**Institution: Loughborough University**

**Unit of Assessment: C25 Education**

**Title of case study: Developing and Implementing Support Mechanisms to Tackle the 'Mathematics Problem' in Higher Education**

**1. Summary of the impact** (indicative maximum 100 words)

Research conducted between 1997 and 2013 at Loughborough University helped to tackle the 'mathematics problem': a significant challenge for the entire UK Higher Education (HE) sector. Significant impact during the assessment period has arisen from the development of Mathematics Support Centres at UK and international Higher Education Institutions (HEIs), based on the model developed at Loughborough University, and from an online resource, **math**centre. A collaborative network of practitioners has facilitated the dissemination of the 'Loughborough Model', and resulted in changes in institutional policy and practice. Direct beneficiaries have been teaching and support staff in HEIs and students across a broad range of disciplines.

**2. Underpinning research** (indicative maximum 500 words)

Beginning in the late 90s, an on-going programme of research at Loughborough University (LU) has focused on the mathematics learning of undergraduates, including both specialist mathematics students and those who use mathematics in other disciplines. This programme was initiated by widespread concerns in the academic community of a "mathematics problem": the acceptance that incoming undergraduates were insufficiently prepared for the mathematics components of their courses. Early evidence for this was provided by Croft along with recommendations on how to address the problems through a variety of support measures **[3.1]**.

Alongside this mathematics-specific work, other colleagues at LU embarked upon research into how technology could be successfully incorporated into student support mechanisms in HE and, in particular, how widespread use of computing facilities impacts on students' use of learning spaces. Crook's ESRC-funded research found that students equipped with IT equipment in their residences valued the accessibility and flexibility of online learning resources, but that they also wanted the complementary experience of engaging in a real-world learning community **[3.2]**.

Informed by these findings, Croft began to develop and evaluate online and real-world support mechanisms designed to address the mathematics problem, which collectively became known as the 'Loughborough Model'. An online collection of reusable learning resources, known as **math**centre, was developed by a consortium led by Croft (funded by the Learning & Teaching Support Network). In line with Crook's findings, mechanisms to support a real-world mathematics learning community were also developed. The earlier embryonic mathematics support available at LU was transformed in scope to include a large campus-based Mathematics Support Centre (MSC) offering physical resources for students to access, social working spaces to encourage collaborative work, and a drop-in advisory service.

After these initiatives had been set up, a (still on-going) iterative cycle of design research was initiated which led to the development of further mathematics support resources and mechanisms. Key findings from this body of research include:

(a) MSCs can have positive impacts upon student communities and students' self-images **[3.5]**;

(b) MSCs can substantially improve progression rates of students from non-traditional backgrounds **[3.3]**;

(c) MSCs can be provided to mitigate the issues students with specific learning difficulties encounter when studying mathematics and statistics **[3.4]**;

(d) students adopt different and unpredictable patterns of engagement with optional learning resources (including online and real-world support mechanisms) and this must be closely monitored for the resources to have maximum effect **[3.6]**.

These and other findings have fed into a continuous cycle of design, implementation and analysis that continues to this day. Current research in this area includes projects which focus on the use of peer support in advanced mathematics courses (funded by the HE Science, Technology,

Engineering and Mathematics (STEM) programme, £30k) and web-based presentation systems for teaching mathematical proof (funded by JISC, £70k).

Key Researchers: Dr Lara Alcock (2007-date, Senior Lecturer in Mathematics Education), Professor Tony Croft (1996-date, Professor of Mathematics Education), Dr Charles Crook (1996-2004, Reader in Psychology), Dr Carol Robinson (2002-date, Senior Lecturer in Mathematics Education), Dr Matthew Inglis (2008-date, Senior Lecturer in Mathematics Education).

