Rational Numbers

Investigating compulsion for mathematics study to 18

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The Pearson Think Tank

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Contents

1 Executive summary 5

2 What is the mathematics 'problem'? 8

3 The impact of the C: mathematics disengagement at 16 16

4 What evidence is there that mathematics to level 3 will benefit different individuals and the economy? 23

Recommendations 38

References 41

Foreword

I was delighted to hear that this excellent report was inspired by our article 'I would rather die. . .' (Brown, Brown and Bibby, 2008). In that paper we found that large numbers of 16-year-olds who were predicted to gain grades A*–C at GCSE were convinced that there was no point continuing their study of mathematics. A variety of reasons was given for this, but most of them could be attributed directly or indirectly to the curriculum and/or teaching methods and/or organisation of teaching groups. These are all factors that teachers feel are imposed on them by high-stakes GCSE mathematics examinations.

Yet government ministers and others have expressed the view that mathematics should be compulsory for all up to the age of 18. Here I must declare an interest, having been a member of the Advisory Committee on Mathematics Education at the point when it first started to argue strongly for this move.

Jane Harris has now very usefully in this report brought together research relevant to this issue of making mathematics compulsory to 18, and has conducted further investigations of her own to examine directly students' attitudes to this.

I strongly support the conclusion of this report that everything possible should be done to encourage greater voluntary participation in mathematics up to the age of 18. I believe additionally that the centrality of mathematics to modern life and employment, as well as to most further study and vocational training, should mean that mathematics should be compulsory for all to age 18, but would want to see this within a baccalaureate-type system in which both mathematics and English are compulsory. England should certainly no longer be an outlier in this respect (Hodgen, 2010).

In particular, if we have to change the system for 11- to 16-year-olds radically in order to persuade 16-year-olds that mathematics is interesting, important and relevant, and is something at which they can and need to succeed, then this is something we should focus on as a key national priority.

I greatly welcome this report as a clarification of the issues, needs and options related to continuing participation in mathematics to age 18, and hope it has a deserved effect on educational policy.

Margaret Brown
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May 2012

1 Executive summary

In comparison to other jurisdictions, England is viewed as having a mathematics ‘problem’ at all age groups, but specifically for those aged 16–18 years. First, we have large proportions of each cohort not reaching the minimum standard at age 16 (40% of learners in 2011 did not achieve their GCSE in mathematics at grade C and above). Secondly, of those who do get a grade C and above, few decide to pursue the subject post-16. This disengagement is caused by a range of factors, including the self-identity of learners as non-mathematicians, the views of learners towards the subject itself (boring, hard) and the fact that many colleges will only accept learners onto AS courses with a grade B or above at GCSE.

Some in the science, technology, engineering and mathematics (STEM) community have been calling for mathematics to be made compulsory for all learners aged 16–18. Reasons given for such a move have included that it would bring us into line with comparable jurisdictions, many of which do have compulsory mathematics up to 18. Furthermore, it has been posited that mathematics to 18 will benefit our economy.

The government has shown its support for increasing participation in mathematics, stating that it hopes to have ‘the vast majority of 16- to 18-year-old learners studying some form of mathematics within the next decade’. The research contained herein sought to investigate the evidence behind the calls for compulsion. Would a further two years of mathematics within the current English qualifications system really bring about dramatic improvements for individuals and the economy as suggested? Furthermore, we investigated the implications of such a move for learners and staff in further education (FE) colleges. Could compulsion be introduced within the current infrastructure, or would we need significant changes to enable full participation? In particular, would there be any negative unintended consequences and, if so, what could be done to guard against them? Finally, we considered ways that the government might think about measuring mathematics participation post-16, with a view that a broad approach must be taken.

Findings

Focus groups were run with learners in four schools and two FE colleges to gain the opinions of learners on compulsory mathematics to 18. Two online surveys were conducted with teachers in FE to ask them about the logistical considerations for introducing such a policy. Findings from the primary research were supplemented with a literature review and interviews with members of the mathematics subject community, including representatives from the subject associations and leading academics.

This paper joins a wealth of research on mathematics participation post-16. Particularly, it builds on the Brown *et al*. (2008) paper ‘I would rather die’ by asking learners their views on compulsion. Our main findings are:

- The academic research evidence base for the benefits of compulsory mathematics to 18 within our current free-choice qualification system is limited.
- The current focus on GCSE grade C is leading to this being seen as an end point, which is affecting post-16 participation.

- Because of the difficulty of mathematics at A level, there are barriers preventing large numbers of learners with grade C, and often grade B, at GCSE from accessing level 3 mathematics provision.
- Learners are very concerned about the introduction of compulsory mathematics for a range of reasons. In particular, they are concerned about the reporting of results from any courses and how these may be used, unfairly, as a differentiator during university applications.
- Learners and FE tutors believe that mathematics must be relevant if we are to increase engagement. Therefore, embedding mathematics within appropriate subject areas should be a key part of moves to increase participation.

Implications

Rising figures for AS and A level mathematics show that more learners are choosing to take the subject post-16. Arguably, the low participation problem with this age group is starting to solve itself (albeit admittedly coming from a low base). In a case study we examined a college where compulsory mathematics was the norm for learners who had not achieved a level 2 qualification. The learners we spoke to presented a worrying picture of some of the unintended negative consequences of this model in relation to engagement (with mathematics and more broadly). Staff in FE colleges raised concerns about the practicalities of introducing compulsory mathematics lessons for all learners and there has, as yet, been no indication as to when such learning might take place in an already crowded timetable. Therefore, we believe the government and policy-makers should reconsider their drive towards compulsory mathematics within the current qualifications system. Were England to move towards a baccalaureate model, we would be supportive of compulsory mathematics for all learners to 18 as part of a wider curriculum model.

We identified that some of the concerns with achievement at 16 would be best addressed by a review of the GCSE in particular, through the introduction of more detailed reporting of learner achievement. We suggest that online competency assessments are introduced during the GCSE course. These assessments would not take the place of the current formal exams; rather, they could be used as a progress report and for formative assessment. Once the final GCSE exam had been sat, learners would receive a report of their skills alongside their single grade result, enabling staff in FE colleges and/or employers to have a greater, more granular indication of achievement and of skills gaps.

We observed that many in the mathematics community are proud of the demands of their subject and that they are keen to maintain high standards at AS and A level. However, by maintaining such standards, in addition to the perception of mathematics being difficult, we believe that learners with a grade C at GCSE are discouraged (sometimes prevented) from continuing with the subject. We recommend that the AS qualification is restructured to enable learners with a C at GCSE to continue with the subject.

The STEM community is keen to show that mathematics is a component of other subjects and disciplines. Therefore, we recommend that, where there is mathematical content in other subjects, this content is given sufficient status and is assessed accordingly. If necessary, we believe it should be increased to enable smooth transition to degree-level study. Furthermore, university STEM departments should be open about the mathematical demands of their courses and should require mathematics for entry if this is necessary.

As the government seeks to reach its target of the vast majority of learners studying mathematics, we suggest it can be more open-minded when deciding how to measure participation numbers in future. Specifically, we recommend that learners studying towards qualifications with significant mathematical content should be counted towards the target.

Therefore, we make the following recommendations:

1. The government should not seek to implement compulsory mathematics learning for all post-16 learners unless it is introduced as part of a wider compulsory baccalaureate model containing a range of subjects.
2. The government should continue its move against early entry to GCSE mathematics (except in the case of learners who will start an AS programme in year 11).
3. The government and mathematics community should consider whether they believe it is more important for mathematics to remain as a 'hard' subject amongst AS and A levels, or whether it is more important that participation numbers rise significantly. We believe that the AS qualification suffers from low participation partly because mathematics is viewed and experienced as an elitist subject. We believe the AS should be redesigned and opened out to be fully accessible for learners with a C at GCSE (or the mathematics community will have to accept that the subject will remain the preserve of a 'clever core').
4. A new way of reporting mathematical progress through GCSE and AS level should be introduced. Learners should take ongoing low-stakes interim assessments throughout their GCSE course which log the competencies demonstrated. GCSE exams would be taken in the usual way, but alongside a single-grade result, learners would receive detailed information on their achievement through the course. All awarding organisations would need to follow the same process and it would need to be fully supported by, and demanded from, government. Equally, university admissions departments would need to be familiar with and request the mathematics reports that such a scheme would generate.
5. Higher education (HE) departments and employers in the STEM sector should demand more mathematics from their entrants (whether this is a full A level or results from smaller level 3 qualifications would be a decision for HE and employers). Whilst this may have an initial impact on numbers of HE applications in the first instance, our analysis shows that to increase mathematics uptake, it is vital that learners see the demand and relevance of the subject.
6. Where mathematics content features in other subject areas at levels 2 and 3, this learning should both be emphasised *within* that qualification and also be recognised *outside* of it. This type of embedded mathematics learning should count towards the government's 10-year target.
7. More should be done by the STEM sector to identify why a large number of people with STEM degrees choose not to work in the subject. Once the reasons are uncovered, we advise that moves are taken to reverse this trend. Arguably, it would be easier to retain those with a love of mathematics and STEM subjects than to convert those who, ordinarily, would have chosen a different route.

In conclusion, the mathematics 'problem' in England is a multi-faceted one with many important stakeholders, all of whom can have different views of the problem as well as different ideas about what should be done about it. We hope that this report will contribute to the debate around ways to increase the number of our young people studying mathematics beyond the age of 16.

2 What is the mathematics 'problem'?

There is no doubt that mathematics attainment at 16 (and participation post-16) is currently viewed as problematic by the government and educationalists in England. Policy-makers are concerned by England's apparent decline in the international league tables and by the economic and social implications of the large proportion of young people failing to achieve the basic expectation at GCSE, and feel that something needs to be done to address these worries. Science, technology, engineering and mathematics (STEM) advocates concur that young people are being ill-prepared for STEM careers, with the low take-up of mathematics at post-16 in England having an impact on both social inequality/equality and our economic resilience. Teaching professionals are under heavy pressure to raise the number of pupils attaining C and above at GCSE mathematics as a key school league-table indicator; yet often schools appear to find this especially challenging. A series of recent reports have addressed these issues, supporting the need for an increased emphasis on mathematics education.

