

Institution: University of Southampton		
Unit of Assessment: 23 Education		
Title of case study: 23-01 Improving mathematics education through classroom resources and teacher professional development.		
Period when the underpinning research was undertaken: June 2009 – July 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Christian Bokhove Keith Jones Charis Voutsina Lianghuo Fan	Role(s) (e.g. job title): Associate Professor Associate Professor Lecturer Professor	Period(s) employed by submitting HEI: August 2012 – present April 1992 – November 2020 October 2004 – present November 2010 – April 2018
Period when the claimed impact occurred: August 2013 – July 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Research undertaken by the mathematics education researchers group within the Mathematics, Science and Health Education research centre (MSHE) at the University of Southampton has substantially contributed to the use of classroom resources and teacher professional development, both in the UK and internationally, with an aim to improve mathematics education worldwide. MSHE researchers have bridged research and classroom practice in three impactful ways: (i) through the creation of two popular Massive Open Online Courses (MOOCs) on Asian maths teaching methods, studied by mathematics teachers, policy makers and parents in over 140 countries; (ii) through the dissemination of digitised versions of seminal mathematics textbooks for secondary education in the School Mathematics Project 2.0 (SMP2); and (iii) by influencing policymakers and teacher training through initiatives like 'Teaching for Mastery', reaching 50% of primary schools (in excess of 8,000) in England.

2. Underpinning research

MSHE has a strong international background with a global reach, conducting research to improve mathematics education across the world. The research team works closely with teachers, students, curriculum designers and textbook developers to create international communities of interest and practice, leading to improved mathematics classrooms globally. Collectively, our work is in line with recent policy and practical teaching challenges, for example, the emphasis on the use of high-quality resources, such as textbooks, professional development, and learning from mathematics education in Asian countries, which enable better performance in international largescale assessments.

To achieve this aim, the work of MSHE can be grouped into three strands:

1. The study of underlying pedagogical and design principles for mathematics classroom resources.
2. The design and study of the use of classroom resources, with emphasis on mathematics textbooks and technology, in the context of the curriculum.
3. International comparisons on the use of mathematics classroom resources.

In line with MSHE's foci on teacher practice, the curriculum and technologies, *Dr Christian Bokhove's* research focuses on digital books, curriculum and creation of a community of interest with teachers and curriculum designers to improve students' learning experience in mathematics education. Upon his arrival, *Bokhove* collaborated with *Professor Lianghuo Fan*, examining the underpinning pedagogical and design principles for mathematics classroom resources [3.1]. *Fan*

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earlier established a conceptual framework to analyse the sources of teachers' pedagogical knowledge and applied them to investigate how teachers gained their pedagogical knowledge from different sources [3.2]. *Fan's* research also laid a foundation for both mathematics textbook research and development and is widely recognised as a world leading authority on textbook research. *Bokhove* then expanded this line of work (with support from 2012 to 2017) from the EU-funded MC-Squared project and British Academy-funded enGasia projects) towards digital mathematics textbooks. Both projects further supported the creation and use of digital mathematics books, with the enGasia project focusing on learning from Japan and Hong Kong, with regard to the secondary geometry curriculum [3.3] and the development of a framework for digital mathematics textbooks [3.4].

This framework also informed the work that digitised and disseminated quality secondary mathematics textbooks in the School Mathematics Project 2.0 (SMP2). Within one specific part of the mathematics curriculum, *Keith Jones's* research examined the way the geometry component of the curriculum is constructed and taught, and the role teachers play in its interpretation and implementation. In particular, *Jones's* research focuses on the design of the geometry curriculum, the teaching and learning of geometrical reasoning and proof, and the use of digital technologies in geometry education [3.5]. In addition, *Jones's* work with two collaborators, underpins section of the book 'Key Ideas in Teaching Mathematics: Research-Based Guidance For Ages 9-19', for example regarding spatial and geometric reasoning. [3.6]. Generating insight in underlying pedagogical and design principles for mathematics classroom resources, *Dr Charis Voutsina's* research looks at the interplay between different types of knowledge when children engage with mathematical tasks and in particular, the balance between procedural and conceptual knowledge in mathematics. *Voutsina's* research focuses on children's early and primary school mathematics learning, especially related to their conceptual development [3.7].

