment are particularly relevant when teaching mathematics, because of the frequent use of symbols and formulas, as well as gestures and body*.”

4.2. Personal experience

Generally online teaching can work well for specific statistical techniques and the software to implement these, but there can be challenges for the more nuanced interpretation and explanation required to solve a business problem using appropriate techniques. The overall picture is more complex: differences in students’ backgrounds, prior educational experience and home situation are factors which have a bearing on how successfully they engage as online learners. Often it is the weaker students that need the extra *ad hoc* examples, diagrams, body language, gestures etc.

Online teaching and pandemic restrictions, if these continue will also impact on the research. For example, classroom observation and interviews may need to be conducted on-line. As with the teaching itself it might have the effect of inhibiting some students particularly those who struggle with statistical ideas.

5. Some tentative conclusions

Discourse clearly plays a critical role in teaching and learning Statistics. However, the *nature* of discourse has changed dramatically over the years. Discourse in its widest sense now includes various forms of communication through electronic media, something which lockdown has brought into sharp focus. Bernstein’s educational theories are still relevant, but these will need to be adapted for today’s technologies.

It is hoped that this research will produce recommendations for teaching materials and methods and take a small step towards answering the "Statistics question".

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