Institution: University of Nottingham

Unit of Assessment: UOA23

Title of case study: Improving the mathematics skills base in post-16 education

Period when the underpinning research was undertaken: 2007 - 2020

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:
Andrew Noyes	Professor of Education	2001 - present
Geoff Wake	Professor of Mathematics Education	2011 - present
Diane Dalby	Senior Research Fellow	2014 - present

Period when the claimed impact occurred: 2011 - December 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

England's longstanding productivity challenge is partly attributable to a weak skills base. The Industrial Strategy states that improving the teaching of, and participation in, post-16 mathematics is *"one of the most significant interventions that government can make to tackle STEM skills shortages and secure wider benefits for the economy*". Noyes and Wake's unparalleled, longstanding and comprehensive research programme continues to underpin these 'interventions'. Their research has impacted participation, teacher pedagogy and sectoral change in post-16 mathematics learning across England. The research has included 1) design of qualifications and assessments (e.g., Core Maths); 2) framing of mathematical competences in new T-levels; 3) analysis of mathematics policy enactment and development priorities in FE mathematics, and 4) national trials and uptake of pedagogic interventions in colleges. The impact across these four overlapping areas has been enhanced through participation in and leadership of national advisory bodies.

2. Underpinning research

This broad programme of research in post-16 mathematics education covers academic and vocational education; stand-alone qualifications and embedded mathematics; pedagogy and assessment; systemic change and workforce development. Since 2007, QCA (G9), ESRC (G8/7), the Nuffield Foundation (G6/5/3), Gatsby Foundation (G4), the Education Endowment Fund (G2), and the DfE have funded research and development led by Noyes and/or Wake worth nearly £3.9 million. This programme builds on a much longer tradition (1967-) of funded design-research in mathematics education that has been influential throughout the world as evidenced in a previous Impact Case Study (REF2014) from the University of Nottingham's Centre for Research in Mathematics Education (CRME). The Centre's work covers *strategic*, *tactical* and *technical* research and educational design as explained by a former director of the Centre (Burkhardt, 2009).

Noyes and Wake first collaborated on the QCA-funded Evaluating Mathematics Pathways (EMP) project from 2007-10 (G9). EMP piloted new Level 1-3 mathematics qualifications to suit all 14-19 learners in England. The research strongly recommended the creation of *"new learner pathways that will widen and increase participation and engagement in mathematics"* (R5, also R4). The Pathways project also researched the early development of what is now Functional Skills mathematics; the problem-solving components of double-GCSE Mathematics (which were later included in the reformed GCSE, 2017) and a fixed-curriculum A level Mathematics (first examined in 2019). EMP (G9) brought together Noyes' interest in systemic change, cohort tracking and advanced mathematics (G8) with Wake's historical work

on Free Standing Mathematics Qualifications (FSMQs), mathematics in vocational education (R3), work transitions (R2) and mathematical modelling (R2).

Following the EMP work, Wake (G7) continued to research mathematics in transition from pre- to post-16 education. Noyes' post-EMP research (G6/3) focused on changing patterns of post-16 mathematics participation over the period 2005-13, demonstrating the relationship between the study of advanced mathematics and outcomes in a range of degree programmes, as well as in terms of later 'economic return' (R1). It also highlighted the ongoing post-16 participation gap. This work extended earlier secondary data analysis that highlighted between-school variation in GCSE value-added for mathematics, and larger between-institution variations in the chances of completing A level mathematics (G8).

With healthy growth in A level mathematics numbers in recent years, policymakers have become increasingly concerned about GCSE retakes and mathematics in vocational and technical education. Noyes and Wake's research has accordingly focused more heavily on mathematics in further education (FE) since 2015. Wake, together with Hodgen (then UoN) and Dalby (UoN) conducted an international comparison of mathematics in technical education concluding that *"there is an urgent need to describe explicitly the mathematics involved in technical occupations"* (G4, p15).

Most recently, the CRME's post-16 mathematics research programme broadened to include Wake's EEF-funded national trials on strategies for professional development for classroom improvement of GCSE resits (G2) and Noyes and Dalby's Nuffield-funded work on the systemic opportunities for, and obstacles limiting, improvement in mathematics skills development in FE (G3). Wake's work built on his earlier Nuffield-funded project on new PD models for teaching problem solving (G5).

Based on interim findings from the EEF and Nuffield research, the CRME team were sought out to be the research team at the heart of a major £40 million government investment in the FE sector: the Centres for Excellence in Mathematics programme (CfEM, G1). Noyes and Dalby's Nuffield research (R6) has impacted the direction of the CfEM programme, altering the DfE's approach to securing systemic improvement in mathematics learning post-16.

