Evidence for Excellence in Education

NFER Thinks

What the evidence tells us

Why mathematics education needs whole-system, not piecemeal, reform

As students throughout the country receive their GCSE results this week, we argue in this paper that proposals to reform mathematics GCSEs run the risk of disengaging weaker students and exacerbating failure rates.

Despite much good practice in mathematics education in England, there is a large tail of underachievement, and students at the top end of the ability range are not being sufficiently challenged.

Mathematics education is complex and the ability range is large. We need a national consensus to develop clear and flexible routes through mathematics education, so that every learner can progress and achieve their fullest potential. Looking at other countries may give some indications as to what may work well here.

NFER believes that proposals to reform mathematics GCSEs run the risk of disengaging weaker students and exacerbating failure rates. We also argue that:

- despite much good practice in mathematics education in England, there is a worryingly large tail of underachievement
- at the same time, students at the top end of the ability range are not being sufficiently challenged
- system-level change is needed – so that we have a mathematics curriculum, and routes to achievement, that are sufficiently flexible to provide for the needs, capabilities and skills of different learners
- to achieve this, we need national consensus to develop clear, well thought-out routes through mathematics education that lead to defined end points with requirements understood by employers, and by further and higher education providers
- clear links between courses are needed so that students avoid being trapped into mathematical paths at an unsuitably early age, allowing them, instead, to redefine their aspirations in a structured way as they mature.

The challenge of mathematics education

A huge amount of good work has been done on mathematics education in England, both in terms of developing relevant and engaging curricula, and changing the way that the subject is taught and assessed. An example of this is work that NFER undertook for Bowland Maths to ensure that its mathematics case studies would stimulate creative mathematical thinking in key stage 3 students.[1] Large international surveys such as TIMSS (the Trends in International Maths and Science Study), which considers performance across countries over time, suggest that there has been an small improvement in mathematics performance, especially in primary school mathematics, over the last two decades.[2]

However, mathematics education is complex. The needs of learners are very varied and their ability range at age 16 is huge (Brown, 1986).[3] Understanding at 16 is based on over 10 years of mathematics education, which should have developed appropriate foundations on which later learning can build. The current reform of GCSE proposes a more challenging qualification; but we cannot separate the need to challenge and stretch the brightest from the importance of meeting the needs of those who are struggling, or from a view of the curriculum and assessment that has gone before. At 16 we need to stretch and give free rein to the brightest to develop their fullest potential.

But we also need to nurture and guide those who are struggling to become functioning citizens in an increasingly numerate world. This is something we cannot achieve by just looking at one part of the picture – it is something we need to start dealing with by taking a system-level view.

1 As this work was targeted at the individual developers of the case studies, there was no final report.

2 At primary level there has been clear improvement over this period. At secondary level, progress has been less consistent, but our students have gone from a position where their performance was just below average (where average = 500) to above average. PISA data is harder to interpret as changes in response rates, cohort and timing of the survey could have had an impact and could show either a small increase or small decrease.

3 By the age of 16, there is a 10-year learning gap in mathematics between the highest and lowest achieving students. (Brown, 1986).

A tail of underachievement

Various measures suggest an uncomfortably high level of mathematical underachievement in England. For example, GCSE data from 2012 (Joint Council for Qualifications, 2012) shows that 281,128 (41.6 per cent of) failed to achieve a grade C in their GCSE mathematics. Similarly, data from TIMSS 2011 shows that 12 per cent of the year 9 cohort in England failed to achieve the lowest levels in mathematics (Sturman et al., 2012); while the Skills for Life survey (Department for Business, Innovation and Skills, 2012) shows that only just over one-fifth of the adult population (22 per cent) – some 7.5 million adults – are working at level 2 or above in numeracy (roughly equivalent to A*–C at GCSE).

So, evidence from three independent sources demonstrates that too many people during schooling and later life struggle with mathematics. Additionally, industry and higher education complain about how unprepared entrants are for what is required of them (Institute of Physics, 2011; CBI, 2011).

This level of underachievement is a concerning issue, given that research identifies mathematics as an increasingly important skill both for employment and for further education. The *Skills for Business, Working Futures 2004-2014 National Report* highlights a new trend toward management and professional occupations. This report states that these jobs require an increasing ability and willingness to use figures (Advisory Committee on Mathematics Education, 2011; CBI, 2010).