But what do students feel about arguments that, for example, they should be compelled to pursue mathematics to 18? Are we really so different from other countries in our performance and achievement in mathematics? And what are the likely implications for young people and practitioners of some of the current recommendations in circulation?

This report analyses the implications of the potential introduction of compulsory mathematics for all 16- to 18-year-olds. Specifically, the report examines the research evidence underpinning claims that such a move would lead to increased mathematical skills in young people and therefore to an improvement in the economy. This report also draws on findings from focus groups with young people about their response to the prospect of compulsory mathematics post-16, as well as those of further education (FE) college practitioners who would be vital to the success of such a policy move.

The importance of mathematics in England

Mathematics, alongside English, already enjoys the highest status amongst other curriculum subjects in schools in England. Children are externally tested in mathematics during primary school via the Key Stage tests at age 10–11. All then go on to take a compulsory GCSE qualification in the subject. From the Early Years Foundation Stage through to the end of Key Stage 4 at age 16, mathematics is already compulsory. However, the government has recently stated its desire for 'the vast majority of young people to continue to study mathematics to the age of 18 over the next 10 years' (Department for Education [DfE], 2011a).

In future, those learners who do not achieve a grade C or above in their GCSE mathematics at 16 will be required to continue studying towards it until they do so, or until they finish full-time college at 18. This was one of the recommendations from the Wolf report (Wolf, 2011), which has been accepted by government.

As well as being a compulsory subject up to the age of 16, mathematics attainment comprises a key element in how schools are judged under the league-table system. Whilst schools are assessed on a range of measures, arguably the most important of these is seen as the '5 GCSEs at A*–C including English and Maths' (5ACEM). Although the government is actively seeking to provide more information about school performance for parents, with a 400% rise in data available in 2012, the reality is that, when asked in a recent study, 87% of parents still view the ACEM measure as either 'somewhat or very important' (Millar and Wood, 2011) when making school applications.

This emphasis on mathematics is further signalled by its inclusion in the English Baccalaureate (EBac), which was introduced as a new performance measure in the performance tables from 2010 (Gove, 2010). The reporting of the EBac is influencing qualification choice, with more young people now entered for GCSEs in the subjects concerned.[1] These key indicators of mathematics attainment have a strong impact on schools' reputations and on their outcomes in Ofsted inspections. As such, it is no surprise that schools tend to concentrate heavily on pupils' mathematics performance, including practices such as focusing on the C/D candidates in mathematics to raise their position in the league tables (Ofsted, 2008; DfE, 2011b), and early entry of candidates to ensure they have their mathematics GCSE 'banked'.

Hence, there can be no doubt that the government views the GCSE qualification in mathematics as a key success benchmark. However, the government is far from satisfied with current outcomes, as just over 40% of students do not achieve a grade C, which is viewed as the basic 'pass' level (Joint Council for Qualifications [JCQ], 2011). The government is also concerned by the views of employers, 65% of whom see a pressing need to raise standards of numeracy among 14- to 19-year-olds (Confederation of British Industry [CBI], 2011). The current education secretary, Michael Gove, has stated that he wants all learners to achieve GCSE mathematics (at grade C and above) as the minimum standard and will want learners to continue trying post-16 until they achieve this (DfE, 2011d). For those students who do not get a grade C or above, further study and re-sits of the qualification are very common and will increase as the recommendations from the Wolf report are realised.

Anxiety over a range of apparent crises in mathematics education across the age spectrum, including long-term low numbers of learners studying A level mathematics (Noyes, 2009), prompted the commissioning of the Vorderman report (Vorderman *et al*., 2011) by the Conservative party whilst in opposition. The report makes 38 recommendations, with those key in relation to this study being:

- All learners should continue mathematics to age 18.
- Mathematics qualifications should be exempt from general regulations.

Gove wrote the foreword for the report and he has spoken publicly of his support for it. In his speech at the Royal Society in June 2011 he specifically endorsed the extension of mathematics study to 18, asserting: 'I think we should set a new goal for the education system so that within a decade the vast majority of pupils are studying maths right through to the age of 18.'

The raising of the participation age to 18 from 2015 provides the opportunity to make mathematics compulsory up to the new leaving age – although there are wide implications for such a move which this report will examine.

The government's recent consultation on 16–19 study programmes (DfE, 2011a) built on Gove's speech at the Royal Society by including a question on how mathematics might be made more attractive to learners. The subject currently has a drop-out rate which is considerably higher than that in other curriculum subjects, with fewer students who achieve a grade C opting – or, indeed, being allowed – to continue

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[1] 23.7% of all year 11 pupils were entered for all the subject areas of the English Baccalaureate and 17.6% passed every subject area with grades A*–C in summer 2011. This compares with 22.0% who were entered and 15.6% who achieved the English Baccalaureate in 2009/10 (DfE, 2011e).

post-16. In 2010, fewer than 20% of students studied mathematics post-16 (Nuffield, 2010) although this number was higher than in 2009 and numbers continued to rise the following year. In 2011, there was an 8% increase in entrants to the A level examination, and approximately 25% more entries for AS mathematics (JCQ, 2011). The government and STEM community are looking to increase these numbers further still (Advisory Committee on Mathematics Education [ACME], 2011b). The rising AS and A level figures show an increasing interest in the subject. Therefore, we might argue that if figures continue to follow the same rising trend, participation levels may reach the vast majority over time without any further interventions or need for compulsion.

Whilst the government has not specifically stated that it wishes to make post-16 participation in mathematics compulsory, ministers frequently make comparisons with other countries where it is, and suggest that England ought to adopt the approach (Gove, 2011).

The government is looking to ensure that children are given a proper grounding in the basics of mathematics at a young age to prepare them for the demands of secondary education and beyond (Paton, 2012). The recent draft mathematics curriculum will increase demands on primary children suggesting that 5- and 6-year-olds will be expected to count up to 100, recognise basic fractions and memorise the results of simple sums by the end of the first year of compulsory education. Hence, although mathematics is being reviewed in primary schools, retains an elevated place in the English National Curriculum and is a key performance indicator, the government shares the concerns of those in the STEM community that: (a) insufficient numbers of young people are achieving the basic standard in mathematics; (b) insufficient numbers are pursuing mathematics study at post-16; and (c) these trends have negative consequences for England's economic competitiveness and civic competence (Herrmann, 2009).

Is England falling in the international rankings?

The current English government often makes use of international rankings to discuss (unfavourable) comparisons between the mathematics skills of learners in England and their contemporaries around the world. For example, the Schools White Paper 2010 (DfE, 2010) states:

> *The truth is, at the moment we are standing still while others race past. In the most recent OECD PISA survey in 2006 we fell from 4th in the world in the 2000 survey to 14th in science, 7th to 17th in literacy, and 8th to 24th in mathematics.*

The two most quoted international comparison studies are the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) tests and the Trends in International Mathematics and Science Study (TIMSS). However, the results from the two surveys present quite different accounts of England's performance.

England has apparently moved down the recent PISA rankings for mathematics, being placed 28th (out of 65) in 2009, having been 24th (out of 55) in the previous 2006 series (PISA, 2010). However, the TIMSS results show that learners' performance in the TIMSS tests has *improved* over the same period. In the Grade 4 mathematics test (year 5) only four countries outscored England: Hong Kong, Singapore, Chinese Taipei, and Japan. England improved on its level of performance in 2003, which itself was an improvement on the 1995 survey. The English year 9 learners fared equally well in TIMSS, with only Korea plus the four Pacific Rim countries mentioned above outscoring them. No European country outperformed England in any of the assessments, and nor did the United States or Australia (Sturman *et al*., 2008).

The marked differences in England's performance for the two comparison assessments beg questions as to how far the assessments accurately represent English mathematics competence, and whether, therefore, it is appropriate for the government to place as much emphasis on international comparison as is presently the case.

Recent critical analysis of the reporting of mathematics results from PISA and TIMSS tests and the meaningfulness of the apparently changing international comparisons has cast doubt on the gloomy picture presented by the English government. Jerrim (2011) argued that:

- Results from both PISA and TIMSS are subject to issues that render them problematic for studying change in average test performance in England over time.
- Statements that England is falling behind in mathematics such as those made by policy-makers in the 2010 white paper are based upon flawed interpretations of the underlying data.
- England's movement in the international achievement league tables neither supports nor refutes policy-makers' calls for change.

Enthusiasm for mathematics in England

It is clear, therefore, that international data suggesting England is falling behind at mathematics competence must be treated with caution. However, much research has shown that in other countries mathematics is more positively promoted and that there is substantially more uptake after the age of 16 (Kounine *et al.*, 2008; Hodgen *et al.*, 2010; Norris, 2012).

There is a variety of potential explanations for this, including state intervention, and these will be examined below. But one significant factor to consider when comparing mathematics trends in England with those of other countries is culture.

Reviews of international practice have shown that high attainment may be much more closely linked to cultural values than to specific mathematics teaching practices. Studies have shown that countries ranked highly on international studies – Finland, Flemish Belgium, Singapore and Korea – do not have particularly innovative teaching approaches (Hodgen *et al.*, 2010).

It seems that the UK has a culture where being less skilled in mathematics and numeracy is perceived as acceptable and not uncommon. It has become acceptable to say 'I'm no good at mathematics', whereas people would be ashamed to admit that they couldn't read (Kounine *et al.*, 2008; National Numeracy, 2012). Many adults in Anglo-American countries are not embarrassed to proclaim their ignorance or poor performance in mathematics, in contrast to other subjects (Sam, 2002). The newly launched National Numeracy charity has a remit to address attitudes to mathematics, specifically the view that it is culturally acceptable to find it difficult. In this country it is almost a badge of honour – across the social spectrum – for people to say 'I'm no good at maths' (National Numeracy, 2012). Until this social attitude towards mathematics changes, it will be very difficult to create a dramatic shift in meaningful participation rates in post-16 mathematics education, as learners do not see the need to increase their mathematical skill. Therefore any interventions to increase participation in mathematics must seek to instigate an overall cultural shift.

