RESEARCH ARTICLE

Public Engagement for Student Empowerment

Matthew Jones, School of Management, UCL, London, U.K. Email: matthew.m.jones@ucl.ac.uk
Zainab Kazim Ali, Design Engineering and Mathematics, Middlesex University, London, U.K. Email: z.kazim@mdx.ac.uk
Snezana Lawrence, Design Engineering and Mathematics, Middlesex University, London, U.K. Email: s.lawrence@mdx.ac.uk
Brendan Masterson, Design Engineering and Mathematics, Middlesex University, London, U.K. Email: b.masterson@mdx.ac.uk
Alison Megeney, Design Engineering and Mathematics, Middlesex University, London, U.K. Email: a.megeney@mdx.ac.uk
Nicholas Sharples, Design Engineering and Mathematics, Middlesex University, London, U.K. Email: n.sharples@mdx.ac.uk

Abstract

The ability to disseminate and communicate densely mathematical and technical material to a non-technical audience and coworkers is a key employability skill for mathematics graduates. As educators it is important that we consider how to bridge this gap and how we can embed these skills into already tightly packed programmes. At Middlesex University we have long believed in embedding communication skills in our undergraduate mathematics programmes to empower our students from diverse backgrounds. Importantly, while these students are with us, we also present them with the opportunity to work as mathematical ambassadors and apply these skills in-situ during outreach and public engagement events. These events include SMASHFest, Big Bang, Thorpe Park, World Skills, Teen Tech, and MDX STEMFest. This increases their confidence and knowledge of mathematical topics further while enhancing their employability, communication skills, and social capital.

Keywords: Communication, outreach, student confidence, affective domain.

1. Introduction

The demands placed on mathematics graduates from employers have changed in recent years. Increasingly, graduates are expected to have programming and communication skills along with more traditional skills such as problem-solving. While mathematics students are well regarded when it comes to working with highly technical material, they are perhaps less well known for their communication skills (Groves, 2012). These shifting demands and the change in the post-pandemic education landscape have caused us to rethink how we approach the design of the mathematics programmes at Middlesex University (Jones, et al., 2022).

Throughout this process our goal was to design a suite of mathematics programmes that would allow our students to demonstrate their ability, meet the shifting needs of the graduate job market, and remains mathematically rigorous. Our design decisions were shaped by knowledge of the features of our student body.

The demographics of the Middlesex student body have particular challenges: 59% of full-time undergraduates are from IMD quintiles 1 and 2 and 38.5% were eligible for free school meals (Office for Students, 2024). Digital poverty also presents a significant obstacle for success of students in a

job market where digital skills are increasingly in demand. Recent research has shown that students from backgrounds such as these a significantly disadvantaged in closed book exam assessment when compared with their peers who do not have these difficulties (Megeney, 2016).

Middlesex University has always placed a heavy emphasis on applied, practical skills that prepare its graduates for the workplace. This gave us license to radically rethink our approach to assessment and consider what employability skills are required by maths graduates in today's job market. There is a danger that universities have placed too much significance on examining students' ability to apply various techniques in familiar settings (Crawford, 1996). In comparison, not enough time is spent on teaching other soft skills such as communication and problem solving (Borovik and Gardiner, 2007), which are vital to a successful career as a mathematician.

These observations led us to two innovations in our mathematics programmes: firstly, given our students are from demographics that tend to be disadvantaged by examinations we decided to focus exclusively on authentic assessment to assess the students. Middlesex University (Centre for Academic Practice Enhancement, 2022) defines authentic assessment as follows:

- Is realistic;
- Requires judgement and innovation;
- Asks students to 'do' the topic;
- Replicates or simulates the context in which adults are tested in the workplace;
- Assesses the student's ability to efficiently and effectively use a repertoire of knowledge and skills to negotiate a complex task;
- Allows opportunities to rehearse, practise, consult resources, and get feedback.

Our interpretation of this definition is that students should be given the opportunity to enhance their employability skills while still testing their mathematical ability in their assessment (Masterson, et al., 2024). Secondly, we sought ways to integrate problem solving, communication, and outreach to enhance students' confidence and employability skills.

In this paper we will examine students' perceptions of how these activities have contributed to their development as mathematicians. We conducted a survey of student's attitudes towards the communication/outreach elements of their degree programme. This was part of a larger survey that included the quasi-pre/post measure of students' attitudes towards mathematics using the MAPS (Code, et al., 2016) the results of which are to appear in (Jones, et al., 2025).