A viable solution?

The proposed reforms to GCSEs focus on improving standards, with the expectation that lower achievers will be ‘dragged up’ in the wake of the reform (Hansard. HC, 2013). We believe, however, that there is a risk that this strategy will further disenfranchise the weakest and lead to greater failure rates (Stipek and Gralinski, 1991; National Council of Teachers of Mathematics, 2007). Any strategy to improve mathematics achievement should involve engagement[4] at an early stage in a child’s development[5] and additionally needs to encourage more learners to study post-16 (Brown et al., 2007).

Evidence shows that increasing examinations pressure motivates only those who already do well and runs the risk of further disengaging those who do not (Madaus and Clarke, 2001). This is not a ‘liberal’ argument for paying attention to the needs of those who are failing. Nor is it a shallow, nationalistic appeal to become a top-ranking mathematics nation as an aim in itself. This is a hard-edged social and economic argument – as a nation, we cannot afford the societal costs of having 78 per cent of the population failing to reach a skills for life numeracy level 2.

But at the same time we cannot ignore the top-end of the achievement scale. We risk as much by limiting the potential of able young people by having a curriculum that is too basic, too prescribed, or too easy as we do by making it too hard for those who need support to become functionally numerate. We need a cadre of highly numerate mathematicians to propel the economy forward and to supply industry and higher education with the minds, and the skills, that they need.

4 “What matters more, in terms of motivation, is whether students see ability as fixed or incremental” (Wiliam, 2005).

5 Research shows that statistically if you have failed in mathematics by the age of 11 you will continue to fail (GB. Parliament. HoC. Public Accounts Committee, 2009).

So what is the answer?

So far we have been discussing mathematics ability as if there are just two types of mathematics learners: those who fly and those who struggle.

The reality is much more complex. Mathematics is not a single discipline, much less a single coherent cognitive construct. Mathematics covers a broad church of disciplines and that is part of the problem.

Various stakeholders[6] use the terms 'mathematics' and 'numeracy' with very different meanings. We need to be much more precise in what we mean and in what knowledge, skills, attitudes and abilities we require for learners (and acknowledge that we will require different options for different students and that employers and different higher education routes will require different combinations from them).

The idea of one size fits all is so patently wrong for mathematics that it is good that the Department for Education (DfE) has taken evidence and is moving away from a single non-tiered qualification, but we need to go much further. We all – and especially the mathematics establishment – need to move the debate on and start talking about the complexity of mathematics and the need for multiple routes and end points up to age 16 and beyond.

While we would argue strongly against 'policy borrowing', it is worth looking overseas to illustrate how undifferentiated and narrow our English mathematics provision is compared to what is done in other countries. This may in turn give us some indications as to what may work well here.

Singapore and Alberta

Singapore and Alberta (in Canada) are both high-performing jurisdictions that take different views on education. Singapore is a highly competitive and streamed system while Alberta takes a much more comprehensive view of education. Interestingly, both allow for clearly defined (and accepted) routes through to differing end points, depending on the needs and abilities of the learners within a single overarching plan for mathematics education.

The other interesting similarity is that they both allow for easy transfer between routes as learners' development and needs change. They recognise that trying to determine the trajectory of a learner leaving primary school for the rest of their lives is unfair on the learner and a huge waste of future potential ability.

The diagrams on the following page provide graphical illustrations of compulsory education routes through mathematics in Singapore, England and Alberta. These diagrams give an indication of the comparative lack of flexibility within the English system.

Conclusions

The idea of clearly defined (and accepted) routes through to differing end points is the crux of our argument. **We need to allow every learner to progress as far as they can in mathematics covering appropriate content (and not just appropriate in terms of difficulty but in intended future utility) – not only for their own sakes but for the overall benefit and improvement of society**.

But to get to this structured provision encompassing the needs of all – and we do have universal compulsory education, so we do need this – requires an agreed and common consensus. We need to stop arguing for a limited set of requirements for mathematics; but rather acknowledge that mathematics education is complex and that the ability range is large. We need to cater for all our young people and provide clear paths that meet all their needs.