Whilst there have recently been increases in level 3 maths A level uptake (Porkess *et al.*, 2009; Royal Academy of Engineering, 2011) and England achieved high rankings in mathematics in TIMSS (Sturman *et al.*, 2008), other statistics raise concerns over mathematics skills and uptake. Recent figures estimate that 22% of 16- to 19-year-olds are functionally innumerate and that only 15% of learners take mathematics in formally recognised qualifications beyond GCSE (Vorderman *et al.*, 2011), although this does not take into account those learners studying for qualifications with embedded mathematical content. England also ranks amongst the lowest in the world for rates of students studying mathematics in upper secondary education (Norris, 2012).

The government often makes comparisons between mathematics participation rates in our 'free choice' post-16 curriculum and those of other countries where less choice is the norm. With specific reference to these international comparisons, the Vorderman report (Vorderman *et al*., 2011) makes a clear recommendation in support of compulsory mathematics to 18, stating: 'Merely to bring us into line with the rest of the developed world (with whom we compete economically), mathematics, in some form, must be made compulsory to the age of 18. This recommendation is a matter of urgency' (recommendation 7a, p.9).

Alternatively, we might argue that, as we are competing economically under our current system (i.e. mathematics not being compulsory post-16), there is no real need for change.

When comparing mathematics participation in other jurisdictions, what is not discussed in the Vorderman report is that where mathematics is compulsory across general education (i.e. to 18, in the majority of developed countries), it is never the *only* compulsory subject. In addition to mathematics, the first language is almost always compulsory, a second language is usually compulsory and science is often compulsory (Hodgen *et al*., 2010). The table below, taken from the Hodgen *et al*. 2010 report, *Is the UK an Outlier?*, shows which countries from the 24 sampled[2] have a policy of compulsory subjects in the 16–18 phase.

	First language is compulsory	**Mathematics is compulsory**	**Second language is compulsory**	**Science is compulsory**	**One or more other subjects is compulsory**
Australia (NSW)	✓				
Canada (BC)	✓	✓	✓	✓	✓
Czech Republic	✓	✓	✓		
Estonia	✓	✓	✓	✓	✓
Finland	✓	✓	✓	✓	✓
France		✓	✓		
Germany	✓	✓	✓	✓	
Hong Kong	✓	✓	✓		✓
Hungary	✓	✓	✓	✓	✓
Ireland					
Japan	✓	✓		✓	✓
Korea	✓	✓	✓	✓	✓
The Netherlands	✓		✓		✓
New Zealand					
Russia	✓	✓	✓	✓	✓
Singapore		✓			✓
Spain	✓		✓		✓
Sweden	✓	✓	✓	✓	✓
Taiwan	✓	✓	✓	✓	✓
USA (Massachusetts)	✓	✓	✓	✓	✓
England					
Scotland					
Wales					
Northern Ireland					

NSW, New South Wales
BC, British Columbia

[2] The Hodgen *et al*. (2010) survey included 24 countries. Sixteen of these are members of the OECD, two are OECD accession countries and three are non-OECD countries from the Pacific Rim, which were chosen by the authors because of their high performance in international surveys of attainments in mathematics, PISA and TIMSS.

This table provides information on subjects that are compulsory across upper secondary general education or across vocational education. We can see that, of the 24 countries listed, over half (15) make mathematics compulsory to 18, but just as many make a second language compulsory to this age, and even more (16) make the country's first language mandatory to 18. Most countries making (any) subjects compulsory to 18 reflect a baccalaureate-style approach, with 15 of the 24 countries making three or more subjects compulsory, and nine of these making at least five subjects mandatory to 18. A recent international comparison of senior secondary assessments has shown that other countries tend to have a greater number of options for mathematics study at this level, rather than just a single qualification (Ofqual, 2012a). This may be contributing to low participation rates in England, as learners do not wish to use a whole option on mathematics. In a baccalaureate model with more breadth of subjects, perhaps learners would be more willing to engage in mathematics?

So far, the government has not made any supporting statements for driving increased participation across any subject other than mathematics. Consequently, rather than coming into line with other OECD countries, England would be totally isolated in having only mathematics as compulsory post-16. Such a move could have widespread implications, as will be discussed throughout this report.

To conclude this section, the government should exercise caution in using international test results and/or participation rates to formulate policy, especially as an exclusive elevation of mathematics as a compulsory subject of study post-16 would represent an anomaly rather than matching other competitor nations, as is often posited. No other country has mathematics as a single compulsory subject. This being said, our analysis highlights the number of countries where the study of mathematics (among other subjects) is compulsory to 18, lending some support for the government concern at the comparative lack of post-16 take-up in the (non-mandatory) English case.

One option for introducing compulsory mathematics to 18 to put us on a more equal basis as with our competitor countries, would be for the government to introduce it as part of a baccalaureate model where a broad range of subjects were required, rather than singling out this one subject. The evidence base in support of this is more robust, but it would require a dramatic shift in government policy for this model to be introduced for all learners. There have been no signs from government that such a move is one they are considering; so for the remainder of the report we will focus on mathematics being implemented as a compulsory subject in isolation.

Study methodology

Literature review

The Centre for Use of Research in Effective Education (CUREE) was commissioned to carry out a literature review around mathematics disengagement and the economic benefits of studying mathematics beyond 16. The literature review was intended to scope out evidence and potential implications around compulsory mathematics to 18 for all learners and also to support the evidence from the focus groups. The research was systematic and expertly conceived but pragmatically limited by time and resources. An in-house search of CUREE's database of international research was carried out. This was supplemented by conducting British Education Index (BEI), Educational Resources Information Center (ERIC), Australian Education Index (AEI) and Google Scholar searches using the terms 'disengage', 'students', 'post-16' and 'maths'; 'mathematics', 'economic' and 'benefits'; 'effective strategies', 'students', 'post-16' and 'maths'. An ERIC search specifically used the terms 'maths', 'assessment' and 'post secondary education'. In addition, research resources on the Excellence gateway, the National Centre for Excellence in the Teaching of Mathematics (NCETM) and the National Research and Development Centre for Adult Literacy and Numeracy (NRDC) websites were hand-searched. These studies were initially filtered for relevance and coverage of the key issues. Only those studies with an explicit and plausible methodology were identified for data extraction. The literature review took place between January and April 2012.

Interviews with the mathematics experts

Interviews were carried out with representatives from seven mathematics organisations. In addition, we spoke to five leading academics in the mathematics education sector and three authors of other influential mathematics reports. These people were selected on account of their published material and influence in the field. Some of these interviews were in person and some were by telephone. Interviews took place between December 2011 and February 2012. An interim round-table event was held in March 2012 where a range of stakeholders, including academics, practitioners and interested parties, gathered to inform the emerging literature review.

Focus groups with learners

The qualitative findings in this report are taken from a total of eight focus groups held with students in four schools and two FE colleges. In total, 72 students (ranging from those in Year 11 who achieved GCSE grade A* in year 10, to those in year 12 who had yet to pass their GCSE at grade C or above) took part in the research. Institutions represented a geographical spread across England. The focus groups lasted approximately 30 minutes each.

Two distinct sets of focus groups were carried out with year 11 learners in each of the schools, making eight focus groups with year 11 learners in total. Four focus groups were carried out with learners who had taken their GCSE mathematics at the end of year 10, and four focus groups were carried out with learners who would be sitting their final GCSE exam in summer 2012.

Year 11 students who had yet to complete their GCSE were questioned on:

- whether they were planning on continuing with their mathematics post-16 and how they would feel if they were told they had to do mathematics to 18;
- whether they thought doing more mathematics would have any effect on their study of other subjects at college;
- what form of mathematics post-16 might benefit them, if any.

Year 11 students who had already taken their GCSE were asked, in addition, how they felt about the early-entry experience.

The focus groups in FE colleges were run to compare how learners who were already in year 12 would feel about compulsory mathematics alongside their other subjects. Two focus groups were run in each of two colleges. Two focus groups with year 12s who were taking a level 2 mathematics course (GCSE re-sit in one college, functional mathematics level 2 in the other) and two groups with learners who had got their grade C in GCSE mathematics and had chosen not to continue with mathematics post-16.

Year 12 students who had yet to achieve a level 2 mathematics qualification were asked:

- how they felt about retaking a level 2 mathematics course;
- how important success in their mathematics course was to them;
- whether they chose to take their level 2 course, or whether they were compelled to do so;
- how they would feel about continuing with mathematics up to 18.

Year 12 students who had achieved GCSE Grade C or above in mathematics were asked:

- how they chose which courses to study in college and why they chose not to study mathematics;
- how they would feel if they had to study mathematics to 18;
- how studying mathematics might affect their other subject choices.

Case-study centres were recruited through subject associations and networking opportunities with a view to covering a cross-section of the country. A recruitment agency was also engaged to recruit two schools. Senior management in participating colleges identified young people to take part. The focus groups ran in February and March 2012.

Verbatim responses are reproduced to evidence the qualitative findings. To protect participants' anonymity, pseudonyms have been used for school/college names.

Online teacher surveys

Two online surveys were carried out using the Pearson Teacher Panel, a channel whereby Pearson customers have the opportunity to share their views to help develop products and services. The first survey was of teachers in FE colleges delivering subjects other than mathematics – 110 teachers from a sample of 448 responded to the survey.

Teachers were asked the following open-ended questions:

- How would you feel if you had to deliver some form of contextualised maths within your own subject?
- How would you feel if the contact time for your course delivery was reduced to allow your learners to attend compulsory maths lessons?