3. References to the research

R1. Adkins, M. & **Noyes**, A. (2016). Reassessing the economic value of advanced level mathematics. *British Education Research Journal*. 42(1), 93-116, https://doi.org/10.1002/berj.3219

R2. **Wake**, G. (2015). Preparing for workplace numeracy: a modelling perspective, *ZDM - The International Journal on Mathematics Education*. 47 (4), 675-689, https://doi.org/10.1007/s11858-015-0704-5

R3. **Wake**, G. (2014). Making sense of and with mathematics: the interface between academic mathematics and mathematics in practice. *Educational Studies in Mathematics*. 86 (2), 271-290, https://doi.org/10.1007/s10649-014-9540-8

R4. **Noyes**, A., **Wake**, G. & Drake, P. (2011). Widening and increasing post-16 mathematics participation: pathways, pedagogies and politics. *International Journal of Science and Mathematics Education*, 9(2), 483-501, https://doi.org/10.1007/s10763-011-9281-4

R5. **Noyes**, A., Drake, P., **Wake**, G., & Murphy, R. (2010, December). Evaluating Mathematics Pathways: Final report. University of Nottingham. Retrievable from https://www.education.gov.uk/publications/standard/publicationDetail/Page1/DFE-RR143

R6. **Noyes**, A. & Dalby, D. (2020). Mathematics in Further Education Colleges Final Report. University of Nottingham. Retrievable from https://www.nottingham.ac.uk/research/groups/crme/documents/mifec/final-report.pdf

Funded research:

G1. *Centres for Excellence in Mathematics*. DfE-funded consortium with CRME running national trials of classroom interventions. £1,375,000 2019-2023 (PI: **Noyes**, Co-Is: **Wake** and **Dalby**).

G2. *Maths-for-Life*. Education Endowment Foundation funded research and RCT into improving GCSE resit outcomes through the use of dialogic teaching; £641,115, 2017-19 (PI: **Wake**).
G3. *Mathematics in Further Education Colleges.* Nuffield funded research on mathematics education policy implementation and curriculum practice in colleges; £256,000, 2017-19 (PI: **Noyes,** Co-I: **Dalby**)
G4. *The mathematics in STEM technical education for 16-19 year olds in England: An analysis of current provision and comparison to successful systems*. Funded by the Gatsby Foundation; £21,387, 2015-17 (PI: **Wake**).
G5. *New Models of professional practice for teaching mathematical problem solving*. Nuffield funded research and development project in professional learning for mathematics teachers; £170,565, 2015-16 (PI: **Wake**).
G6. *Rethinking the Value of Advanced Mathematics Participation*. Nuffield funded research on A level mathematics uptake and economic returns; £149,500, 2013-16 (PI: **Noyes**).
G7. *Promoting participation and engagement in post-compulsory mathematics education for STEM*. ESRC grant RES-189-25-0235 Knowledge transfer project; £99,518, 2010-11 (PI: **Wake**).
G8. *Geographies of Mathematical Attainment and Participation (GMAP).* (PI: **Noyes**). ESRC grant RES-061-25-0035; £191,000, 2007-2010.
G9. *Evaluating Mathematics Pathways.* Funded by QCA; Approx, £975,000, 2007-2010 (PI: **Noyes/**Murphy**,** Co-Is: **Wake**).

4. Details of the impact

The multiple impacts of the research programme range in scale, type and distinguishability. There is not a 1-1 correspondence between output and impact but rather a many-many relationship between a multi-stranded, long-running body of research, translational and advisory work, and impacts on policy and practice.

The case foregrounds the research/researchers' impact on two key developments in Level 3 qualification pathways for post-16 learners in England: 1) Core Maths qualifications, and 2) General Mathematical Competences (GMC) embedded in the Technical-Level qualifications (T-levels). It also evidences ongoing impact on mathematics across the further education sector arising from 3) research on college-level policy enactment, and 4) the Centres for Excellence in Mathematics programme's classroom trials and professional development.

In the two cases of qualification development, Noyes and Wake play different yet complementary roles in the pathways to impact. Noyes' research leadership and advisory roles afford opportunities to synthesise research and influence ***strategic*** change (e.g., through the Royal Society). Noyes and Wake both offer ***tactical*** research impact in the form of implementation strategy and scalable findings, whilst Wake's research features more strongly in the ***technical*** design of curriculum, pedagogy and qualifications.

Core Maths

Noyes' leadership of the EMP and GMAP projects (2007-11) resulted in him being invited as the sole Professor of Education to advise the Royal Society's Advisory Committee on Mathematics Education (ACME) on post-16 reforms. Noyes' synthesis of those (and related) research projects, and membership of the working group (2011-12), led to the publication of two key Royal Society reports on the need for a new post-16 mathematics qualification (A) and the strategic considerations necessary for successful implementation (A). In response to the RS reports and following Noyes and Wake's government-funded EMP recommendations that new post-16 maths qualifications should be developed, the Department for Education (DfE) invited the Royal Society/ACME to convene an expert panel to advise them on qualification design. Wake was the only mathematics education researcher invited onto the expert panel that developed the blueprint for Core Maths (2013, B) and this enabled him to apply his research on qualification development and mathematical modelling into the new Core Maths qualifications. The tactical design principles of the qualifications were strongly influenced by Wake's research (A) and long-running experience of designing similar

qualifications (e.g., AS Use of Mathematics) which *"undoubtedly influenced government thinking leading to the current suite of Core Mathematics qualifications"* (C).