NFER is not alone in arguing this. There are others who are calling for well thought out reform (Vorderman et al., 2011; Mathematics in Education and Industry, 2005; Noyes et al., 2011) and who believe that the time is right for cross-party agreement on how to tackle the problem of mathematics achievement, in order to avoid mathematics education becoming a 'political football' rather than being viewed as the 'national treasure' that it should be.

NFER believes that we need national consensus to develop clear, well thought out routes through mathematics education. There is a need for clear end points with requirements that can be understood and endorsed by employers, and by further and higher education providers.

We also believe that there need to be clear links between these courses to prevent students being trapped into mathematical paths at an unsuitably early age; instead allowing them to redefine their aspirations as they mature in a structured way.

6 Employers say that even those who pass GCSE cannot apply maths in the workplace are not functional in mathematics (CBI, 2006).

Compulsory education routes through mathematics in Singapore, England and Alberta

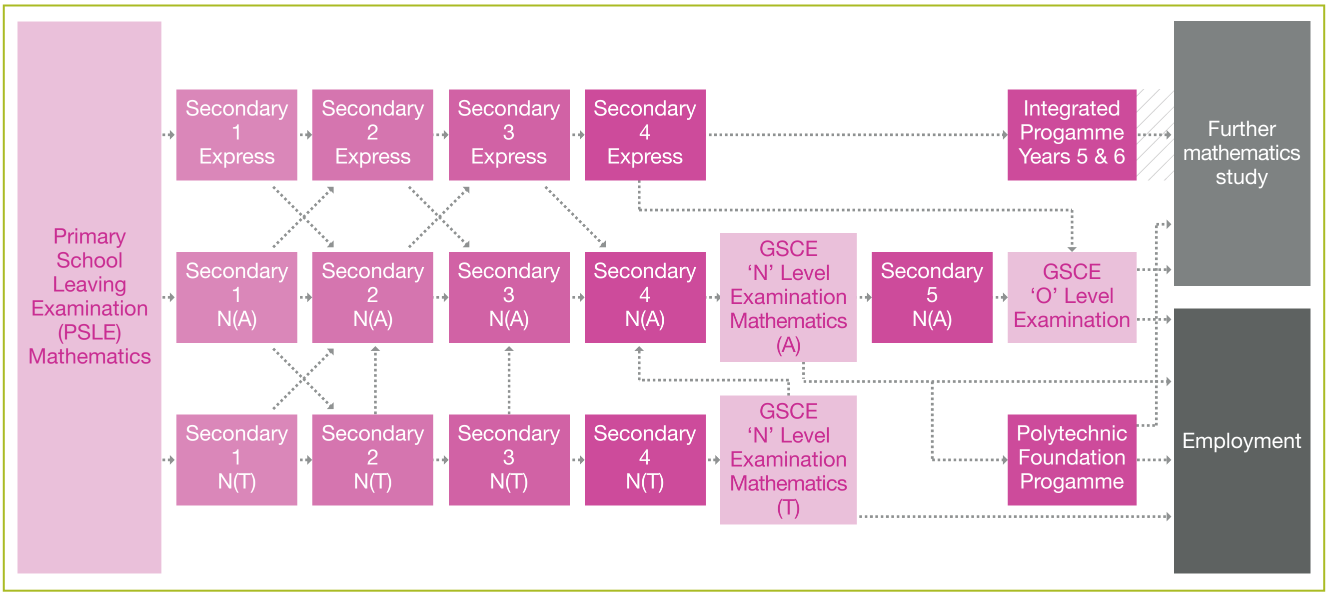


Figure 1. Mathematics educational pathways in the Singapore curriculum

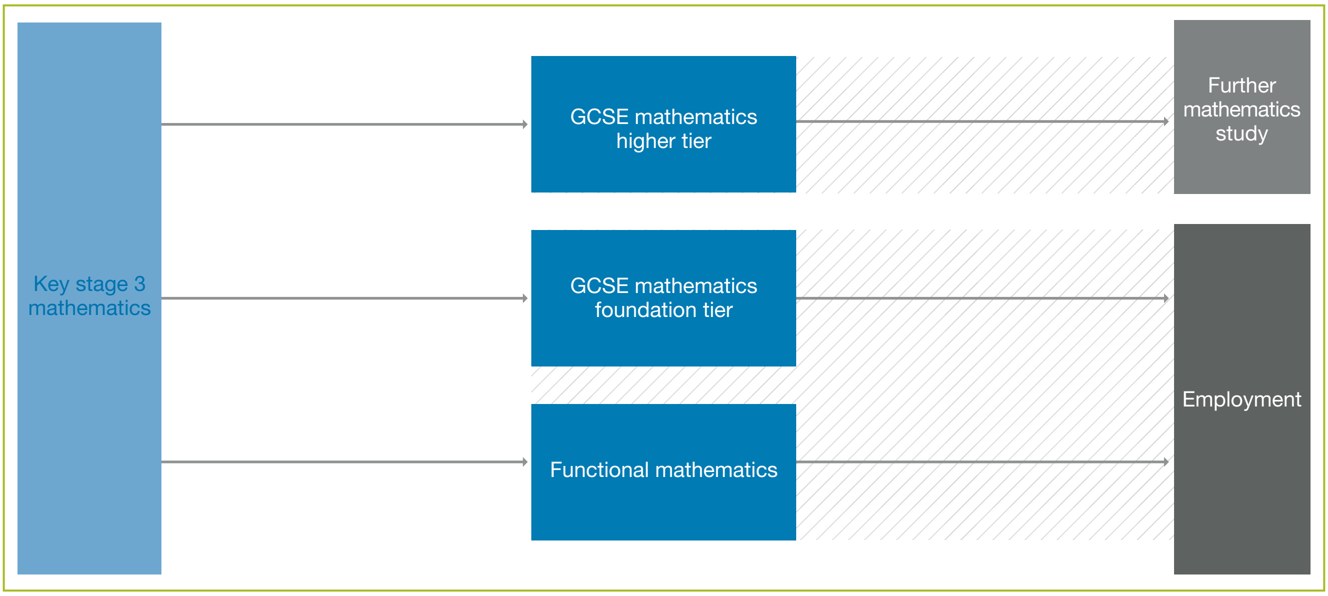


Figure 2. Mathematics educational pathways in the England curriculum

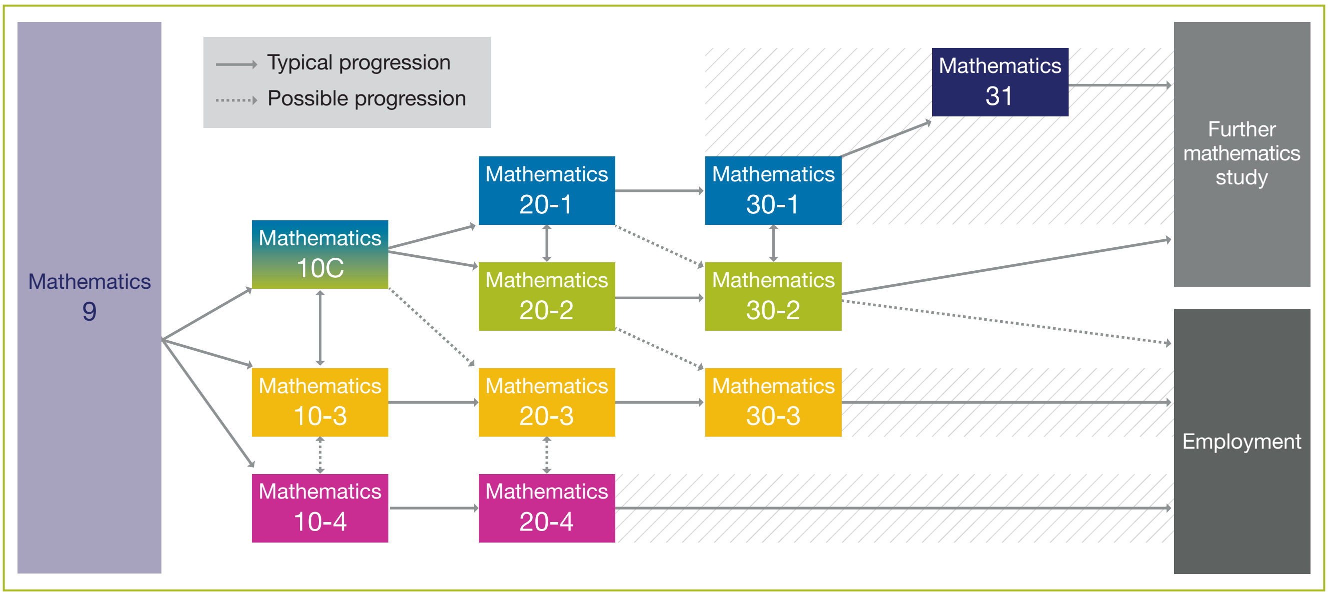


Figure 3. Mathematics educational pathways in the Alberta curriculum

References

Advisory Committee on Mathematics Education (2011). *Mathematical Needs: Mathematics in the Workplace and in Higher Education.* London: The Royal Society [online]. Available: www.acme-uk.org/media/7624/acme_theme_a_final%20(2).pdf [13 August 2013].