The second survey was of teachers delivering mathematics in an FE setting – 38 teachers from a sample of 124 responded to the survey. Teachers were asked the following questions:

- Do you have capacity in your current department to offer maths qualifications to ALL post-16 learners at your centre? (Respondents were then asked to clarify their responses.)
- Do you think the current post-16 maths qualifications provide an adequate breadth of options to suit ALL post-16 learners (e.g. something for students who have a C at GCSE maths and don't wish to continue)?

3 The impact of the C: mathematics disengagement at 16

What is a grade C and what does it mean?

A grade C in GCSE mathematics can be achieved through a variety of marks on individual questions and examination papers. The GCSE qualification, like all general qualifications, uses the compensatory model of assessment, meaning that lower ability in some topic areas as examined in the paper are compensated by strong performance in others, leading to an overall grade mark and then a grade. Furthermore, the current tiering system means that GCSE grade C can be achieved by mastering very little content on the foundation tier paper, or by *not* mastering a range of skills that are important in mathematics (e.g. algebra) on the higher-tier entry (Vorderman *et al.*, 2011). With these marked differences in what the grade C indicates in terms of mathematical skill, it is highly questionable to assume that there is any common standard in mathematical ability amongst all those who have passed.

Even though it has such high currency, the GCSE at grade C is of limited success in terms of end-user requirements. Those entering employment with the minimum standards are perceived not to have the skills they need (CBI, 2006; Hurst, 2012) and the same criticism is made of those going on to study AS level mathematics (Vorderman *et al.*, 2011). In their recent report, Ofsted (2012) went even further to say that even those learners who get top grades at GCSE do not necessarily do well when going on to AS:

> *While unitisation of courses has led to lower failure rates at A level, too many pupils fail AS: consistently nearly 20% in AS mathematics and close to 10% in AS further mathematics. Given that the large majority of pupils embark upon AS having gained an A* or A grade at GCSE and rarely a C grade, these failure rates are a concern and raise questions about pupils' readiness for successful study of advanced-level mathematics.*

If the end users of a GCSE grade C are not satisfied with learners who have achieved it, any suggestion for post-16 reform must also consider the GCSE. The current linked pair pilot seeks to address content issues of the existing qualification (Vorderman *et al.*, 2011), but the new qualifications alone are unlikely to solve the post-16 participation 'problem', as there are a range of other interconnected factors that create disengagement at this age.

Why are so many learners disengaged with mathematics at 16?

When considering a move to compulsory mathematics for post-16 learners, we must first examine why England has such low levels of uptake at present. The concern about disengagement from mathematics extends from low-achieving 16-year-olds who lack functional numeracy (and interest in further study or work engagement in the subject) to high-achieving students with no interest in studying the subject at a higher level. This concern exists in a broader social context; a survey of 2,068 adults found that whilst 80% would feel embarrassed to tell someone they were bad at reading and writing, only 56% would feel similar embarrassment in relation to mathematics (YouGov, 2012). This cultural apathy towards mathematics is also noted by significant business people. Eric Schmidt, the executive chairman of Google, was recently quoted as saying that 'cultural prejudices are responsible for the country's low mathematical ability' (Collins, 2012). England has relatively high levels of innumeracy (Vorderman *et al*., 2011), and low rates of mathematics progression at post-16 (Vorderman *et al*., 2011; Norris, 2012). After 12 years of compulsory mathematics education, why do large numbers of each cohort not pass their GCSE at grade C and above? And for those who do, why are so many deciding not to continue with mathematics beyond level 2 (GCSE grade C)? Until we address the reasons why learners are disengaged from mathematics, even the introduction of compulsion for the subject is unlikely to lead to significant increases in mathematical outcomes for this age group. It is important to differentiate between increased attendance at compulsory mathematics lessons and increased mathematics skill levels. Increased participation may not necessarily lead to increased skill levels if learners are disengaged.

In some cases, learners decide not to do any mathematics post 16 as they simply find the subject dull (Ofsted, 2008) or tedious (Nardi & Steward, 2003) or a range of other negative descriptors (Brown *et al*., 2008). Many students, particularly those in secondary schools, describe lessons as focusing on the acquisition of skills, carrying out routine exercises and preparing for tests. Mathematics classes are also less likely than other subjects to involve the use of audio-visual resources, practical activities or group work (CUREE, 2008). Smith (2010) found that students in a class which did not allow open discussion gave this as a reason for wanting to drop out of further mathematics. In this context, it is perhaps not surprising that learners are pleased to leave the 'dull and tedious' subject behind. Evidence also shows that the prevalent practice of setting (by ability) shapes learners' mathematical experiences and attitudes. Those placed in the top set were happy with their grouping, but those placed in lower sets felt that their attainment and expectations had been constrained (Boaler, 2005). Therefore, those learners placed in lower sets are likely to be disengaged from mathematics and not want to continue post-16.

Kyriacou & Goulding (2006) found that the most important factor for mathematics engagement at Key Stage 4 was the extent to which students saw themselves as mathematicians. This indicates that students who do not identify themselves as mathematicians at 16 are unlikely to choose to continue with the subject post-16. Whilst this report concentrates on post-16 mathematics engagement, research into mathematical identities (Bibby *et al*., 2007) has shown that these are formed in primary school (see also Archer, 2012). Such findings suggest that any initiatives to widen participation post-16 may only bring limited positive effects, unless they are supported by parallel initiatives in primary schools facilitating positive mathematical identities to be formed and maintained.

Mathematical self-identity is important for both boys and girls; however, girls are more likely to view mathematical ability as an innate quality (often one they do not possess), and are less likely to see themselves as mathematicians (Nardi & Steward, 2003; Mendick *et al*., 2008). Furthermore, mathematics (and the physical sciences) is associated with cleverness which is linked to constructions of masculinity, so a long-term STEM identity may be 'more challenging for girls than it is for boys' (Ong, 2005; Carlone & Johnson, 2007; Archer, 2012). Learners also view those who are good at mathematics as 'boffins' with potential risk of stigmatisation and bullying (Francis, 2009), although some learners may identify with such a label (Mendick & Francis, 2012). Archer (2012) suggests that gender differences are further exacerbated in the case of working-class girls due to middle-class associations with achievement/the mind and working-class associations with the body/underachievement. She argues that working-class girls are then excluded not only from the identity of the ideal student, but also, in particular, from STEM aspirations.

Girls' confidence in their mathematics capabilities falls between the ages of 12 and 14 years (Brown *et al.*, 2010), but they do not always see any underachievement as their fault (Boaler, 2011). Instead, the girls in Boaler's study blamed the curriculum, and the way it is taught, for denying them access to understanding. Researchers have also found teacher perceptions can have an impact on girls' engagement, often seeing girls as 'not brilliant' or learning 'in the wrong way' (Walkerdine, 1998; Boaler, 2011). These various factors have an impact on girls' post-16 take-up rates, with those who achieve a grade B at GCSE being particularly under-represented at A level compared with their male counterparts. Nearly twice as many boys achieving a grade B at GCSE do some form of advanced mathematics post-16 (Noyes, 2009). A simple way to raise the number of students following level 3 mathematics programmes might be for a female-focused recruitment drive targeting girls predicted to get a grade B at GCSE mathematics. Any such recruitment drive for AS and A level mathematics would need to take account of the various factors specific to girls' disengagement. For example, different learning resources, teaching plans and delivery methods might all be needed to encourage more girls to participate.

Aside from these factors, there are other practices in schools that may be having an impact upon post-16 participation. One such practice is entering learners early for GCSE, typically at the end of year 10. What impact is this having on learner engagement?

'I would have got the grade I wanted first time round': Effects of GCSE early entry on post-16 engagement

Over recent years, the number of early entries for GCSE mathematics has risen dramatically. Figures from JCQ analysis, quoted in the Vorderman report (Vorderman *et al.*, 2011) show the number of learners aged 15 entered for GCSE between 2008 and 2010:

Year[3]	Number of candidates	% of entry
2008	32,908	4.46
2009	60,712	8.04
2010	83,179	10.9

Arguably, it is possible that this dramatic rise in early entries is having an effect on participation post-16. The increase in early entries across all ability groups has been explained by the influence of school performance tables, as schools try to maximise the chances of learners achieving the coveted GCSE grade C by enabling them to have more than one examination attempt (ACME, 2011a). ACME is clear in its view that this impact of league tables is negative: 'We believe that a target-driven culture based on league tables has skewed behaviour in schools and that action must be taken to correct this.'

Likewise, Tim Oates and the Expert Panel have criticised early entry and acceleration in their review of the National Curriculum (DfE, 2011c). Although schools and learners may believe that early entry, and consequent opportunities for re-sits, will improve overall grades, research from DfE has shown that learners who take their GCSE early perform statistically worse than those who enter in the usual timeframe, i.e. at the end of year 11 (DfE, 2011b). These findings were the same at all grades of the GCSE. With evidence that early entry does not improve grades, we investigated the impact the practice was having on learners.

[3] It has not been possible to obtain the number of learners entered early for GCSE in 2011 as these figures are apparently not held by DfE or Ofsted as a matter of course. We believe these figures should be collected and that they should be available.

The focus groups with year 11 learners showed mixed views as to whether it was a good thing to have taken GCSE mathematics early. Positive comments fell into three broad categories:

- benefits of a 'progress report';
- 'banking' results if a 'C' is achieved;
- benefits to self-esteem for high achievers.

