

<b>Institution: University of Nottingham</b>
<b>Unit of Assessment: 25</b>
<b>Title of case study: Improving the teaching of mathematics in the United States by using formative approaches</b>
<p><b>1. Summary of the impact</b></p> <p>A design research programme in mathematics education by The University of Nottingham has been taken up by two powerful US change agents - the Bill and Melinda Gates Foundation and the National Council of Supervisors of Mathematics - as a key element in their strategies to improve the quality of teaching and learning in secondary mathematics classrooms across the US.</p> <p>Beginning with small-scale design research on diagnostic teaching in mathematics, effective principles for the design of lessons were developed to enable teachers to adapt to students' learning needs. These principles were then engineered into robust products and processes through systematic, closely observed classroom trials.</p>
<p><b>2. Underpinning research</b></p> <p>Design research takes a formative approach, using educational theory and ongoing feedback from end-users to systematically design and refine innovative products and processes ('tools'). This is an iterative process, in which both the tools and the theories are refined [1]. The impact of this work is built on a sustained, coherent programme of design research in mathematics education.</p> <p>Building on earlier work at The University of Nottingham led by Professor Hugh Burkhardt (emeritus professor since 1996), Malcolm Swan has explored the advantages to learning of promoting active classrooms where students teach their peers or devise their own assessments. For example, a funded study into diagnostic teaching in Further Education (FE) (1995-1997) showed that collaborative discussion materials can be highly effective when used appropriately, even with low attaining students. The study also offered insights into the ways in which teachers' beliefs (about mathematics, teaching and learning) affect the ways in which they use teaching materials and, conversely, the ways in which the materials affect beliefs and practices [2].</p> <p>This programme of work led Swan and the team to the conclusion that in order to achieve large-scale impact, the research needed to focus more explicitly on developing replicable models for teacher learning and on-going professional development (PD). Design principles for teacher learning were developed through structured reflection on a sequence of carefully-planned teaching experiences. These principles were refined through work on the government-funded <i>Learning Mathematics through Discussion and Reflection</i> project (2000-2002). The resulting PD toolkit, which supported the diagnostic teaching of algebra, was published by the Department for Education and Science (DfES) and distributed to all FE colleges. This led to a research project on the effects of implementing collaborative approaches to learning mathematics in 40 GCSE retake classes. Swan's book <i>Collaborative Learning in Mathematics</i> [3], which summarises this project, was described as "an outstanding piece of research; it is up there with the best applied educational research in the UK, and the best international mathematical education research" by Margaret Brown (Education Sub-Panel Chair, RAE 2008). Alan Schoenfeld, ex-president of the American Educational Research Association, and Elizabeth and Edward Conner Professor of Education, University of California at Berkeley commented:</p> <p style="padding-left: 40px;">I think Swan's work is exemplary and that it should be widely known. By way of preliminaries, I note that the challenge he took on is significant: having a real impact on teacher's beliefs and practices is extremely difficult. Hence any clear signs of positive impact are notable in themselves. But in this case, the impact is just the tip of the iceberg.</p> <p>The DfES then commissioned the design of a multimedia PD resource, <i>Improving Learning in Mathematics</i> [4, 5], for teachers working across the 11-18 age range. The material was trialed in 90 colleges before being distributed to all English FE colleges and secondary schools. OfSTED described this resource – commonly known as 'the Standards Unit box' - as offering "highly successful approaches to teaching, learning and professional development" (OfSTED, 2006) and the Royal Society's Advisory Committee on Mathematics Education called it "exemplary" (ACME, 2006).</p>

This design work for professional development continued through the development of the Bowland Professional Development Modules which incorporated further influential research on formative assessment and problem solving [6]. Bowland Maths was an award finalist at the 2010 British Educational Training and Technology Show and has been used by 60% of schools in England as well as being the foundation for further collaborative work funded by the European Commission's framework programme 7.

### 3. References to the research

1. Burkhardt, H. (2006). *From design research to large-scale impact: Engineering research in education*. In J. Van den Akker, K. Gravemeijer, S. McKenney, and N. Nieveen (Eds.), *Educational design research*. London: Routledge. Available on request.
2. Swan, M. (2000). GCSE mathematics in further education: challenging beliefs and practices *Curriculum Journal* 11, 2, 199-224 (DOI: 10.1080/09585170050045209).
3. Swan, M. (2006). *Collaborative Learning in Mathematics: A Challenge to our Beliefs and Practices*. London: National Institute for Advanced and Continuing Education (NIACE) for the National Research and Development Centre for Adult Literacy and Numeracy (NRDC). (350 pages + CD Rom showing professional development resources and research instruments). Available on request.
4. Swan, M. and Wall, S. (2005). *Improving Learning in Mathematics*: Sheffield: Department for Education and Skills, Standards Unit. (Multimedia publication - DVD, teaching materials, professional development resources, approx 500 pages). Available online at: <http://www.nationalstemcentre.org.uk/elibrary/collection/282/improving-learning-in-mathematics>.
5. Swain, J. and Swan, M. (2009). Teachers' attempts to integrate research-based principles into the teaching of numeracy with post-16 learners. *Research in Post-Compulsory Education*. 14, 1, 75-92. (DOI: 10.1080/13596740902717424 - returned in REF 2).
6. Swan, M., Pead, D., Doorman, M. and Mooldijk, A. (2013). Designing and using professional development resources for inquiry-based learning. *ZDM: The International Journal on Mathematics Education*. (DOI: 10.1007/s1185801305208 - returned in REF 2).