1.1. Communication

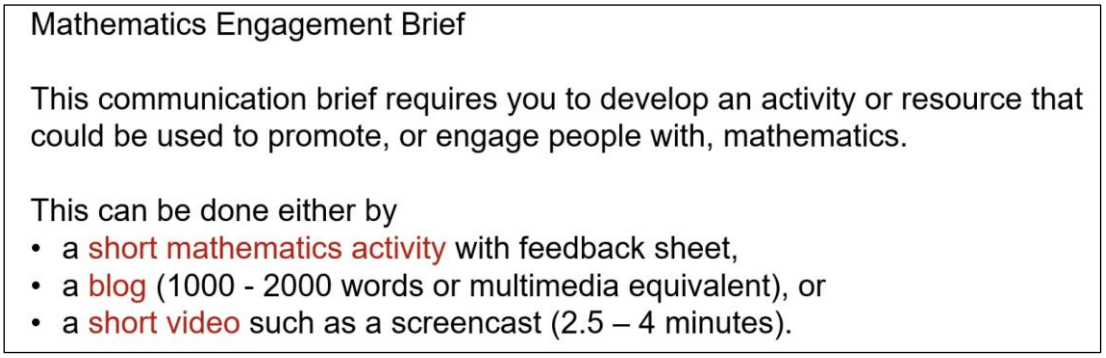
When we originally designed our undergraduate mathematics offerings, we attempted to get students to engage with all aspects of mathematics, going beyond mathematical tasks and techniques, to develop a range of skills valued by students and employers (Megeney, 2016). One of the skills that we identified was communication skills.

The ability to disseminate technically dense material and communicate it to colleagues and other stakeholders is a skill increasingly in demand skill among graduates (Megeney, 2016). Unfortunately, this is also something mathematics graduates are not particularly well known for (Groves, 2012). However, communicating mathematics is an important part of being a mathematician (French, et al., 2023). Communication is integral to finding flaws in others' arguments and conveying your own individual reasoning (Borovik and Gardiner, 2007).

In the first iteration of the programmes, communication skills and other soft skills were catered for in a weekly programme workshop entitled Engaging with Maths. However, these skills were not assessed in this workshop.

When the undergraduate programmes were being revalidated for the academic year 2022-23 it was decided that communication would be embedded throughout the programme. In particular, it has a dedicated level 5 module *Problem-Solving and Communication*. This module does not seek to introduce any new mathematical techniques but rather encourages students to draw from techniques developed in other modules to solve unfamiliar problems then consider their reasoning in selecting their chosen methods and communicate this to lecturers and their peers.

In seminars and workshops students are encouraged to discuss the problem-solving techniques with one another with the goal being to solve a given problem. This allows students to evaluate each other's reasoning, see the problem from different perspectives, and learn to communicate their reasoning in a manner that is coherent to their classmates and lecturer. In this module students explore a variety of different ways to communicate their reasoning including report writing, in-person presentations, multi-media presentations, and oral examinations.


Mathematics Engagement Brief

This communication brief requires you to develop an activity or resource that could be used to promote, or engage people with, mathematics.

This can be done either by
- a short mathematics activity with feedback sheet,
- a blog (1000 - 2000 words or multimedia equivalent), or
- a short video such as a screencast (2.5 – 4 minutes).

Figure 1: Communication assessment brief

Figure 1 is an extract from one of the briefs for a communication assessment. Here students are asked to develop a maths related resource or activity. The students are given several options on what form they want the resource to take. Encouraging the students to carefully consider how they want to communicate, and what would be the best form of submission for their resource, further enhances their communication skills and their confidence.

The communication skills that students were introduced in the Problem-Solving and Communication module are then further embedded throughout the programme. Often this takes the form of essay, report writing, and project-based assessment in modules such as *Data Mining*, *Graph Theory*, *Galois Theory*, and *Cryptography and Blockchain*.

It is vital that students see that communication skills are embedded in multiple places in the programme so they understand that communication is a vital part of their mathematical education that should not be ignored and will be beneficial to their career prospects.

1.2. Outreach activities

The maths team at Middlesex University has long been involved in outreach events. In the past staff and students have either taken part in or led the following outreach events SMASH Fest UK, Big

Bang, Thorpe Park, World Skills, Teen Tech, New Scientist Live and MDX STEMFest. These events range from having hundreds of visitors for the MDX STEMFest to tens of thousands for New Scientist Live. Our motivations behind participating in these events are two-fold. First, many of these events are aimed at increasing participation and interest in STEM in socio-economically disadvantaged areas.