Some learners viewed their early entry more as a progress report than their final attempt at the exam and they referred to the benefits of having the chance to re-sit:

> 'It allowed us to get more experience, especially if we wanted to retake it. So that was helpful.'
>
> *(Female, School B)*

> 'They did give some people the chance in the lower sets to improve their grades as the re-sits would still be earlier than the original.'
>
> *(Male, School A)*

A further positive of the practice was discussed by some learners who had achieved grade A. They spoke of the benefits to their self-esteem in knowing that they have achieved:

> 'You kind of feel better about yourself when you feel you can pass the exam earlier than the original timing. And you feel proud.'
>
> *(Male, School A)*

> 'It was a privilege to have the opportunity.'
>
> *(Male, School B)*

There were also a range of negative comments about early entry. The negative comments referred to a range of topics, including the potential negative effects of multiple re-sits as well as those questioning why early entry occurred at all:

> 'At first I didn't want to take it early, because nowadays they look at how many times you take the maths exam and they look at the number of re-sits, so I was really worried that would affect me.'
>
> *(Female, School B)*

> 'I think that in year 10 a lot of people are unprepared as well, like, I know for a fact the exam that I took in year 10, if I took it in year 11 I would have got the grade I wanted the first time around and not the second. You are unprepared in year 10 and you don't know the knowledge, because it is a 2-year course after all. You wouldn't expect to do your history GCSE in a year because it's a 2-year course so I don't understand why they make you do maths.'
>
> *(Female, School B)*

Lower-attaining schools are more likely to have early entrants (DfE, 2011b), and are more likely to have a large proportion of their pupils entering early (in 2010 almost half of the below-floor schools had at least 50% of pupils entering mathematics early against a figure of 20% of all schools).

Early entries must be reduced as the practice has a range of negative effects. First, learners overall gain lower grades (DfE, 2011b) meaning fewer have the mathematics skills and competencies to continue with the subject post-16. Secondly, some learners who pass their GCSE at grade C or above 'bank' this result and do no further mathematics in the rest of year 11. Aside from those learners who achieve an A* in year 10, any learner who sits their GCSE early should have the opportunity to re-sit and improve their grade in year 11. Those who 'bank' less than an A* are losing out on two counts. First, they do not have the chance to reach their full potential after 2 (or 3) years studying for their GCSE. Secondly, 'banking' results early creates a period of mathematics disengagement during year 11 that may contribute to learners choosing not to continue with mathematics AS in year 12, even if they do achieve high grades. For those who were not planning to continue with mathematics anyway, the 'two-year gap' (identified by ACME [2011b] as a problem for learners who then need to access some mathematics in other subjects at degree level) is increased by several months, arguably making a bad situation worse. The positive aspects to early entry as described by the learners could easily be replicated without resorting to early entry of exams. Formative assessment throughout the course could provide the progress report, and exam paper practice is also easily replicated within the classroom environment. Therefore, there is no good mathematical reason for this practice to continue and it should be discouraged.

Although the Secretary of State has written recently to the chief inspector of Ofsted to see how early entry can be discouraged (Gove, 2012a), we suggest that unless measures are taken, the current incentives to enter learners early will ensure that the practice continues. Therefore, it is important that schools are made aware of the research from DfE in order that the number of learners being entered early is reduced.

We need to challenge current understandings – reflected in the early-entry practices of some schools – of the GCSE C grade as an 'end point'. As we have seen from the quotes from the focus groups, such understandings are perpetuated by the strong focus on this benchmark indicator. It is vital that learners start to view the early entry as a marker rather than an end point. A second recommendation is that, apart from learners who achieve a grade A* in their early entry, all should have the opportunity to re-sit their exam in order that they may improve their grade at the end of year 11.

Ofsted (2008) suggested that the extent of the focus on the GCSE C/D grade boundary has led to a range of problems with mathematics achievement, a view supported by Vorderman *et al*. (2011). Michael Gove has also said that he wants to prevent the focus on C/D candidates (DfE, 2011d). Learners realise and accept the importance of the grade C and are prepared to work hard to achieve it, sometimes having a maths tutor to help:

> 'Maths and English are very important. Everyone has already said that to us. They have drilled it into us that it's important.'
>
> *(Female, School D)*

> 'Maths is my weakest subject and I also got a maths tutor as well, so I really am hoping that if I get my GCSE, I won't have to do any maths at all. Never again.'
>
> *(Female, School B)*

ACME (2011a) has also reported a worrying trend that borderline C/D students, in particular, are being entered for their GCSE with many different examination boards over the course of a year in order to increase their chances of obtaining a C grade with one of them. This style of cramming and 'teaching to the test' does very little to benefit the learners once they have achieved the coveted C. Many C-grade learners find themselves in difficulty when it comes to applying their mathematics knowledge in further education or in work, as their grade C comprises limited understanding. Focusing on the C/D boundary at the expense of learners either side of this marker is not helping any of our learners. Those in the top ability range need equal support so they can reach their full potential and become our STEM specialists of the future. Those at the lower end of the scale need support so they can achieve their level 2 qualifications in order to function in society. The focus on the C/D learners at the expense of the others, especially considering our concerns over what a C actually means, is an unintended consequence of school accountability measures and minimum standards. Reducing the significance of the C so that it becomes one point along a continuum is a position towards which we must move if we wish to alter current practices.

Further compounding the problem with post-16 mathematics participation rates, our research showed a perception among some of the learners that once you have your C grade GCSE in mathematics (or above) you know 'the basics', which constitutes enough knowledge to function adequately. It is likely that this opinion has been formed partly through learners not identifying themselves as mathematicians (Nardi & Steward, 2003; Kyriacou & Goulding, 2006) but also because learners view the GCSE grade C as the finish line (ACME, 2011a) rather than as a stepping stone for progression to further mathematics study:

> 'When you've done GCSE maths, you know the basics that you need to carry on with life.'
>
> *(Female, School B)*

> 'I think you get enough knowledge at GCSE to carry you through.'
>
> *(Male, School D)*

Such a focus on this point leads some learners to see the C grade as their only aim rather than as one point along a continuum:

> 'I've got my C and that's what you need to get a job.'
>
> *(Male, School A)*

> 'The thing is, for the job that I want, I only needed to get a C and that's it. I only need to know basic maths; I don't need to know anything that's la-de-dah.'
>
> *(Female, College B)*

Conversation between a male and female from College B:

> *Male:* 'If you've got a good enough grade in maths, like a C grade, you shouldn't have to continue to do it.'
>
> *Female:* 'You don't have to.'
>
> *Male:* 'Ain't you listening? Even if you've got the grade, you still have to do it until you're 18. So what I am saying is that if you've got a C grade or something like that before you are 18, then why should you carry on doing it?'

Indeed, it seemed that at least one learner was almost oblivious to there being anything else in mathematics beyond GCSE:

> *Researcher:* 'Why did you decide not to continue with maths?'
>
> *Female (College A):* 'Because I already passed it.'

It is crucial, therefore, for schools, colleges and policy-makers to ensure that the importance of the grade C at GCSE mathematics is seen in the wider context of further mathematics learning in general. Learners need to be aware that, although the GCSE grade C is important, there is more mathematics learning they could and – depending on their choice of subjects in FE – should be pursuing. Schools can only do this in collaboration with HE and employers, who ought to be much clearer about the mathematical demands of their courses and roles.

4 What evidence is there that mathematics to level 3 will benefit different individuals and the economy?

In their calls to address the mathematics 'problem' by increasing participation post-16, the government and sections of the mathematics community talk of the economic benefits such a move would bring to individuals and to society. Here we investigate the research evidence to confirm or refute the claims.

Learners working below level 2

Many studies have highlighted the links between a basic level of numeracy and improved life chances (McIntosh & Vignoles, 2001; Parsons & Bynner, 2005; Grinyer, 2006; Machin *et al*., 2001; Vignoles *et al*., 2011). Parsons & Bynner (2005) found that numeracy skills were more important for women than for men, irrespective of their standard of literacy. Women with poor numeracy were less likely to be in a full-time job at the age of 30, less likely to have an interest in politics and more likely to feel that they lacked control over their lives. If they were in work, they were more likely to be in an unskilled or semi-skilled job. Poor numeracy rather than literacy was found to be a predictor of women being part of a non-working household. This report is fully supportive of all learners achieving a basic level of numeracy and mathematical competence in order that they might function well as individuals in society and maximise their life chances. This basic level is widely assumed to be a level 2 qualification – usually a C grade in GCSE mathematics or above.

Learners wishing to progress in the STEM sector

At the opposite end of the scale, people with mathematics degrees have greater than average earning potentials across their lifetime when compared with graduates from other disciplines (Walker and Zhu, 2003; Universities UK, 2007; Johnstone *et al*., 2010). Any learner who is planning on taking a mathematics degree will already take A level mathematics, most likely with further mathematics alongside. These learners are not considered as part of the following discussion as they are not part of the 'problem'. However, learners who need to use mathematics in other disciplines have been identified as a significant part of the problem.

Research has shown that there are large numbers of learners studying for STEM and other degrees who struggle with the mathematical content (Mulhern & Wylie, 2005; ACME, 2011b; Institute of Physics, 2011; Koenig, 2011). It is vital that learners who wish to progress in the STEM sector have appropriate advice and guidance so that they follow study programmes that enable them to reach the mathematical competence required. University departments also have their part to play in solving the problem. Sometimes, departments have chosen to shy away from making excessive mathematical demands of their applicants through fear of applicants being frightened off. Koenig (2011) reported that the majority of biosciences degree programmes she looked at only required GCSE mathematics (92%). Furthermore, she also reported that the largest group of learners with only GCSE had the qualification at B or C grade.

The fact that universities do not demand higher entry requirements in mathematics only exacerbates the problem. Learners then struggle with the mathematical content when studying for their degrees, as they are unprepared. Our evidence has shown that learners engage in mathematics when they see it as relevant. Universities and employers need to be more open and demanding in order that STEM and mathematics-related learners have a clear idea of how relevant and important further mathematics study will be for them. Such a move would ultimately increase post-16 participation for all those looking to progress in STEM areas.