Alberta Education (n.d.). *A Number of Options: Progression Through Course Sequences* [online]. Available: www.education.alberta.ca/teachers/program/math/options.aspx [13 August 2013].

Brown, M. (1986). 'Developing a model to describe the progress of secondary school students: findings of the graduated assessment in mathematics project.' In: Vorderman, C., Budd, C., Dunne, R., Hart, M. and Porkess, R. (2011). *A World-Class Mathematics Education For All Our Young People* [online]. Available: www.tsm-resources.com/pdf/VordermanMathsReport.pdf [13 August 2013].

Brown, M., Brown, P. and Bibby, T. (2007). '"I would rather die": attitudes of 16-year-olds towards their future participation in mathematics', *Proceedings of the British Society for Research into Learning Mathematics,* **27**, 1, 18–23.

Confederation of British Industry (2006). *Working on the Three Rs: Employers' Priorities for Functional Skills in Maths and English.* London: CBI [online]. Available: www.saradunn-associates.net/fileadmin/saradunn/downloads/extranet/SCIE/SISCo/Background_docs/CBI-06-8-31_functionalskills0906.pdf [13 August 2013].

Confederation of British Industry (2010). *Making it All Add Up: Business Priorities for Numeracy and Maths.* London: CBI [online]. Available: www.cbi.org.uk/media/878615/7B754FFBFF7969E58025778B0053AF26__20100801-making-it-all-add-up.pdf [13 August 2013].

Confederation of British Industry (2011). *Poor Standards of English and Maths Among School Leavers Could Hinder Growth – CBI/EDI: Business Plan to Spend More on Training This Year* [online]. Available: www.cbi.org.uk/media-centre/press-releases/2011/05/poor-standards-of-english-and-maths-among-school-leavers-could-hinder-growth-cbi-edi/ [13 August 2013].