Secondly, and more relevant for the present paper, we encourage our students to participate in these events. The goal being that by being exposed to an audience whose mathematical experience is different, and usually less extensive, than their own will deepen their communication skills and build their confidence. The environment of these outreach events is less controlled than that of the classroom. In the classroom students are communicating with their peers or their lecturers, i.e. those who have a similar level of knowledge in mathematics or greater than the student. At these outreach events students will need to interact with a range of people with a variety of backgrounds and abilities in mathematics.

Interactions such as New Scientist Live and the STEM festival require the students to consider how they can effectively communicate mathematics to a non-mathematical audience. The students will have to think on their feet and consider the object of the outreach event from several different angles in order to successfully communicate to a diverse audience including members of the public, children of all ages, students and aspiring students of scientific disciplines and science professionals. Many of our students will work in jobs where they may be one of a small number of people who will have a maths degree, or a degree with significant mathematical content. Our maths degrees are designed to prepare our graduates to be the mathematical expert in their professional team or organisation. Therefore, the ability to communicate with non-mathematicians is just as important communicating with fellow mathematicians. These kinds of interactions will also increase the students' confidence in their communication and ability in mathematics (Megeney, 2016).

2. Methodology

We conducted an anonymous survey of current students and recent graduates of our undergraduate mathematics programmes between July and August of 2024. The survey was based on the Mathematical Attitudes and Perceptions Survey (MAPS), developed by Code, et al., (2016) and discussed in detail in Jones, et al., (2025). In our questionnaire, students completed (a subset of) the MAPS, reflecting on their attitudes before university, then answered specific questions about key elements of our learning and teaching approach, before completing (the subset of) the MAPS a second time reflecting on their current attitudes.

In this paper we report on the specific questions about the communication and outreach elements of our learning and teaching approach. Each student rated the statements "Outreach activities made me more confident", "Outreach activities increased my anxiety", "Outreach activities helped me prepare for my professional career", and "Outreach activities are an important part of mathematics", and similar statements for "communication activities". They were also given a free text response where they could tell us about their experience with these activities. We were interested in the perceived impact of these activities on students' confidence, anxiety and whether the students consider communication and outreach as central to mathematics. For the results of the MAPS questions see Jones, et al., (2025).

When conducting our analysis we encoded students' responses to the Likert scale questions on a -2 to 2 scale. Then to summarise we simply took the average. The results of the anxiety questions were multiplied by -1 so positive score have the same interpretation across questions.

3. Results

In their responses students were generally very positive towards both the communication and outreach activities.

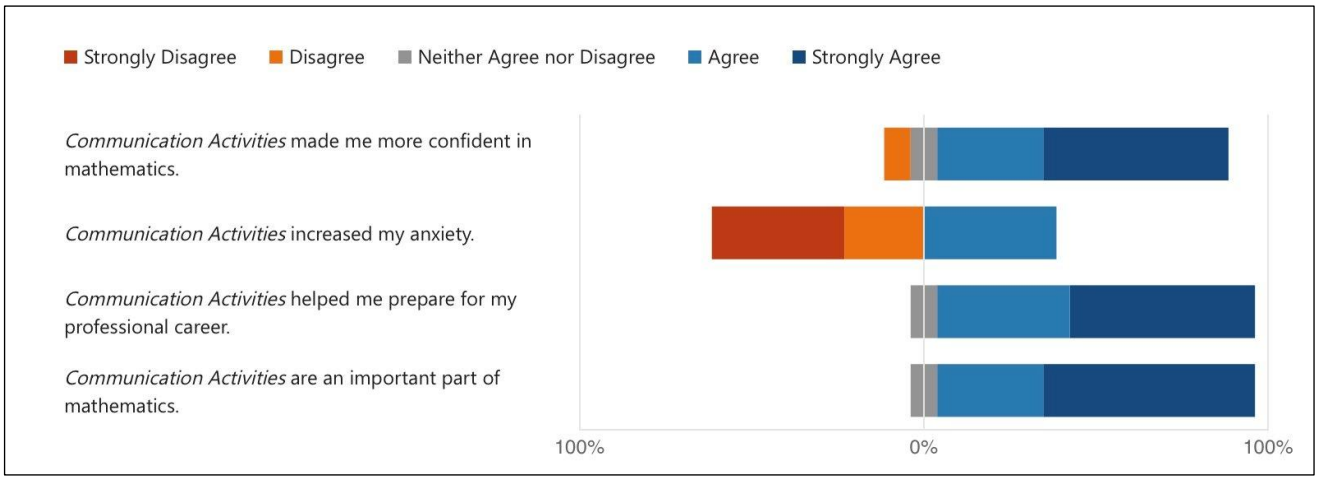


Figure 2: student attitude towards communication activities

From Figure 2 it can be seen that not only did the communication activities make them more confident in their own mathematical ability but the students also saw these kinds of activities as vital for preparing them for their professional careers. Some recent graduates left comments like:

"This allowed me to improve my presentation skills as it exposed a weakness of mine which I had previously believed was not an issue for me. This realisation inspired me to improve on my speaking skills."

