

# CETL-MSOR Conference 2015

**The University of Greenwich**  
**8th - 9th September 2015**

Conference Proceedings  
Edited by Dr David Green

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## Acknowledgements

CETL-MSOR 2015 would not have been possible without the hard work of the organising committee: Tony Croft, Michael Grove, Duncan Lawson, Trevor Hawkes, Moira Petrie and Tony Mann. Thanks are also due to Daryl Davies for the administrative support he provided to the conference, Chantal Jackson for the production of the conference promotional materials and proceedings, and finally David Green for editing and collating these proceedings.

Published by the **sigma** Network

March 2016

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ISBN: 978 1 911217 04 6

Content Editing: David Green

Design and Layout: Amy Bishop - Creative and Print Services, Loughborough University

Printed by Loughborough University

# Engaging with Mathematics: How mathematical art, robotics and other activities are used to engage students with university mathematics and promote employability skills

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## Abstract

There has been much discussion about what exactly employability skills are for mathematics students and how they can be embedded, promoted and developed in mathematics curricula. Mathematics graduates are highly employable and are valued for their reasoning skills, analytical and logical approaches to problem solving, and their abstract thinking. It is the more general employability skills that are more difficult to promote in a mathematics specific context within programmes.

When designing the BSc and MMath Mathematics programmes at Middlesex University the team considered how to develop and enhance employability skills whilst promoting and engaging students with all aspects of mathematics.

In this paper we will discuss the types of skills developed, the activities used to promote them, and reflect on the successes and challenges of the venture. Additionally we will discuss plans for future development and enhancement of the initiative.

## Introduction

In 2013 Middlesex University identified a number of growth subject areas for programme development, mathematics was one of them. The mathematics team were given the opportunity to reintroduce specialist mathematics degrees including a BSc and MMath Mathematics.

It was felt that developing employability skills in the curriculum, as well as the theoretical and rigorous content of the programmes, was fundamentally important; and the team felt that these two should not be separate strands but rather intertwined in the learning and teaching strategy. A number of questions prompted the design:

- Will this degree promote development of the skills valued by employers?
- What makes mathematicians employable?
- How do students encounter mathematics and mathematical skills?
- How can we promote engagement with mathematics?

A number of successful approaches used to develop graduate skills in mathematics degrees are detailed in Waldo (2011a and 2011b) and Rowlett (2012) where a number of case studies are discussed that employ different techniques to develop particular skills. In Waldo (2011b) the range of activities was quite broad, but the perception by students of the importance of engaging in the activities was vital.

Whereas many specialist skills are developed by mathematics students as a natural consequence of their progress on their programmes, other more generic skills require embedding. Hibberd and Grove (2009) state that “employers have repeatedly said that they not only value graduates’ specialist skills but would also look for development of a range of generic skills, what might be called employability skills including amongst others written and oral communication, team working, and IT skills”. This embedding of skills is also encouraged in the mathematics, statistics and operational research subject benchmark, QAA (2007).

With this in mind the team felt that engagement with the discipline was vital. The skills should be developed and linked, where possible, to mathematics.

## The approach to skills

The mathematics team at Middlesex University took a holistic approach, developing skills both within modules and within a series of programme seminars, activities and workshops called Engaging with Mathematics. This reflects the suggested questions and ideas for developers in Challis, Robinson, and Thomlinson (2009: p41), whether or not skills should be integrated in the mathematical content of the programmes, in a separate “skills module”, or as a combination of the two approaches.

The team felt that the aim was 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. Activities were designed and embedded within the specialist mathematics programmes that enable students to explore and experience mathematics in different forms as well as promoting the development of knowledge and skills. Some activities were embedded within modules promoting skill development alongside module content and some activities formed part of a broader programme-wide initiative.

The broader approach was the Engaging with Mathematics series. This included, amongst other events, a weekly timetabled workshop on mathematical problem solving, communication, engagement activities, and progress review and reflection activities. Further sessions included constructing a mathematical sculpture with students from outside the department and across the breadth of the student population, the mathematics and robots workshops, undergraduate seminars, problem solving sessions, communication sessions, and outreach activities.

In order to ensure the skills were developed in a mathematical context we asked ourselves what it meant to learn mathematics successfully. The discussion concerning the nature of mathematical learning and the structure of good mathematical problems by Borovik and Gardiner (2006) reflects this design in recognising that mathematics is cumulative and systematically learnt; it builds and integrates as it progresses. Furthermore, mathematics must be motivated; students need an emotional involvement with it in order to fully develop their ability. Understanding material is key and linking to real life is important. To keep students engaged, problems and activities must be challenging, accessible, developmental, revealing and extendable. These principles would influence the teaching philosophy of the programme and all activities in the Engaging with Mathematics initiative.

Identification of employability skills was an important aspect of the design and how these could be developed through activities. These included understanding patterns, being rigorous and logical, abstracting from real-world situations, clarity of thought and reasoning, problem solving, communicating results (in particular conveying to others one’s own mathematical thinking), demonstrating a critical approach (in particular criticising other people’s arguments), working as a team to solve a problem, and using computers effectively. This is not exhaustive but contains those activities linking to the general employability skills. Activities that promoted and developed these skills are discussed below.