3. References to the research

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- 3.1 Fan, L., & Bokhove, C.** (2014). Rethinking the role of algorithms in school mathematics: a conceptual model with focus on cognitive development. *ZDM-International Journal on Mathematics Education*, 46(3), 481-492. <https://doi.org/10.1007/s11858-014-0590-2>
- 3.2 Fan, L.** (2013). Textbook research as scientific research: towards a common ground on issues and methods of research on mathematics textbook. *ZDM-International Journal on Mathematics Education*, 45(5), 765-777. <https://doi.org/10.1007/s11858-013-0530-6>
- 3.3 Bokhove, C.,** Miyazaki, M., Komatsu, K., Chino, K., Leung, A., & Mok, I. (2019). The role of 'opportunity to learn' in the geometry curriculum: a multilevel comparison of six countries. *Frontiers in Education*, 4, 63. <https://doi.org/10.3389/feduc.2019.00063>
- 3.4 Bokhove, C.,** (2017). Using technology for digital maths textbooks: More than the sum of the parts. *International Journal for Technology in Mathematics Education*, 24(3), 107-114.
- 3.5 Jones, K., & Fujita, T.** (2013). Interpretations of National Curricula: the case of geometry in textbooks from England and Japan. *ZDM-International Journal on Mathematics Education*, 45(5), 671-683. <https://doi.org/10.1007/s11858-013-0515-5>
- 3.6 Watson, A., Jones, K., & Pratt, D.** (2013). *Key Ideas in Teaching Mathematics: Research-Based Guidance For Ages 9-19*. Oxford: Oxford University Press. Available on request.
- 3.7 Voutsina, C.** (2012). Procedural and conceptual changes in young children's problem solving. *Educational Studies in Mathematics*, 79(2), 193-214. <https://doi.org/10.1007/s10649-011-9334-1>

Key grants

Guidance on teaching key ideas in secondary mathematics. Nuffield foundation, 2010-2012, £34,359, (Watson PI, Jones Co-I) – for 3.6.

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Project "M C Squared". European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no 610467, 2013-2016, £26,000 for Southampton, (Kynigos PI, Bokhove Co-I) – for 3.4.

Using technology for comparing and strengthening geometry teaching in England, Japan and Hong Kong. British Academy PM130271, 2014-2017, £29,000 (Bokhove PI) – for 3.2 and 3.4.

Towards a School Mathematics Project 2.0. ESRC impact acceleration fund, 2018-2019, £21,390, (Bokhove PI).

World Class Maths: Asian Maths Pedagogy. MacMillan Education, 2017-2020, £60,000 (Bokhove PI).

4. Details of the impact

As a result of the underpinning research, MSHE's projects generate impact at different levels on the use of classroom resources and professional development, both in the UK and internationally. Impacts can be grouped around three main themes.