Furthermore, if mathematics is seen as a more mainstream subject choice at AS, dissipating perceptions that only 'geeky males' participate (Boaler, 1997, 2002; Archer, 2012) it is possible that even more learners may start to engage. Alternatively, a baccalaureate model to 18 where mathematics is one subject amongst a range of compulsory subjects would benefit progression in STEM subjects, as all learners would study mathematics to a higher level but this would be as part of a wider compulsory core. A model like this would hopefully avoid disengagement from mathematics, as learners would not see the subject as the only one they are 'forced' to take against their will.

The importance of linking mathematical learning with the learning that takes place on vocational courses is emphasised in several studies (Stone *et al*., 2005; Casey *et al*., 2006; Hoachlander, 2008; Koenig, 2011) and there is some evidence that linking learning with real-world contexts plays an important positive role in the performance and attitudes of those on A level courses (Little & Jones, 2010).

A recent Department for Business, Innovation and Skills (BIS) research paper (BIS, 2011) showed that not all those with STEM qualifications at degree level choose to work in the sector. As well as ensuring that those who enter the sector are fully prepared mathematically by increasing the uptake of mathematics qualifications, the sector itself should, arguably, do more to attract and retain graduates once they are qualified. Investigations to understand why STEM graduates do not continue to work in the area have already begun (National Assembly for Wales, 2011; Academy of Medical Sciences, 2011; National STEM Centre, 2012). Ensuring those who have STEM skills are using them in their employment is arguably a more effective way of increasing the country's economic benefits than focusing exclusively on potential supply from level 3. Any encouragement or interventions designed to increase the number of learners taking mathematics at level 3 who will then pursue a degree in the STEM sector must be supported with appropriate advice and encouragement to ensure that larger numbers find work in the STEM sector and, importantly, remain working in STEM careers.

Learners who currently stop mathematics at GCSE grade C

Science, technology, engineering and mathematics community commentators have been especially concerned at the drop-out rate of those students who have achieved a grade A*–C at GCSE, but who have chosen not to continue with the subject post-16 (ACME, 2010; Vorderman *et al*., 2011). Some of the reasons why these learners choose not to continue with mathematics have been identified in the previous section, but now we examine the evidence behind the government's and STEM community's calls for compulsory mathematics for those learners who have cleared the level 2 hurdle but who have chosen to stop studying mathematics. Specifically, what evidence is there to show that mathematics at level 3 will benefit these individuals and the economy, if they do not intend to pursue mathematics in HE?

In her 2002 book, *Does Education Matter?*, Alison Wolf quoted a 1999 study by Dolton and Vignoles which compared the wages associated with those who had studied maths at A level (in the mid- to late 1970s) with those who had studied other subjects. The study took into account participants' work history, level of education, personal circumstances (including social class) and region of work. The study used reading and maths results for tests taken when respondents were 7, 11 and 16 to control for the ability[4] of the students. They found that males with mathematics A level earned 10% more than similarly educated men who did not have it. They did not find similar benefits associated with science or language A levels. This finding has been quoted in the academic literature (Creeser, 2006; Foreman-Peck, 2007; Andrews *et al*., 2006; Kounine *et al*., 2008) but it has also entered the folklore, with colleges routinely using it to promote their A level mathematics courses.[5] The sentiment that advanced mathematics qualifications increase earnings was also expressed by Michael Gove, who wrote in his foreword to the Vorderman report: 'Mastery of mathematics is key to success in the modern economy. The better educated a country and its citizens; the more likely they are to prosper. Few qualifications confer an economic advantage like mathematics qualifications.'

Whilst the findings of the 1999 study are not in dispute, it is not necessarily the case that the wage returns of a group who took their A levels over 30 years ago can be compared with the expected wage returns for learners taking A levels in 2012 and beyond. Kounine *et al*. (2008) have shown that comparisons between O level mathematics curricula in the 1970s and GCSE curricula in the 2000s demonstrate that during this time-frame, the content of the courses has become broader but shallower as a result of curriculum and assessment reforms. It may be that similar changes have occurred with A level, given reforms over the same period. Therefore, learners who take A level mathematics now are having a different experience from those who did so in the mid-1970s.[6] Consequently, wage-return benefits of A level mathematics may have altered given that the knowledge and skills of students passing the exam in 2012 will differ from those in the original study. We suggest that the evidence base should be refreshed by a similar analysis applied to more recent A level mathematics returns to see if similar results are found.

In terms of other studies showing the effects of mathematics to level 3 on increased wages, there was very little in the research literature. Greenwood *et al*. (2011) investigated the additional wage premium or penalty associated with having gained a vocational STEM qualification. They used data from the UK Labour Force Survey from 2004 to 2010 (163,218 people). This study controlled for age, gender, region and highest qualification but not for an individual's academic ability. They found that several level 3 qualifications in mathematics were associated with a lower hourly wage. The study did not, however, include A level qualifications, which is the route generally taken by learners wishing to pursue degrees and careers in the STEM sector. The study does suggest that the type of mathematics qualification studied is important for wage returns, with A levels appearing to be more lucrative.

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4 The authors noted that these tests could not measure purely innate ability.

5 See, for example, numerous prospectuses, e.g. http:www.abbeylondon.co.uk/abbey-london-blog/2012/why-should-you-study-a-level-maths.aspx, http://www.nelson.ac.uk/index.php/sixth-form/a-levels/maths and http://www.openstudycollege.com/courses/a-level-maths.html

6 I am not making reference to standards at this point, but rather stating that we are not comparing sets of students with the same knowledge base.

Vorderman *et al*. (2011) stated:

> *Unless major alterations in our mathematics education are made, and quickly, we are risking our future economic prosperity. The effect of mathematics is understood in many leading industrialised nations including those of the Pacific Rim whose students perform particularly well in international comparisons.*

However, the link between high scores in PISA mathematics and economic prosperity may not be as clear-cut as this Vorderman quote suggests. Using data from the PISA and TIMSS, Chen & Luoh (2009) investigated the link between test scores (mathematics and science) and cross-country income differences. The analysis suggested that after controlling other variables that are typical in the study of cross-country economic growth, the strong link between test scores and cross-country income differences disappears.

We have been unable to find any specific academic research in the literature that shows that an increase in the number of people whose highest mathematics qualification is at level 3 will benefit the country's economy – suggesting a somewhat scant evidence base on which to precipitate compulsion to 18 for all learners.

Reports have mapped the changing nature of the UK workforce over the last 50 years and, following recent trends, it is predicted that the need for STEM capabilities and aptitudes in a country's workforce will increase over the coming years (HM Treasury, 2007; Department for Innovation Universities and Skills [DIUS], 2009). If these predictions are accurate, it means we need more people with STEM capabilities at level 3 and beyond. It does not mean that we need everybody to study mathematics to level 3. Even if compulsion were introduced, it would not lead to all learners wanting to work in STEM; many would still choose other sectors.

Therefore, as well as looking for ways to encourage those who do not currently to engage with post-16 mathematics, ensuring those who are already choosing STEM get the right amount and type of mathematics to prepare them for their STEM degree is also important, which is arguably more important than moving towards blanket compulsion as these are the learners who will go on to be our next scientists and engineers. Encouraging more learners to study mathematics post-16 will ensure opportunities for further study in the STEM sector remain open (Teach First, 2011). However, we believe that encouragement is the best lever here. Encouragement, not compulsion, is more likely to achieve greater engagement as the following quotes would suggest:

> 'If I am told to do something, I don't do it. In fact I do the exact opposite. I think that is the way with everyone else as well. I am not like stupid or anything and I don't think that anyone else is, but I think they are made to feel that way if they don't do as they are told.'
>
> *(Female, School B)*

> 'With your own choices, you can open up your own doors into what you want to do when you are older, but if someone chooses your choices, then they close some of those doors, so it's kind of hard to get into a job that you want to do.'
>
> *(Female, School B)*

Compulsory mathematics, even if introduced with the best of intentions, could have negative unintended consequences, as our research has shown.

Choices, choices – effects of compulsion on learners

When looking at choice of subjects for A level study, we must remember that learners are not choosing to take mathematics in a vacuum. The choice they make is not between studying mathematics or not. Rather, it is choosing whether they wish to study mathematics as one of their preferred options against other qualification and subject options. Mathematics is competing against other subjects to be chosen. A study that analysed key data about participation and attainment in science and mathematics in the UK found that attitudes to mathematics were less positive at the end of the compulsory years of secondary schooling than earlier (Royal Society, 2008), exactly at the time when students are selecting which subjects to pursue. Understandably, students want to choose subjects they are good at as well as those that will be useful to them in their chosen careers (Matthews & Pepper, 2007). For those who struggle with mathematics or don't enjoy it, but who do well in other subjects, dropping maths appears a logical choice (Rodeiro, 2007). We know that B- and C-grade GCSE learners who progress to A level do less well in mathematics than in other subjects. In 2009, of the learners with a grade B in GCSE mathematics who took the traditional A level, 20% got a grade E and 8% failed. The comparable figures for English are 3.5% and 0%, respectively, and for history 8% and 1% (Nuffield, 2012b). In such a competitive HE and employment market, why would learners opt to disadvantage themselves by choosing a subject where their grade might be low?

In collecting evidence for this report, we ran focus groups with eight sets of year 11 learners at four different schools. We also ran four focus groups with year 12 learners in two FE colleges. Year 11 learners in the focus groups were vocal about the importance of choice when going on to FE. All groups stated that they wanted the chance to choose the things they were best at in order to maximise their qualification grades and, therefore, future prospects:

> '[You want] to do what you want to do when you leave school and [it's] a chance to develop the skills that you're already good at.'
>
> *(Male, School A)*

> 'The whole point of A levels is you narrow it down. GCSEs you do all the subjects – you then pick and narrow it down. Of these narrowed down, you pick one off that you will do for uni. That is the whole point. It's your choice. It's what you want to do.'
>
> *(Male, School B)*

Quietly disengaged learners often report that mathematics is not relevant to them (Nardi & Steward, 2003) and the relevance – or not – of mathematics to the learners' future aims came through strongly when discussing whether they were planning on continuing with the subject. Brown *et al*. (2008) found a close association between reasons for non-participation in level 3 mathematics and the predicted grade at GCSE. The most common reason for A* students intending not to take the subject was that it was not required for their future degree/career. Year 11 learners in the focus groups showed they were already thinking of their future, with most having an idea of the career they were hoping to enter. For those whose plans didn't include mathematics, the response to suggestions of compulsion was negative:

> *Female (School A):* 'If I had to go to college and had to do maths I wouldn't be enthusiastic, as my career doesn't need A level maths.