Department for Business, Innovation and Skills (2012). *The 2011 Skills for Life Survey: a Survey of Literacy, Numeracy and ICT Levels in England (Research Paper Number 81).* London: Department for Business, Innovation and Skills [online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/36000/12-p168-2011-skills-for-life-survey.pdf [13 August 2013].

Great Britain. Parliament. House of Commons. Public Accounts Committee (2009). *Mathematics Performance in Primary Schools: Getting the Best Results (HC 44).* London: TSO [online]. Available: www.publications.parliament.uk/pa/cm200809/cmselect/cmpubacc/44/44.pdf [13 August 2013].

Hansard. House of Commons (2013). 'Curriculum and exam reform', *House of Commons Daily Hansard,* **558**, 113, 7 February, 441–56 Deb.

Institute of Physics (2011). *Mind the Gap: Mathematics and the Transition from A-levels to Physics and Engineering Degrees.* London: Institute of Physics [online]. Available: https://www.iop.org/publications/iop/2011/file_51933.pdf [13 August 2013].

Joint Council for Qualifications (2012). *Provisional GCSE (Full Course) Results – June 2012 (All UK Candidates).* London: JCQ [online]. Available: www.jcq.org.uk/Download/examination-results/gcses/gcse [13 August 2013].

Madaus, G. and Clarke, M. (2001). 'The adverse impact of high stakes testing on minority students: evidence from 100 years of test data.' In: Orfield, G. and Kornhaber, M. (Eds) *Raising Standards or Raising Barriers? Inequality and High Stakes Testing in Public Education.* New York, NY: The Century Foundation.