Another recent graduate contacted us separately to highlight the impact these activities have had on their career trajectory:

"I just wanted to let you know that I've gotten my graduate job as a data analyst! Specifically, they were impressed with my communicating mathematics project."

These responses are typical of the responses we have received regarding the communication activities on the degree programme.

It is also clear from Figure 2 that not only do students view these activities as important for themselves and their own career, but they also view communicating mathematics as an important part of mathematics in general. It is worth noting that this was all achieved without significantly impacting the students' anxiety.

The data for the outreach activities paint a similar picture as can be seen in Figure 3:

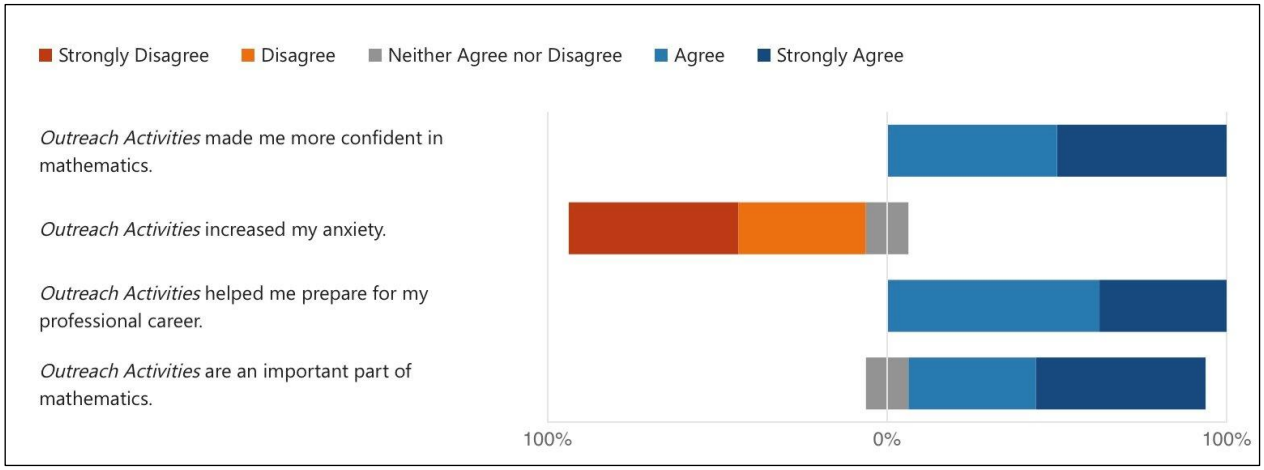


Figure 3: Student attitude towards outreach activities

Again, we see that students generally responded that they found these activities beneficial for their own confidence in mathematics and preparing them for the working world. They also view these activities as an important part of the subject area, and they do not appear to increase student anxiety. We have had several students comment on what exactly they find beneficial about these events:

"By facing the public for hours at a time and having to explain mathematical concepts to people of varying age groups, this allowed me to improve my public speaking and improved my ability to adapt to various situations."

"During World Skills, it was great to be able to express my passion for Mathematics and impart that to the general public. It made me more confident in my mathematical knowledge as I knew the content and it helped me form a coherent answer that was easily digestible."

"Working with a crowd and having the lecturers around to correct me if I'd said something wrong made it easier for me to speak about different topics within maths without worrying about saying this the wrong way. Such activities helped me grow as a mathematician by offering confidence in myself and what I know to be true."

The common thread here is growth in confidence students obtained from participating in these activities.

Figures 2 and 3 provide an overview of how the participants feel about these activities in general. As we've observed, overall, the results for communication activities are the same as those for outreach activities. However, we include a side-by-side jitter plot for communication and outreach activities so we can compare the distribution of individual responses for each of these activities.