Researcher: 'What's your career?'

Female (School A): 'Er, I want to be a lawyer. No, barrister.'

'None of the options I've chosen link in with maths. I think it's a waste of time if I carry it on, to be honest. I'm doing English literature, French, Spanish and maybe politics but I'm not sure of that.'

(Male, School B)

Thus it appears that many young people fail to see the relevance of mathematics for their future learning and careers. This adds weight to our argument that all university departments and employers who need mathematical competencies and/or qualifications should state this explicitly. Then there would be no doubt for the learners about the relevance of the subject.

Effects of compulsory mathematics on engagement with FE in general

The mathematics community has produced several reports describing the benefits of compulsory mathematics study to 18 (ACME, 2010; Hodgen *et al*., 2010; MEI [Mathematics in Education and Industry], 2011; Vorderman *et al*., 2011) and in the case of learners who have not passed their GCSE at grade C or above, compulsory post-16 maths will become the reality when the recommendations from the Wolf report (Wolf, 2011) are implemented. However, what has not been discussed is any effect this might have on learners' attitudes towards their other study programmes and their engagement levels with education more generally. As discussed earlier, learners choose not to study mathematics partly as there are other subjects they are more keen to study.

Learners in the focus groups expressed two main concerns about the idea of compulsory mathematics lessons to 18. First, they felt the pressure caused by any compulsory mathematics would have a negative impact on their achievement in their other study programmes. Secondly, if the results of any compulsory mathematics course were reported, learners felt that universities and employers would focus on their achievement in this mathematics course, rather than on their other chosen subjects, or use it as a differentiator that could make them appear as less able candidates overall.

In terms of the effect compulsory mathematics might have on their other subjects, learners expressed a fear that subjects that they are good at would be compromised if they had to do additional mathematics. Learners predicted they would focus on mathematics at the expense of their other choices:

'Constant thinking that you're going to do quite well in your other subjects but there is always [the thought that] maths… is going to bring you down.'

(Male, School C)

'Also, if you do other subjects and you struggle with maths… your other subjects won't come out as good because you're spending so much time on maths if you're not good at it. That's what I've found.'

(Female, School D)

'If you fail [compulsory maths], it might put you off your course. And then you'd be worried about retaking it and not thinking about your course. Or you wouldn't know what to do.'

(Female, School A)

One FE college we visited had implemented a policy of compulsory mathematics for all learners who had not achieved a grade C or above at GCSE. These learners take functional skills qualifications in mathematics at an appropriate level. This provides an example of what might happen to large groups of learners when the recommendations in the Wolf report (Wolf, 2011)[7] are implemented. Learners reported low levels of engagement with the compulsory mathematics classes and, importantly, lower levels of enjoyment in their other subjects:

'I used to skip every Monday.'

(Female, College B)

'I didn't used to turn up until it had finished.'

(Female, College B)

'My friend didn't used to come in on that whole day.'

(Female, College B)

'You sort of dreaded the lesson.'

(Female, College B)

'No one took it on board.'

(Female, College B)

'Maths with me goes in one ear and out the other.'

(Female, College B)

From this evidence, these particular learners appear to be gaining little from these additional lessons; if anything, it is cementing their dislike for mathematics. Had we interviewed all of the learners taking mathematics post-16 in this college, it is probable that some would have been more positive. Nevertheless, the point is that compulsion in practice does not only have positive implications. In fact, for the student who was apparently missing whole days from college to avoid the mathematics lesson, the compulsory mathematics class pushed her away from education. Year 11 learners who were asked to imagine having to do another two years of compulsory mathematics also expressed similar sentiments:

'It would make me not want to go in. If I'd got maths for two periods, I wouldn't want to go in.'

(Female, School C)

'It would stress me out. On those days I wouldn't enjoy going to college.'

(Male, School C)

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7 Compulsory study of GCSE mathematics qualifications (or stepping stone qualifications) up to age 18 for those learners who have yet to achieve the GCSE grade C and above.

An unequal playing field

Learners of varying mathematical ability viewed the concept of compulsory mathematics to 18 as unfair. The students who did not wish to continue with mathematics beyond level 2 believed that those who were 'naturally better'[8] at mathematics would have an advantage in Key Stage 5, as they would not have to study a subject they found difficult and would not normally have chosen.

Learners were also concerned that if any compulsory mathematics programme were externally assessed with reported results, it would lead to unfair comparisons being made.

Currently, level 3 students' subject choices are informed by three factors:

1. instrumental factors concerning the subjects necessary for their chosen post-18 education or career route;
2. subjects that they feel they excel at (and, relatedly, can access);
3. subjects that they enjoy (factor 3 is often directly linked to factor 2).

But, importantly, the latter two factors also anticipate positive outcomes. Students tend to choose the subjects at which they believe they will perform best, whether this be A level courses or vocational courses. Universities and employers, therefore, tend only to see the best results the learners have to offer, as subjects they dislike and/or are less good at are screened out earlier on. Learners in the focus group fear that employers or universities admissions teams would focus on the compulsory mathematics results, perhaps even to the detriment of the results of the chosen courses:

> 'If you're not that good at maths but you're good at other subjects, employers might think you're not very good at maths and they might not choose you, even though you're very good at other subjects.'
>
> *(Male, School C)*

> 'If it would be compulsory, someone else might have done better than you in that subject, which isn't really fair. Especially if you didn't want to carry on with maths.'
>
> *(Male, School C)*

> '[Compulsion] will have a big effect on people because unis, top unis, won't even look at you unless you have As and A*s but because of doing the maths… so you just got a C in that because you put that much into maths that you didn't have time for the other subjects and you end up getting Cs and Bs.'
>
> *(Male School D)*

Learners were very aware of how competitive it is both in the university applications process and in the job market, and they were concerned that they would not be judged on an equal footing with their contemporaries who had chosen to study mathematics as one of their A level subjects. Learners who wanted to stop mathematics at level 2 argued that they would have to reveal their achievements in mathematics – a subject which they would not normally have continued – rather than being judged purely on their strengths, which is the case at present. This situation would not occur for learners who choose to do A level mathematics: any additional mathematics qualification grade would be emphasising their strengths.

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[8] 'Naturally better' suggesting that learners who say this do not view themselves as natural mathematicians. This is in agreement with the literature on mathematical identities and self-efficacy (Brown *et al*., 2008).

The view that compulsory mathematics would be unfair was shared across all groups of learners including some who were planning on continuing with mathematics post-16:

'I like maths and I want to carry it on. However, if they told me I had to carry on with English at A level then I wouldn't be happy, so I can imagine there will be people who feel that way about maths.'

(Male, School C)

'I wouldn't want to do English. And there might be people who are in the class who are just doing maths because they have to, rather than because it is what they chose, then they are going to be messing around… then it's harder for those of us who want to do it.'

(Female, School C)

When considering the case for compulsory mathematics post-16, focusing on either those learners who have yet to achieve a level 2 mathematics qualification or those who do not currently choose to continue with their mathematics post-16 having passed their GCSE at C grade or above, it is vital to consider the negative effects that any compulsory mathematics classes might have on learners' other chosen study programmes. Were compulsion to be introduced, policy-makers must consider carefully the nature of any assessment for the courses, and also the reporting of those assessments. Learners have expressed real concern over any move to compulsion, with a range of valid arguments for why they think it should not occur, and policy-makers will need to take these concerns into consideration.

Can it happen logistically?

As stated earlier, the government wishes to see the 'vast majority of learners studying some form of mathematics up to the age of 18 within the next decade' (Gove, 2011). This aim must be considered in the context of the current infrastructure. For example, how would it be delivered? Do colleges have the capacity? ACME (2010) has made recommendations for the teacher development needed if significantly higher numbers of learners study mathematics post-16.

We ran two online polls to investigate what a move to compulsion might mean for practitioners in FE centres. The first poll was of mathematics teachers and the second was of teachers of subjects other than mathematics.

In all, 55% of mathematics teachers (from a total of 38) who responded to the online poll said that they did have the capacity to deliver some form of mathematics to all post-16 students within their centre. Indeed, some were already doing so:

'All post-16 learners have access to a maths qualification of one kind or another.'

However, of the 45% who said they would not have capacity, some stark pictures were drawn:

'I would need to triple my staffing to cope, which would be hard enough just to find the staff, let alone pay the salaries.'

'Horrendous staff cuts; staff with low esteem for maths; staff with low ability and confidence to teach maths; staff without specialist training/qualifications.'

'Staff would need to increase from 8 to 24 fte [full time equivalents] and double the teaching rooms.'

When asked whether the current choice of post-16 qualifications was broad enough to provide a suitable pathway for all post-16 learners, 71% of respondents said no:

> 'Students with a C grade who have chosen not to do A level maths will have little interest in Functional Skills Level 2.'
>
> 'A level maths is too difficult for the majority of learners.'
>
> 'I think more relevant maths would be useful.'

For compulsory mathematics to be introduced, or even to raise participation rates without compulsion, investment in the infrastructure will be vital.

Effects on teachers of subjects other than mathematics

At no point has the government said mathematics should be taken in place of learners' other qualifications. Therefore, when in the timetable this additional mathematics learning would take place has yet to be identified. There are two distinct ways of finding the time for additional mathematics to be covered post-16 within the existing system. Either learners take discrete classes in mathematics alongside their chosen subjects, or the mathematics is embedded within those other subjects/qualification choices. We polled teachers of subjects other than maths to discover how they would feel about losing face time with their learners so they might attend separate mathematics lessons, and also asked how they would feel about teaching some form of contextualised mathematics embedded within their classes.