1. MOOCs for 'World Class Maths' impacted on teachers' practices

Mathematics education researchers in MSHE created two Massive Open Online Courses (MOOCs), 'World Class Maths: Asian Teaching Methods' and 'World Class Maths: Asian Teaching Practice', which drew directly from their research on Asian maths teaching methods. Bokhove, Fan and Voutsina worked with the international publisher MacMillan Education and FutureLearn to design and deliver the series of MOOC courses on Asian maths pedagogy, with targeted learners of mathematics teachers, policy makers and parents from across the world. The courses have made a strong **impact on professional practice** as expressed by individual learner teachers in the course(s) [5.1]. Of the 12,000+ people, mostly teachers, from 140+ countries who started the courses, more than 90% of the survey respondents said they '*gained new knowledge or skills by taking the course*' and more than 55% 'have applied what they have learned'. Further qualitative examples of impact are '*Great course, have already begun to implement the bar model.*', '*I have learnt a lot, I changed some of my teaching practices and added new principles in them. I like the practicality of the principles and believes that they can be applied to while teaching several concepts in math. I am excited to use the others.*', '*I have already started incorporating CPA and variation theory [two Asian methods from the courses] into my maths teaching.*', '*I have learnt a lot, I changed some of my teaching practices and added new principles in them*' and '*This course helped me a lot to improve my maths teaching. Obviously, I enjoyed this course a lot*'. More quantitative and qualitative impact is available in the testimonial evidence [5.1]. Publisher Macmillan also confirm "**concrete impact on teachers and parents across the world and so also on thousands of children who are learning mathematics.**" [5.2]. In addition, Macmillan see the courses as an integral part of their Continuing Professional Development (CPD) that accompany their primary mathematics textbook [5.2].

2. Digitised and disseminated School Mathematics Project 2.0 (SMP2) textbooks were used by more than 1,240 people

The second impact theme extends MSHE's commitment to high quality classroom resources. Bokhove's textbook focus of his research has culminated in his most recent work to create a high quality and affordable mathematics textbook series for secondary school(s) in the project 'Towards a School Mathematics Project 2.0' (SMP2). The first step in this ambitious study used materials from the archive of the School Mathematics Project (SMP), which recently returned to the University of Southampton. Building on the iconic project in English mathematics education from the 1960s to the 1990s, the classroom materials have been digitised and been made available to mathematics educators through the SMP2 project from April 2019. We have subsequently researched their usage, and since being made available, more than 1,240 people, mainly from the

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UK, have accessed and consulted the different books more than 36,000 times, emphasising that the **current and potential impact of the new SMP activities on their teaching practices is significant**. Those that acquired the books, including mathematics educators, have reported that the digitised materials were used for a variety of reasons, including instruction, lesson/teaching ideas, additional exercises and home-schooling [5.3]. The aspect of home-schooling has become especially pertinent and relevant within the post-February 2020 Covid-19 context.

3. Impacting mathematics education policy stakeholders

The third impact theme concerns how MSHE brings our insights under the attention and adoption of mathematics education stakeholders such as the Government, teacher training institutions and subject organisations. *Jones'* research has had a part in **shaping curriculum reform in England, including the statutory equality analysis**, which aimed to assess the impact of new GCSE content in mathematics by reference to the protected characteristics of pupils or students. *Jones'* book 'Key Ideas' was used in the DfE's Subject content of reformed GCSEs in English and mathematics: equality analysis" (see Annex B of the document), published in November 2013 [5.4]. *Jones'* research also **informed the development of school textbooks and other teaching material**, with publisher Pearson's KS3 textbooks referred to as being "*built around a pedagogy based on leading mathematics educational research and best practice from teachers in the UK*" [5.5] with the book as 'general source'. *Jones'* book features as the main item in a list of "Pedagogy References" that Pearson publishes for their new KS3 textbooks that are "built around" what is referred to as "leading mathematics educational research" [5.5]. They are part of their 11-16 maths 5-year curriculum. *Jones'* book also appears on the reading lists for numerous UK and international PGCE courses [5.6].

