Institution: Loughborough University

Unit of Assessment: C23 Education

Title of case study: Addressing the quantitative skills deficit in higher education through university-wide mathematics and statistics support

Period when the underpinning research was undertaken: 2000-2011

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Tony Croft	Professor of Mathematics Education	1996 – date
Charles Crook	Reader in Psychology	1996 – 2004
Matthew Inglis	Professor of Mathematical Cognition	2008 – date
Carol Robinson	Professor of Mathematics Education	2001 – 2019

Period when the claimed impact occurred: August 2013 – July 2020

Is this case study continued from a case study submitted in 2014? Yes

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

Each year students arrive at UK universities to study subjects across STEM disciplines and the social sciences, but many are underprepared for the mathematical demands of their courses. Loughborough University researched this quantitative skills deficit to develop and evaluate a model of Mathematics Support Centres that combined a physical building with high-quality online learning resources, leading to the following impacts: (i) new MSCs have been established in universities without existing provision, both in the UK and internationally (e.g., Czech Republic and Norway); (ii) mathematics support offered by MSCs based on the Loughborough model has improved the learning outcomes of over 34,000 students per year in British/Irish universities, and more internationally.

2. Underpinning research (indicative maximum 500 words)

A long-running programme of research at Loughborough University has focused on the mathematics learning of undergraduates, including both specialists and those who use mathematics and statistics in other disciplines. This programme was initiated following widespread agreement in the mathematical community that incoming undergraduates were underprepared for the mathematical and statistical demands of their courses. Early evidence on the extent of the problem was provided by Croft [R1].

Simultaneously, Loughborough University also embarked upon research into how technology could facilitate student support and how computing facilities affect students' use of learning spaces. Crook's research found that students with IT equipment in their residences valued the accessibility and flexibility of online resources, but also benefitted from engaging with real-world learning communities [R2].

Developing, implementing, and evaluating the 'Loughborough Model'.

Informed by these findings, Croft began to develop, implement, and evaluate online and real-world support mechanisms intended to address the mathematics problem, which collectively became known as the 'Loughborough Model'. He led a design-research consortium funded by the Learning & Teaching Support Network (a predecessor of the Higher Education Academy) that developed and evaluated mathcentre.ac.uk and statstutor.ac.uk. These sites provide online collections of research-informed instructional videos and written resources. Informed by Crook's work, he also led the development of a

Mathematics Support Centre (MSC) in which students could find physical resources, collaborate on mathematical and statistical studies, and access drop-in advice from staff. By 2006 Loughborough University's provision had expanded to two large campus-based MSCs.

These MSCs provided sites for iterative cycles of design research and efficacy studies, leading to further research-based resources and to a deeper understanding of student engagement and study habits. Key findings include:

(a) MSCs substantially improve progression rates of students from non-traditional backgrounds [R3];
(b) MSCs provide sites where strategies designed for working with neurodiverse students can be implemented, mitigating the issues faced by students with specific learning difficulties [R4];
(c) MSCs have positive impacts upon student communities and students' self-images by reducing the number of students who perceive mathematics as an individual performance-oriented pursuit [R5];
(d) Students adopt different and unpredictable patterns of engagement with optional learning resources (including online and MSC support) and this must be closely monitored for the resources to be maximally effective [R6].

More recent Loughborough research in this area includes projects that explored mechanisms by which mathematics support has become embedded in institutional learning strategies (funded by HEFCE), and the interface between peer-assisted learning programmes and mathematics support, particularly for single-honours mathematics students (funded by the National HE STEM Programme).