## Mathematical sculpture – Sword Dancing

The team secured funding for a research professor and mathematical sculptor, George Hart, to come to Middlesex for one week to work with staff and students. The Sword Dancing sculpture was one of the team's more ambitious activities. It brought together staff and students from across the University in a joint mathematical construction activity over two days. Together staff and students from a variety of disciplines built a sculpture comprising of two pieces that mirror each other, designed by George Hart, entitled Sword Dancing. Mathematics students worked with students from architecture, dance, education, engineering, drama, design, and music.

The construction workshop ran as if it was a large puzzle to be solved. Students from different disciplines worked in small teams initially to look at how three different component parts of the sculpture could be fitted together. They needed to work as a team to manipulate the components but also communicate why they felt that one particular orientation of components would successfully work and combine to form a larger component of the sculpture which had repeating elements within it.

The construction of the large mirrored elements of the sculpture took approximately eight hours spread over two days and students and staff felt a strong sense of achievement at the end of the activity. This was a very successful activity and it was noted by tutors that the level of engagement and confidence of students had increased.

Students were required to reflect on the success of the activity as part of the first year portfolio. One student commented that 'working with other students gave me an insight into how they tackle problems, where I tried to find the most logical answer the students working with me looked at how the pieces would go together in a more artistic form. We combined these approaches to solve the problem'. Another commented that 'it broadened my horizons.' 'I chatted to people from other areas which led me to do additional reading which I really enjoyed and broadened my knowledge'

## Zometool workshop – constructing 120-cell

Mathematics students and staff worked together to construct polyhedra and a three dimensional projection of the 120 Cell during a Zometool construction kit workshop facilitated by George Hart (see <http://www.zometool.com>). This developed confidence, communication skills and problem solving skills. This was the first building mathematics themed workshop undertaken by staff and students jointly and was more difficult than the team had originally thought. The students found it a challenge to view staff as peers in the activity and the staff found it challenging not to lead individual team activities.

A variant of this activity was undertaken with the new BSc Mathematics cohort who joined in October 2015. This required staff and students to build components for a canopy. The students commented on this in their week 4 reflective programme activity positively remarking that the most interesting learning experience so far was 'building the shapes to put together to make a canopy. I found the shapes really interesting. Mathematics is awesome!', and 'helping build the structures. It was interesting how it would all fit together.'

## Robots and Mathematics

Sessions for motivation and engagement were key. Sessions like the mathematics and robots session extended material seen in the students' first year material on vectors and matrices. These required students to build on their existing knowledge and extend concepts and ideas. It developed understanding and application of theory and problem solving skills.

## Problem solving

Almost all sessions in Engaging with Mathematics included a problem solving element. Sessions included mathematical puzzling, logic in the real world, and outreach mathematics. These were all in addition to the sessions already detailed. All had a problem solving approach and required students to work together on a variety of tasks and communicate their solutions and reasoning to others.

## Communication

The communication strand involved some practical sessions on writing mathematics, developing mathematical arguments, typesetting mathematics in Word and PowerPoint, motivating mathematics, and a session on how to give technical presentations. These complemented activities such as discussions on Mathematics in the media and the seminar series.

Another very simple activity that was successful was the 'fact of the week', a way for students to get to know each other and build confidence ready for in class presentations. All students were required to stand up in class, introduce themselves and then tell the others a fact for that week. Initially facts were about themselves and their backgrounds, but further into term students are required to identify something of a mathematical nature.

Students commented in their reflective activities that one of the most interesting learning experiences they had had so far was 'engaging with Mathematics, building structures and learning how to write Mathematics', and 'the facts about class mates in Data and Information'.

## Outreach

We were keen to involve students in outreach to promote communication, team working and problem solving skills. Students took part in SmashFest2015, going out to schools and taking part in on-campus school visits.

## Reflections on the first year of the initiative and conclusions

The initiatives have only run for one year but the feedback we have received has been very positive. The motivation and engagement of students has increased and the first cohort of the programme set up a Mathematics society. In its first year the society ran a giant Soma cube activity supported by the Mathematics team. This year the society has recruited 150 new members and they are running their own events independently.

Students are more confident in class and in their approach to mathematical activities. There was a notable change in student engagement after the Sword Dancing construction activity. All staff noted the difference in student engagement and skill level in sessions after this activity was completed.

After discussions with the students it was noted that the timing of the scheduled sessions was not helpful and this will be improved for the next run of the initiative. All students recognised that their skills had progressed in their portfolio assignment but felt that the way this was recorded and reflected upon should have been more systematic. This will also be improved in the next phase.

The team now face new challenges for the second run of the initiative:

- Should year 1 and year 2 students integrate on all activities or should there be dedicated sessions for both individual cohorts and a combination of both?
- How can the team ensure that students have a strong enough voice in the design of activities?

One challenge is to ensure that all activities have a sufficiently strong mathematical focus so that the connection between learning mathematics and the employability skill is maintained.

A targeted series of Mathematics careers and employment workshops at higher levels is clearly needed and it is vital that students are exposed to a variety of career mathematicians who will inspire and potentially mentor students in the job hunting process.

The team feel that the initiative has been beneficial to students and plan to evaluate the scheme more comprehensively at the end of its second year.

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