**3. References to the research** (indicative maximum of six references)

**Papers**


**3.1.** Armstrong P. K. and Croft, A. (1999). Identifying the learning needs in mathematics of entrants to undergraduate engineering programmes in an English university. *European Journal of Engineering Education*, 24, 59-71. DOI:10.1080/03043799908923538

**3.2.** Crook, C. K. and Barrowcliff, D. (2001). Ubiquitous computing on campus: Patterns of engagement by university students. *International Journal of Human-Computer Interaction*, 13, 245-258. DOI:10.1207/S15327590IJHC1302_9

**3.3.** Symonds, R. J., Lawson, D., and Robinson, C. L. (2007). The effectiveness of support for students with non-traditional mathematics backgrounds. *Teaching Mathematics and its Applications, 26*, 134-144. DOI: 10.1093/teamat/hrm009

**3.4.** Perkin, G and Croft A.C. (2007). The dyslexic student and mathematics in higher education. *Dyslexia, 13*, 193-210. DOI: 10.1002/dys.334

**3.5.** Solomon, Y., Croft, A., and Lawson, D., (2010). Safety in Numbers: mathematics support centres and their derivatives as social leaving spaces. *Studies in Higher Education, 35*, 421-431. DOI: 10.1080/03075070903078712

**3.6.** Inglis, M., Palipana, A., Trenholm, S., and Ward, J. (2011). Individual differences in students' use of optional learning resources. *Journal of Computer Assisted Learning*, 27, 490-502. DOI: 10.1111/j.1365-2729.2011.00417.x


**Quality**

All outputs listed in this section report significant, original and rigorous research. Each was published in an international peer-reviewed journal, and has had lasting influence on the field. Outputs 4, 5 and 6 were published in journals ranked in the "INT1" category by the European Reference Index for the Humanities (ERIH). This is the highest category in the classification system, and represents "international publications with high visibility and influence among researchers in the various research domains in different countries, regularly cited all over the world". Output 1 was published in an "INT2" ranked journal (the second highest category of international journal). Output 2 reports research funded through the highly competitive ESRC review process, and was published in a highly-ranked computer science journal (the 13th highest-ranked journal in the ISI "cybernetics" category).

**Grants**

ESRC L132251034, Learning Sites: Networked Resources and the Learning Community, to Light (Bournemouth), Crook (Loughborough) & White (Southampton), £149,131, 1997-1999.

**4. Details of the impact** (indicative maximum 750 words)

This case study describes wide-reaching impact resulting from still on-going research: (a) the development and use of **math**centre (www.mathcentre.ac.uk) and (b) the adoption of mathematics support by HEIs in the UK and elsewhere. These have impacted on the learning outcomes of large numbers of students studying a wide range of courses with a mathematical or statistical component including those with additional needs such as dyslexia. Mathematics support informed by the Loughborough Model has had significant reach: it is now embedded in many HEI's support policies (e.g. Office for Fair Access (OFFA) Agreements at Coventry, Sheffield, York and

elsewhere) and facilities (details below).

In response to Croft's and Crook's research, LU led a consortium in setting up **math**centre, an online collection of learning resources (leaflets, workbook, video tutorials) designed to support students in the transition to mathematically demanding undergraduate courses. This resource continues to be widely used and in the period 06/2008 to 05/2012 received 1.65 million visits from 1.1 million visitors, which includes a widespread international user base. These resources are used extensively by the academic community: an analysis in 2012 showed 80% of UK universities directed students to **math**centre from their institutional Virtual Learning Environments (VLEs). **math**centre resources are a valued and highly trusted resource, the MSC manager at the National University of Ireland Maynooth wrote that his institution uses "material directly from **math**centre, mainly videos, texts and quizzes" **[5.1]**, and that his evaluations have shown that students who use these resources regularly "do better in their modules than those who do not" **[5.1]**.

In line with the findings of Crook's ESRC-funded research, LU not only developed web-based mathematics support, but also a real-world support centre designed to foster a productive learning community. An initiative to develop such provision led to a collaborative venture with Coventry University, and LU was awarded Centre for Excellence in Teaching & Learning (CETL) status by HEFCE (2005-2010). A key goal of the CETL, which became known as **sigma**, was to encourage the development of MSCs at other universities. This was accomplished via two mechanisms.