Mathematics in Education and Industry (2005). Delivering Curriculum Pathways in Mathematics. Trowbridge: MEI [online]. Available: www.mei.org.uk/files/pdf/Pathways.pdf [13 August 2013].

National Council of Teachers of Mathematics (2007). *Five "Key Strategies" for Effective Formative Assessment.* Reston, VA: National Council of Teachers of Mathematics [online]. Available: www.nctm.org/uploadedFiles/Research_News_and_Advocacy/Research/Clips_and_Briefs/Research_brief_04_-_Five_Key%20Strategies.pdf [13 August 2013].

Noyes, A., Drake, P., Wake, G. and Murphy, R. (2011). *Evaluating Mathematics Pathways: Final Report (DfE Research Report 143).* London: DfE [online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182076/DFE-RR143.pdf [13 August 2013].

Stipek, D. and Gralinski, J. (1991). 'Gender differences in children's achievement-related beliefs and emotional responses to success and failure in mathematics', *Journal of Educational Psychology,* **83**, 3, 362–71.

Sturman, L., Burge, B., Cook, R. and Weaving, H. (2012). *TIMSS 2011: Mathematics and Science Achievement in England.* Slough: NFER [online]. Available: www.nfer.ac.uk/nfer/publications/TMEZ01/TMEZ01.pdf [13 August 2013].

Vorderman, C., Budd, C., Dunne, R., Hart, M. and Porkess, R. (2011). *A World-Class Mathematics Education For All Our Young People* [online]. Available: www.tsm-resources.com/pdf/VordermanMathsReport.pdf [13 August 2013].

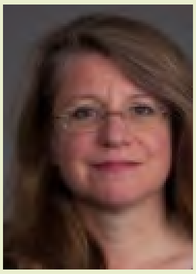
Wiliam, D. (2005). 'Keeping learning on track: formative assessment and the regulation of learning.' In: Coupland, M., Anderson, J. and Spencer, T. (Eds) *Making Mathematics Vital: Proceedings of the Twentieth Biennial Conference of the Australian Association of Mathematics Teachers.* Australia: The Australian Association of Mathematics Teachers Inc [online]. Available: www.aamt.edu.au/content/download/19063/252036/file/mm-vital.pdf [13 August 2013].

NFER

NFER is a charity with a reputation worldwide for providing independent and robust evidence for excellence in education and children's services. Our aim is to improve education and learning, and hence the lives of learners, by researching what is happening now. Our authoritative insights inform policy and practice, offering a unique perspective on today's educational challenges.

We work with an extensive network of organisations, all genuinely interested in making a difference to education and learners. Any surplus generated is reinvested in research projects to continue our work to improve the life chances of all learners from early years through to higher education.

Gillian Whitehouse



Gillian Whitehouse is an experienced research director of large-scale assessment development projects in NFER's Centre for Assessment, which sits within the research department. She specialises in assessment projects for both the primary and secondary age range, and has led a number of research and development projects including an evaluation of curriculum and assessment standards for the Sultanate of Oman and the development of science and maths standards and tests for STA and the Welsh government.

Prior to this, Gillian worked for Pearson Edexcel and then for the University of Cambridge International Examinations where she programme managed the development and implementation of the Pre U Diploma, the Cambridge Primary and Secondary One curriculum and assessment, UK accreditation of IGCSE and the development of a new 3–19 national curriculum and assessment instrument for the Egyptian government.

Her particular interests are national and international qualification and assessment systems and the development of educational standards.

Newman Burdett

Dr Newman Burdett is head of the Centre for International Comparisons. He is a scientist by background and an educational assessment expert with experience of conducting research, reviews and policy advice in both national and international contexts.

He is a fellow of the European Association for Educational Assessment. The Centre for International Comparisons manages the international comparisons conducted at NFER, including providing international benchmarking of educational initiatives for countries and organisations around the world and international surveys such as PISA, TIMSS and PIRLS.

His particular interests are national assessment policies, how to monitor educational outputs and how to compare national education systems and standards.

Published 20 August 2013

National Foundation for Educational Research
The Mere, Upton Park
Slough, Berks SL1 2DQ

T: 01753 574123
F: 01753 691632
E: enquiries@nfer.ac.uk
www.nfer.ac.uk