Four of the major Awarding Organisations developed six different qualifications that were introduced as 'Core Maths' in 2014. Currently, 607 post-16 institutions are delivering Core Maths. Nearly 36,000 students have been awarded Core Maths so far with 11,792 in 2020 reflecting 30% year on year growth (A).

Mathematics in Technical Level Qualifications

In 2016, the Government announced its once-in-a-generation ambition to transform technical education in England in the form of T- level qualifications for 16-18-year olds. In 2017, the Treasury-commissioned "Smith Review of Post-16 Mathematics" recommended that *"The Institute for Apprenticeships should work with the Royal Society Advisory Committee on Mathematics Education to ensure appropriate expert advice is available to the panels of professionals developing technical routes…Defining the appropriate mathematics for each of the technical routes is likely to be complex. The mathematics should be designed to reflect the requirements of the relevant occupations, wider society and the emerging economy. It needs to be coherently structured, taught and assessed"* (para. 134). By 2018, Noyes had been appointed to chair the Royal Society's committee on Post-16 Mathematics Pathways on the basis of his research portfolio in this area (e.g., R4 and 5). The first task of this group, which included Wake, was to advise the DfE along the lines suggested by Smith (A, D).

Building on Wake's research, and Wake and Dalby's Gatsby-funded analysis on the state of mathematics in technical education in England (R3, G4), Noyes and Wake led the framing of advice to the DfE (D). This included defining a set of General Mathematical Competencies (GMC) for adoption into this once-in-a-generation reform of technical education (D, E). Wake's research synthesis and justification for GMCs (D,G) - *"a quite outstanding document…of considerable national importance"* (A) - was praised and adopted by the DfE and is now embedded in this reform programme. As a result, *"all students taking T levels will be impacted by how Noyes/Wake's work has framed mathematical competences. This will, in turn, contribute to addressing England's longstanding quantitative skills deficit"* (A). In addition, the GMC development has shaped *"the design and content of CPD for technical teaching staff, both within the ETF/DfE TLPD contract and more widely"* (F). Furthermore, the DfE were so impressed by this research-informed justification for the mathematics spine of the T-levels that the groups leading on the literacy and digital strands were directed to develop parallel frameworks (E).

Noyes'/Wake's impact on qualification development has also happened in a) other jurisdictions *"Geoff and Andy's research and development has had a huge impact on the development of qualifications in Scotland"* (H); and b) other qualifications *"approximately 200,000 learners have been impacted by working towards a qualification [Level 2 certificate in Further Mathematics] with a strong emphasis on algebraic fluency and mathematical problem solving"* (C, R5/G9).

Wider impact on mathematics in Further Education

Noyes and Wake's research leadership on different projects on system change (G3) and on teaching practice (G2) for mathematics education in FE resulted in the CRME being appointed by the Education and Training Foundation to run the core research strand of the £40 million Centres for Excellence Programme (F/G1). Wake is leading this extensive national programme of professional development and trials of classroom interventions that will help to achieve the mathematics education improvement goals of the Industrial Strategy (E).

Noyes' MiFEC research (G3) *"has been highly influential in shaping DfE's activities and longer-term plans"* (E) resulting in the DfE changing their priorities for the CfEM programme to focus more on whole-college approaches to improving mathematics provision. Moreover, Noyes and Dalby were invited by the DfE to design a national programme for training cross-college managers of mathematics (and English) as these are critical to the DfE's improvement agenda (E). Post-16 mathematics education is a high priority for the DfE and Noyes and

Wake's past and ongoing research has impacted thinking and planning in this strategically important area.

Whilst the latter impacts are ongoing, they have substantial sector-wide momentum. They have had impact on sector reform processes (E) and national professional development programmes: *"based on this body of work ETF is revising at least one of its professional development programmes…to include the Noyes and Wake research base, and making methodological changes, which will ultimately lead to changes in the professional skills of the participants in this programme"* (F). Coupled with the aforementioned focused work on qualification developments, the evidence is of comprehensive impact on complex sectoral change in post-16 mathematics, particularly in further education.

5. Sources to corroborate the impact

A. Corroborative statement Royal Society.
B. Browne, R., Koenig, J., MacKay, N., Sheldon, N., Sillcot, N., & Wake, G. (2013). Report from the expert panel on core maths. London: Advisory Committee on Mathematics Education/Royal Society. *Retrievable from* *https://royalsociety.org/-/media/policy/Publications/2013/expert-panel-on-core-mathematics-report-10-2013.pdf*
C. Corroborative statement Assessment and Qualifications Alliance.
D. Corroborative statement Gatsby Foundation.
E. Corroborative statement Department for Education (DfE).
F. Corroborative statement Education and Training Foundation (ETF).
G. Mathematics for the T Level Qualifications: a rationale for General Mathematical Competences (GMCs) (2018) The Royal Society.
H. Corroborative statement Scottish Qualifications Authority.