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

R1: Croft, A. C. (2000). A guide to the establishment of a successful mathematics learning support centre. *International Journal of Mathematical Education in Science and Technology, 31*, 431-446. doi: 10.1080/002073900287192
R2: Crook, C. K. & Barrowcliff, D. (2001). Ubiquitous computing on campus: Patterns of engagement by university students. *International Journal of Human-Computer Interaction, 13*, 245-256. doi: 10.1207/S15327590IJHC1302_9
R3: Symonds, R. J., Lawson, D., & 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
R4: Perkin, G. & Croft A.C. (2007). The dyslexic student and mathematics in higher education. *Dyslexia, 13*, 193-210. doi: 10.1002/dys.334
R5: Solomon, Y., Croft, A., & Lawson, D. (2010). Safety in numbers: Mathematics support centres and their derivatives as social learning spaces. *Studies in Higher Education, 35*, 421-431. doi: 10.1080/03075070903078712
R6: Inglis, M., Palipana, A., Trenholm, S., & 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. All outputs appeared in international journals that adopt a rigorous peer review process. Outputs R5 and R6 were returned to REF2014 as part of a submission that was rated 100% 2* or above. This body of work was funded by competitively awarded grants from the Higher Education Academy (£250k), Learning & Teaching Support Network (£65k), HEFCE (£4.85m and £818k), and JISC (£80k).

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

Our research led to the establishment of Mathematics Support Centres (MSCs) at HEIs across the UK and internationally. A key pathway to current impact was established in

previous REF assessment periods, when Loughborough's expertise attracted HEFCE Centre for Excellence in Teaching and Learning (CETL) status, jointly with Coventry University, in 2005. The CETL and its successors, branded as **sigma**, offered funding and advice to assist with the creation of MSCs based on the Loughborough Model. In 2016, the significance of **sigma**'s work for the mathematical community was recognised via the award of the Institute of Mathematics and its Applications' Gold Medal to its founding directors, Croft and Lawson. The medal had never previously been awarded to education researchers. The citation noted the "*outstanding contribution to the improvement of the teaching of mathematics*" made by **sigma**'s *"scholarly, research-informed approach*", and the "*increasing numbers of support centres set up using the good practice and support developed by **sigma***" [S1].

During the assessment period the impact of our research has taken two forms. First, new MSCs that follow the Loughborough Model have been set up at universities which previously had no such provision, both in the UK and internationally. Second, students who have used the MSCs have seen positive impacts upon their learning, including improved learning outcomes.

1. Transformed the mathematics support delivered by universities.

During the assessment period, our research drove the adoption and implementation of MSCs at Bournemouth, East London, Greenwich, King's College London, Lancaster, Leicester, Nottingham Trent, Royal Holloway, and the University of the Arts London (2014-2016). These nine newly established MSCs meant that an additional 175,000 students could access mathematics support by 2017/18 [S2]. Writing about their decision to establish an MSC, the Deputy Vice-Chancellor of the University of Greenwich explained that "***sigma** played a major role in the University's decision to provide this facility and in helping make the service effective*" [S3]. Further, the MSC Director at Royal Holloway wrote that "*without the **sigma** network Royal Holloway would not have been able to establish the kind of Maths, Stats and Numeracy support for students we now have*" [S3].

Wide dissemination of our research on mathematics support has extended the reach of its impact internationally. For example, the University of Agder (Norway, 12,000 students) created an MSC in 2015. Its Director wrote that "*the findings of Loughborough's research on Mathematics Learning Support were instrumental in the design of our services […] we took inspiration from the Loughborough model*" [S4]. The Head of the MSC at Masaryk University (Czech Republic, 35,000 students) wrote that their MSC "*was established in February 2016, inspired by research undertaken at Loughborough University*" [S4], and the Director of the MSC at Tomas Bata University (Czech Republic, 9,200 students) wrote that "*the establishment of our centre [in September 2016] was directly influenced by the model of mathematics support developed at Loughborough University*" [S4].

The significance of the Loughborough Model was recognised at the highest levels of government in 2019. Lord Willetts (former Universities Minister) wrote:

> "*I attach great importance to the research and development work conducted over a number of years at Loughborough University's Mathematics Education Centre. Your work was central to the development and evaluation of effective mathematics support mechanisms in higher education institutions across the country – and internationally – and this has led to a significant positive impact upon the quality of teaching and learning of mathematics at the university level*." [S5].