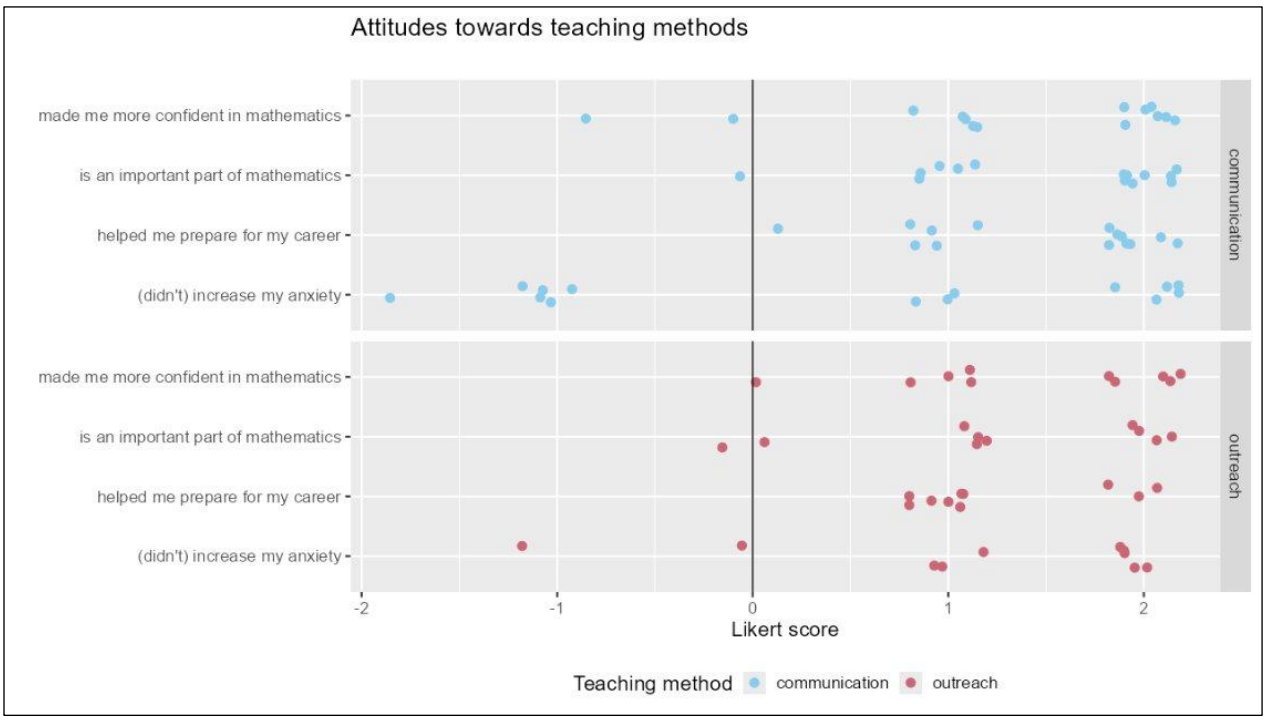


Figure 4: Comparison of individual responses. Each point is an individual student response and are jittered to prevent overplotting.

Table 1: Mean Likert scores of interventions

Question	Intervention	N	Mean score	SD
[Intervention] activities made me more confident in Mathematics	Communication	14	1.29	0.914
	Outreach	10	1.40	0.699
[intervention] activities (didn't) increase my anxiety	Communication	14	0.43	1.505
	Outreach	10	1.20	1.303
[intervention] activities helped me prepare for my career	Communication	14	1.50	0.650
	Outreach	10	1.30	0.483
[intervention] is an important part of mathematics	Communication	14	1.50	0.650
	Outreach	10	1.20	0.789

For the majority of questions there doesn't appear to be any notable differences in the responses for questions concerning communication activities when compared to their outreach counterpart.

The notable exception to this is the questions concerning student anxiety. From the Figure 4 we can see that the communication activities seemed to cause more anxiety than the outreach activities. This is further backed up by the difference in the average scores for both interventions on this question. There are a number of speculative reasons we could offer for this. One is perhaps it is due to the difference in audience between the two activities. For communication activities students often have to present in front of their classmates and lecturer. Whereas for outreach activities the audience is usually members of the public or school children – an audience the students may find less intimidating due to the differing levels of expected mathematical knowledge. Another possibility is that for the communication activities students would have to prepare something in advance of the activity perhaps adding to the anticipation and pressure of the activity. For outreach activities students usually aren't required to prepare anything in advance.