First, **sigma** offered funding for the establishment of MSCs at universities without such centres. This required matched funding and buy-in from senior management and became a catalyst for placing mathematics support on institutional agendas. In 2005 three MSCs were set up with **sigma** funding (Bath, Sheffield, Leeds), all have continued to successfully operate during the REF assessment period. As part of their funding agreement, the MSCs were required to monitor student usage: in the three years from 2008 a total of 9684 visits were made by students to these MSCs (suggesting that there were around 19,000 visits across the assessment period).

Second, **sigma** staff engaged with the mathematical community to disseminate on-going research and the Loughborough Model via practitioner conferences. One clear example is the annual MSOR (Mathematics, Statistics and Operations Research)-CETL Conference, co-organised by Croft, which has grown significantly and is now attended by over 100 delegates annually **[5.2]**.

With the end of CETL funding in 2010, the importance of **sigma**'s work for tackling the 'mathematics problem' was recognised by the HE STEM Programme through the award of £295k in 2010 **[5.3]**. A further £818k of continuation funding was awarded by HEFCE in 2013, and **sigma** was subsequently described as an "important initiative" by the Minister of State for Universities and Science **[5.4]**. To date this additional funding has enabled **sigma** to transfer and embed the Loughborough model at over 20 UK HEIs **[5.3]**. All these MSCs, and others, have made heavy use of the **math**centre online learning resources **[e.g. 5.1, 5.5, 5.6]**.

To illustrate the success of these centres, in 2012 the University of York cited its **sigma**-funded MSC in its OFFA Access Agreement, stating that "[the service] has been very well utilised and we plan to expand this service to meet some additional areas of identified need" **[5.6, 5.7]**, and the 2012 Quality Assurance Agency for Higher Education (QAA) Institutional Review of the university found the MSC to be a headline feature of good practice **[5.6, 5.8]**. Between 2010 (when the service was founded) and 2012 there were 1751 visits to the Centre, and a university-administered evaluation concluded that 95% of users believed that the centre helped their mathematical attainment **[5.9]**.

The significance that the research-based practice developed at Loughborough University has had throughout the higher education sector is now widely recognised. Indeed, external colleagues have praised the impact of the Loughborough Model directly. The Executive Director of the Institute of Mathematics and its Applications wrote that "It is hard to overstate the importance of the expansion of the **sigma** Network to the higher education community." **[5.10]**, and the Director of the Irish Centre for Excellence in Mathematics and Science Teaching and Learning remarked "We stand on the shoulders of giants. From our view, the giants are Coventry and Loughborough Universities and **sigma**. We have unashamedly copied our ideas from them" **[5.2]**.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

The following sources of corroboration can be made available at request:

**5.1.** Letter from the Director of the Mathematics Support Centre, National University of Ireland, Maynooth (29th March 2013).

**5.2.** Waller, D. (2012). The legacy and sustainability of sigma. *MSOR Connections, 12*(2), 39-41. http://bit.ly/17woftH

**5.3.** HE STEM Programme Report ("National HE STEM Programme: Investigating Longer-Term Curriculum Change and Institutional Impact Within Higher Education", by Professor Harry Tolley, Professor David Greatbatch, Dr Helen Mackenzie.

**5.4.** "Robbins Revisited: Bigger and Better Higher Education", Report by Rt Hon David Willetts MP, Minister of State for Universities and Science. http://bit.ly/17DB56B

**5.5.** Letter from the Director of the Maths Learning Centre at Dublin City University, and former Chair of the Irish Mathematics Learning Support Network (15th March 2013).

**5.6.** Letter from the Project Office for Mathematics Support, University of York (15th March 2013).

**5.7.** University of York Access Agreement 2012, http://bit.ly/14hc28X

**5.8.** University of York QAA Institutional Review 2012, http://bit.ly/100lMVH

**5.9.** "The Mathematics Support Community of Practice: A report of the achievements of **sigma** within the National HE STEM Programme", http://bit.ly/ZUwN7h

**5.10.** Letter from Executive Director, Institute of Mathematics and its Applications (28th March 2013).