#### Funded Projects

- Department for Education and Skills (2004-05), Development of Mathematics Teaching and Learning £108 000 (Swan PI).
- National Research and Development Centre (2005-07), Maths4Life £38 500 (Swan PI).
- Bowland Charitable Trust (2007-13) Bowland Maths (four linked projects) £492 000 (Swan PI)
- European Commission (2010-13), Promoting Inquiry in Mathematics and Science Education across Europe. £2 750 000 (Wake and Swan Co-Is; Prof Katja Maass, Freiburg- PI).

### 4. Details of the impact

Design research produced by the CRME, under the leadership of Professor Malcolm Swan (promoted in 2009) has had a substantial influence on the strategies employed by the largest charitable organisation in the world, The Bill & Melinda Gates Foundation, and on the US National Council of Supervisors of Mathematics (NCSM). The Foundation's goal is to vastly increase the number of 'college and career ready' US students graduating from high schools. The NCSM is seeking to improve the quality of mathematics teaching and learning in US secondary schools.

In the US, individual states have autonomy in education, so national improvement strategies are voluntary. Prompted by President Obama, the Gates Foundation funded the development of the Common Core State Standards in Mathematics (CCSSM or Standards). These Standards, which have now been adopted by 46 States, emphasise 'mathematical practices', i.e. the processes of doing mathematics. The Gates Foundation recognised the strategic challenge of finding a scalable implementation strategy to make these mathematical practices a reality in US classrooms. The Foundation aimed to meet this challenge by commissioning formative assessment tasks supported by teaching materials. This was the core of The Gates Foundation's improvement strategy.

In 2009, in recognition of CRME's longstanding experience and expertise in design-research, the Gates Foundation commissioned a large-scale programme to design and trial lessons called 'Classroom Challenges' (CCs) [A]. These lessons were intended to improve the teaching of

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concept development and non-routine problem solving. The principles of diagnostic teaching and formative assessment are key design features of these CC lessons. The CCs are now central to the Gates Foundation's implementation strategy; they have also been adopted by many of the Foundation's influential partners.

Vicki Phillips, Director, College Ready Education at the Gates Foundation writes:

The Foundation saw formative assessment as central to its support for the country's improvement strategy in mathematics. [CRME's] research in this field, and the excellent materials developed from it, were well known. They epitomize the 'fewer, clearer, higher standards' of the Common Core. Our strategy covers school systems across the country. The response from teachers to these Classroom Challenges has been enthusiastic, remarkably so since they take most teachers into new terrain, mathematically and pedagogically. **[B]**

The remarkable response to these materials is evidenced by an average of 76,000 downloads of CCs a month during 2012-13 **[C]**. This is in addition to downloads from other mirror sites (e.g., the Association for Supervision and Curriculum Development).

At school district level, the CCs are now being used to help teachers interpret the Standards. Valerie Mills, the President-Elect of the National Council of Supervisors of Mathematics (NCSM), explains:

In K-12 districts [the CCs] are being used as the basis of study groups and other forms of professional learning. In universities, they are being used in mathematics methods courses to help pre-service teachers become acquainted with the CCSSM. In both settings they are helping educators think more carefully about what it means and what it looks like to teach for understanding, to really 'do' mathematics, and to become proficient in the Standards for Mathematical Practice. The Classroom Challenges are vivid instantiations of the CCSS and have been powerful communication tools for us as we work with the 20,000 teachers in our direct service area and the more than 100,000 teachers across our State. **[D]**

In 2012, the NCSM recognised the power of the CC lessons to improve the teaching of mathematical practices and so decided to base its nationwide professional development strategy for the next two years on formative assessment, built around the CCs. From July 2013, NCSM began a series of three-day 'Leadership Academies' using the CCs. These Leadership Academies each serve several hundred mathematics education supervisors from districts and schools across the country. Valerie Mills explains that

the...resources and the experiences in the Summer Leadership Academy will enable participating leaders to begin to increase the use of formative assessment strategies in their districts, shifting teaching practices and improving student outcomes.

Furthermore, she describes the resources as "sturdy hinges on which to open doors to more effective instruction".

The CC materials are designed to support the original research findings that formative assessment produces more robust long-term learning of concepts and skills, and more independent students who can use their mathematics to tackle non-routine problems effectively and with confidence.

Pearson, one of the largest educational publishers in the world, is now developing the first tablet-based full curriculum for Mathematics. Becoming aware of the CCs, it has now licensed them for inclusion in this online course, and is working with CRME on their adaptation for this new technological environment.

**5. Sources to corroborate the impact**

- A. Chair, Common Core State Standards Mathematics Writing Group
- B. Director, College Ready Education, The Bill & Melinda Gates Foundation.
- C. Data from project website: <http://map.mathshell.org/materials/index.php>. Download statistics available on request.
- D. President-Elect, National Council of Supervisors of Mathematics.