4. Discussion

On completing a maths degree, graduates have many options from continued study in mathematics, or the scientific, financial or technological disciplines that a mathematics background affords, to the wide variety of careers that mathematical skills and knowledge are valued in. Fundamental to these is that our graduates have confidence in their own mathematical ability and are able to talk about mathematics effectively both to peers and a non-mathematical audience.

These aspects of being a mathematician are often overlooked or forgotten about when we design assessment that mainly focuses exclusively on application of various techniques solve problems or prove statements (Borovik and Gardiner, 2007). We have taken an approach that builds communication and outreach into our maths programmes to give students and opportunity to develop their communication skills and confidence in their own ability.

The results are extremely positive: students who have participated in these activities found them to be hugely beneficial for their confidence and preparing them for their career while not having an overly negative impact on the student's anxiety. An interesting point of difference is that the communication activities do seem to have a more negative impact on student anxiety than outreach activities.

5. Future work

As part of an ongoing outreach project we're running in partnership with the Science and Technology Facilities Council (STFC) we're planning several school cocreation events. The project aims to engage school students from disadvantaged areas with STFC activities. Through these cocreation events school students will see how mathematics applied to space travel.

The end product will be an interactive game in which school students can design their own planet, add this planet to their class/school solar system, and explore this universe by solving mathematically themed puzzles.

We plan on recruiting our own students to work at these cocreation events as Mathematics Ambassadors engaging school student and the public in these activities. These cocreation events will take place at science festivals such as New Scientist Live, MDX STEM Fest, or similar and through school visits, particularly schools in disadvantaged areas. At the events we will deliver a number of creative and engaging maths themed activities. Our maths students will be engaging the audience in the activities while also imparting their knowledge of the mathematics that underpin the activity. The goal for our maths students is to enhance their communication abilities and social capitol

through these events. To date students have worked at MDX STEM Festival and New Scientist Live and engaged school students in creative activities like imaginative planetary design and relate them to concepts such as orbits.

Next, our students will visit STFC funded facilities to learn more about their work and accompany us on several school visits over the coming academic year.

6. References

Borovik, A. V. and Gardiner, T., 2007. *Mathematical Abilities and Mathematical Skills.* [Online] Available at: http://www.mathematics.manchester.ac.uk/~avb/pdf/abilities2007.pdf

Centre for Academic Practice Enhancement, 2022. *Assessment Design Guidence 2022-23.* [Online] Available at: https://www.intra.mdx.ac.uk/about-us/services/centre-for-academic-practice-enhancement/learning-teaching-and-assessments/assessments-for-online-delivery/Assessment-Design2022-23.pdf [Accessed 30 10 2023].

Code, W., Merchant, S., Maciejewski, W., Thomas, M. and Lo, J., 2016. The Mathematics Attitudes and Perceptions Survey: an instrument to assess expert-like views and dispositions among undergraduate mathematics students. *International Journal of Mathematical Education in Science and Technology,* 47(6), pp. 917-937.

Crawford, K., 1996. Vygotskian Approaches in Human Development in the Information Era. *Education Studies in Mathematics ,* Volume 31, pp. 43-62.

French, S., Dickerson, A. and Mulder, R. A., 2023. A review of the benefits and drawbacks of high-stakes examinations in higher education. *Higher Education,* pp. 1-26.

Groves, J., 2012. Enhancing the Communication and Speaking Skills of Mathematics Undergraduates. *Further Work Developing Graduate Skills in HE Mathematics Programmes. Birmingham: MSOR HESTEM, 19-22.,* pp. 19-22.

Jones, M., Kazim Ali, Z., Lawrence, S., Masterson, B., Megeney, A. and Sharples, N., 2025. Making Mathematicians. *MSOR Connections,* 23(3), pp. 100-113.

Jones, M., Megeney, A. and Sharples, N., 2022. Engaging with Maths Online - teaching mathematics collaboratively and inclusively through a pandemic and beyond. *MSOR Connections,* 20(1), pp. 74-83.

Masterson, B., Sharples, N., Jones, M., Lawrence, S. and Megeney, A., 2024. Authenticity in Learning, Teaching and Assessment. *MSOR Connections,* 22(2), pp. 29-36.

Megeney, A., 2016. Engaging with Mathematics: How mathematical art, robotic and other activities are to engage students with university mathematics and employability skills. *MSOR Connections,* pp. 61-65.

Office for Students, 2024. *Access and Participation Dashboard.* [Online] Available at: https://www.officeforstudents.org.uk/data-and-analysis/access-and-participation-data-dashboard/data-dashboard/ [Accessed 24 08 2024].