2. Improved the learning outcomes of over 34,000 students per year.

A 2019 survey revealed that 96 British/Irish HEIs (60% of the total, 86% of those responding) now offer mathematics support based on the Loughborough Model [S6]. MSCs at the 68 HEIs who could share usage data served 34,000 students per year across 85,000

MSC visits [S5]. International MSCs based on the Loughborough Model are also well used: for example, the MSC at Swinburne University (Australia) receives 2,000 visits per semester [S4].

By 2020, 60% of English HEIs regarded mathematics support as sufficiently central to their teaching strategies to be referenced in their institutional Teaching Excellence Framework submissions, their Offa Access Agreements, or their Office for Students Access and Participation Plans [S7].

The online resource collections developed under Croft's leadership to support physical MSCs – mathcentre.ac.uk and statstutor.ac.uk – provide pedagogical resources that are valued and trusted by students. Since 2014, they have received over 69m hits/year (1.7m unique browsers/year), and have been accessed from at least 118 UK universities, 355 other UK educational establishments (primarily schools and FE colleges), and many international institutions. The MSC director at Swinburne wrote that because they want to support student learning with "*the best resources*", they introduced mathcentre to their MSC in October 2013 [S4].

The Loughborough Model improves learning outcomes for students [S8]. For example, an evaluation in 2018 found that, after controlling for prior attainment, the odds of a student who attended an MSC once passing their module were 1.63 times higher than for those who had never engaged with the service; the odds for those who attended 15 or more times were almost 14 times higher [S9]. A survey of 1600 undergraduates at nine HEIs found that 36% of students on mathematical courses used MSCs, that 83% of these students found them "worthwhile" or "extremely worthwhile", and that 56% believed mathematics support had had a positive impact on their achievement. As one student wrote "*without the extra help I would have dropped out*"; another remarked that the MSC had given them "*more confidence which came through in the exam*" [S10].

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

S1: Institute of Mathematics and its Applications Gold Medal Citation 2016. https://ima.org.uk/3144/citation-two-ima-gold-medals-2016/
S2: HEFCE Catalyst Fund Final Report of the 'SIVS-specific funding for **sigma**' project.
S3: Letters from UK HEIs: University of Greenwich (28/1/20) and Royal Holloway (23/1/20).
S4: Letters from non-UK HEIs: University of Agder (7/11/19), Masaryk University (27/1/20), Swinburne University (30/7/17), Tomas Bata University (28/1/20) and Technical University of Ostravia (2/2/20).
S5: Letter from Lord David Willetts (26/11/19).
S6: Grove, M., Croft, T., & Lawson, D. (2020). The extent and uptake of mathematics support in higher education: Results from the 2018 survey. *Teaching Mathematics and its Applications, 39,* 86-104. https://doi.org/10.1093/teamat/hrz009
S7: Croft, T., Grove, M. & Lawson, D. (preprint). The importance of mathematics and statistics support in English universities: An analysis of institutionally-written regulatory documents.
S8: Lawson, D., Grove, M., & Croft, T. (2020). The evolution of mathematics support: A literature review. *International Journal of Mathematics Education in Science and Technology, 51,* 1224-1254. https://doi.org/10.1080/0020739X.2019.1662120
S9: Jacob, M., & Ní Fhloinn, E. (2019). A quantitative, longitudinal analysis of the impact of mathematics support in an Irish university. *Teaching Mathematics and its Applications, 38*, 216-229. https://doi.org/10.1093/teamat/hry012
S10: O'Sullivan, C., Mac an Bhaird, C., Fitzmaurice, O., & Ni Fhloinn, E. (2014). *An Irish Mathematics Learning Support Network (IMLSN) report on student evaluation of mathematics learning support: Insights from a large scale multi-institutional survey*. National Centre for Excellence in Mathematics and Science Teaching and Learning. http://doras.dcu.ie/22489/