MSHE members have had impact on national policy as well. *Fan* has served on the Department for Education's national Working Group (2015-2016) on Planning and Resources Review and his research and expertise **influenced policymaking on reducing workload**. This can be seen in the summary of the DfE's 2016 report "Eliminating unnecessary workload around planning and teaching resources" [5.7], where *Fan's* textbook contribution is apparent in this quote from the report: "High quality resources, including textbooks, can support teaching, reduce workload by teachers not having to 'reinvent the wheel', and ensure high expectations of the content of lessons and conceptual knowledge". *Voutsina* was invited to contribute to the consultation process for the development of the new National Primary Curriculum for mathematics in England, published in September 2013. On page 99, there is reference to a balance between procedural and conceptual changes in mathematical learning. This has been the focus of *Voutsina's* published research and the basis for her contribution to the consultation process [5.8]. *Voutsina's* research has directly informed and provided core material for the programmes that the National Centre for Excellence in the Teaching of Mathematics (NCETM) delivers, with funding from the Department for Education (DfE). Influenced by *Voutsina's* research, the Director for Primary Mathematics NCETM has developed a conceptual, **evidence-based framework that guides the work of the NCETM with teachers in schools**. The NCETM framework that has been developed on the basis of *Voutsina's* published research [3.7], depicts and emphasises the need for pedagogy that allows the integration and balance between procedural fluency and conceptual knowledge in primary mathematics. The framework has been used in the large-scale programme that the NCETM delivers for teachers and schools with the following aims: **a)** to develop primary school teachers' mathematics pedagogy and support the implementation of policy initiatives such as Teaching for Mastery and, **b)** to develop collaboration with teachers in China as part of leading the DfE's England-China Exchange programme. The initiative 'Teaching for Mastery' describes the elements of classroom pedagogy that support the development of deep and adaptable understanding of mathematics. To December 2020, it involved 8000 schools. i.e., 50% of all primary schools in

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England. *Voutsina's* research has been **integral to the development of materials used as part of this national initiative, such as the aforementioned conceptual framework [5.9]**. In addition to this, *Voutsina's* paper [3.7] is used as “required reading for teachers” engaged in the national, DfE-funded programme for professional development which is delivered by the NCETM. “Lead teachers (Mastery Specialists) report that it is very valuable to have research such as *Voutsina's* to back up the changes they are making in schools. It brings credibility to their work and motivates others to change.” [5.8, 5.9]. This focus on Mastery also is part of the work of Rosalyn Hyde, Principal Teaching Fellow in MSHE, with significant **contributions to numerous ‘Mastery’ developments**, including a AMET/NAMA joint conference in February 2019 and as lead evaluator on two national Collaborative Projects for NCETM: The China-England exchange programme and the programme for the latest cohort of secondary mastery specialists [5.10].

5. Sources to corroborate the impact

5.1 Statistics, responses and comments from more than 12,000 learners in 13 course runs of the Futurelearn MOOCs <https://www.futurelearn.com/courses/asian-maths-teaching-methods> and <https://www.futurelearn.com/courses/world-class-maths-practice>.

5.2 Impact statement MacMillan education regarding impact on (international) schools. The statement makes clear how the courses are an essential part of the CPD offering of MacMillan, and the extent of the impact.

5.3 Reports of SMP2 usage from 1,240+ interested SMP2 parties.

5.4 <https://www.gov.uk/government/publications/english-and-mathematics-gcse-content-equality-analysis>

5.5 <http://www.pearsonschoolsandfecolleges.co.uk/secondary/Mathematics/11-16/GreatMathsTeaching/CaseStudy/pedagogy-references.aspx>

5.6 Jones' book appears on the readings lists for PGCE courses across the UK (e.g. universities including Birmingham, Brighton, Brunel, Exeter, King's College London, Leicester, Plymouth, Reading, Sheffield Hallam, Southampton, Warwick, UCL, York) as well as the University of Calgary (Canada), University of New South Wales (Australia). For example: https://staff.brighton.ac.uk/school/edu/Docs/Handbooks/Secondary/Handbooks/Mathematics_PGCE_handbook.pdf

5.7 Contribution to national policy: Fan on DfE working group: the group was established to consider how effective lesson planning and use of resources can raise standards without creating unnecessary workload. The teacher workload recommendations have fed into further workload policy.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/511257/Eliminating-unnecessary-workload-around-planning-and-teaching-resources.pdf on page 5.

5.8 Contribution to national policy.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/425601/PRIMARY_national_curriculum.pdf

5.9 Impact statement from Debbie Morgan, Director for Primary Mathematics at NCETM.

5.10 Impact statement Mary Stevenson who was Associate Director for secondary at NCETM.