One model for delivering compulsory mathematics to 18 would be learners receiving discrete mathematics lessons alongside their other study programmes. This would apply to learners working towards their GCSE qualification,[9] as well as those learners who currently give up mathematics after achieving their GCSE grade C. Tutors were asked how they would feel if their contact time was reduced to enable learners to be released for mathematics classes. The response was mainly negative, with tutors concerned that they already have difficulty fitting in all that is required.

> 'This cannot be an option as the time is already at the absolute minimum for the delivery of the course.'
>
> 'Teaching time in colleges is constantly being squeezed in response to budget cuts. This proposal would put further stress on staff to deliver the same content in less time.'
>
> 'The students need contact time for the subjects they have chosen.'
>
> 'I think there would be increased absence on the day maths was taught.'

It would appear that this model would not work for most practitioners. Let us now look at the responses to questions on delivering mathematics by embedding it in other subjects. Some of the practitioners were already delivering embedded mathematics. This was especially true for those whose subjects contained some mathematics:

> 'I already do deliver mathematics in context with construction processes.'
>
> 'We already do it – music technology features acoustics and audio engineering aspects that lend themselves to algebra.'
>
> 'I would be happy to do this as long as it was in context.'

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[9] Both those who are doing an immediate re-sit and those who are working in bridging qualifications at a lower level aiming to achieve a GCSE in future.

Although some practitioners were nervous of such an approach, we believe embedding mathematics, where appropriate, is vitally important if we are to increase mathematical outcomes. A recent report from the Science Community Representing Education (SCORE, 2012) called for a review of the current mathematical content of science A levels to ensure the inclusion of underpinning areas of mathematics within that science. The Nuffield Foundation has called for a similar process to take place in a range of other subjects (Nuffield, 2012a). We fully support these calls and believe that the mathematics content of all subjects should be identified and, where necessary, increased. If there is mathematics required at degree-level study of the subject, such content should be reflected in the level 3 qualifications. This view is shared by some in university biology departments (Koenig, 2011):

> *The maths content of a biology degree comes as quite a shock to these students. I believe there should be more maths in both GCSE and A level biology to help secondary students understand that it is part of modern biology.*

Increasing mathematical demand in other subject areas must be done with sensitivity to the qualification structure and must ensure that this element does not overshadow other aspects of the course. One practitioner in our online poll encapsulated the point as follows:

> 'Relevance is very important. If it is relevant, it is probably already being done.'

However, we also believe that those subjects where there is no clear mathematics content should not have it shoe-horned in, as this could risk the integrity of that subject and damage learner engagement. The upcoming review of A levels (Gove, 2012b) would provide an ideal opportunity to address these concerns.

The experience of learners working below level 2

We know that it is never going to be the case that all learners will become top-level mathematicians, and no one is suggesting that this should be our aim. Equally, we should also admit that, wherever the minimum standard bar is set (currently GCSE grade C), there will some learners, however small a group, who will be unable to achieve it. Options for learners working below the stated minimum should consist of appropriate qualifications and pathways that enable them to show what they have achieved, rather than what they have not.

In the current climate, there are a series of rungs on the mathematics qualifications ladder which lead up to a degree. The lowest rung on this ladder is often perceived to be the GCSE grade C, as this is the gatekeeper to further study and employment (Wolf, 2011). However, there are large numbers of learners in each cohort (around 40%) who do not meet this minimum standard (Birdwell *et al*., 2011; JCQ, 2011; Wolf, 2011). For them, the experience of not achieving the minimum standard leads to one of two outcomes: further attempts at the GCSE or a move into alternative qualifications at a lower level. Learners who have achieved a grade D at GCSE in year 11 often re-sit the qualification. Analysis of results from 2010 showed that only 1% of students with lower than grade D in year 11 achieved a C in November of year 12 (MEI, 2011). Learners who achieve an E grade or below at GCSE are often steered into a realm of lower-level qualifications that are not understood by employers (MEI, 2011).

Moreover, as we have seen, a grade C at GCSE is a relatively poor indicator of general mathematics competence, given that it is possible to pass by attaining in some areas while doing poorly in others and what we know about 'teaching to the test'. Given these points, coupled with the scale of failure to secure a C grade at GCSE, it might be that a new way of arranging qualifications at level 2 and below would benefit these learners by accrediting the learning they have achieved rather than focusing on what they haven't. For example, the GCSE qualification could contain a range of small online tests that learners work their way through before sitting their GCSE exam at the end of the course. These tests would not count towards the GCSE itself, but rather would act as a measure of what had been learnt and understood at any given point. Teachers could use the reports with all their learners during Key Stage 4 as progress reports. The focus group learners who sat their GCSE early appreciated the 'progress report' offered to them by the experience. Such a model would enable the reporting to continue without the need for early and/or multiple GCSE entries.

All learners in Key Stage 4 would continue to work towards their GCSE qualification. The GCSE results could still be reported as they are at present, with a single overall grade. However, alongside this should be more detailed information about the competencies and skills the learners have demonstrated either in the final exam or during the online assessments throughout the course. For learners who do not achieve a grade C at 16, the report could be accessed by their FE provider so future teachers know exactly where a learner's skills gaps lie. If, by 18, learners have still not achieved the GCSE grade C, they would have detailed information on the skills and understanding that they do have, which could be used for applications to HE and for employment. Those learners who have achieved a grade C and above would also have details of their skills in mathematics. Those going on to STEM or related subjects could use this report to fill in the skills gap so that they have what they need for their particular subject area. Equally, those going on to study mathematics at A level might also find such detailed reporting helpful when selecting areas of specialism within the subject.

An even more radical approach would be to extend this model to include mathematics skills monitoring across the board. This could see cohorts of young people being accredited for their mathematics competence from an early age. Learners would move through the usual learning and qualification stages but each stage would have competence levels embedded within it. These would be accessed via online assessments. Content in lower key stages could serve as a tool for formative assessment of younger pupils; and at AS and A level the approach would enable the reporting of skills and understanding gained by learners during all post-16 level 3 mathematics courses, including those courses which may not be completed or passed.

Of course, assessment design for such an approach would be vital to ensure the robustness of the generated reports. Furthermore, we would need to retain end-of-course assessments, otherwise there would be a risk of all mathematics learning being broken down into tiny sections rather than being seen as a whole. However, such an approach would require a seismic shift in approach, e.g. a requirement from the government about the reporting of all mathematics assessments in detail, and co-operation from all awarding bodies to release the data. It is doubtful, for the time being at least, that such a development and reporting system would be supported. However, the technology is available to make such a move a reality over time.

Increasing post-16 participation at level 3

We have examined the causes of disengagement with mathematics post-16 and have looked at the negative effects that a compulsory mathematics model might bring (were compulsion in mathematics alone to be introduced). Now we look at ways in which the problem of post-16 mathematics might be resolved. There are four broad channels through which the government's 'vast majority' participation might be realised:

1. Initiatives that focus on increasing participation post-16 need to begin many years earlier, specifically in primary schools.
2. Access to the AS in traditional mathematics should be increased by reviewing its content.
3. A broader range of mathematics qualifications should be available at level 3. This should be accompanied by the recognition of the mathematics embedded within other A level subjects.
4. Where mathematics is required in other subjects, the mathematics content should be increased to allow for smooth progression to HE, and this learning should be recognised within the government's target.

Aside from improving primary mathematics so that positive mathematical identities are developed and maintained throughout learners' school experience, the further means of dealing with the current low-participation problem are not mutually exclusive.

Although growing, the number of people taking AS level mathematics is still relatively low, with ACME (2011b) stating that less than 18% of learners with a grade B or C in GCSE mathematics went on to study the subject at age 16/17. The mathematics and STEM communities would like more people to study mathematics post-16 (ACME, 2011b; DfE, 2011a; MEI, 2011; Vorderman *et al*., 2011); and indeed they see support of the pursuit of AS level as a key means to address current problems with mathematics drop-out at 16. However, aside from the engagement factors discussed earlier, there are a number of practical barriers in the current system preventing large numbers from doing so. Learners who have achieved a grade C, or sometimes even a B, at GCSE are often discouraged from starting, or are refused entry onto, an AS course, as the typical requirement is a grade A*–B (Matthews & Pepper, 2007), although some suggest that even a grade B at GCSE might not be adequate preparation (Hernandez-Martinez *et al*., 2011). Generally this is because research has shown that learners with lower GCSE grades do not achieve at AS (Nuffield, 2012b). Therefore, one solution might be to redefine the content of the AS qualification, opening it up to enable learners with a grade C to access the course. This is especially important considering that a C at GCSE in mathematics is presented as a passport to further study – yet at present, it is not a passport for further study in mathematics! This is an extremely anomalous situation, especially given that progression to A level in subjects other than mathematics appears to comprise an option for those with a C at GCSE in that topic.

Any attempts to water down the current traditional AS and A level mathematics courses to allow access for grade C learners is likely to be met by accusations of dumbing down both from within and from outside the STEM community. Research has shown that the STEM subjects are amongst the hardest of all A level subjects (Qualifications and Curriculum Authority [QCA], 2008; SCORE, 2008) and whilst this difficulty may afford a higher status to these subjects, it is also a barrier to access. Therefore, there is a tension between the desires of the government and STEM communities that needs to be resolved. On the one hand, there is a desire for more learners to study STEM subjects, but on the other hand, large numbers of learners are precluded from doing so due to the demand for mathematics to remain 'hard'. In all, 207,148 learners achieved a grade C at GCSE in summer 2011 (JCQ, 2011), so that's over 200,000 learners effectively prevented from post-16 participation due to the current qualifications regime. Policy-makers and the STEM community need to decide whether maintaining current levels of difficulty at AS is more of a priority than increasing participation, as the former is preventing the latter.

Alternative options for learners with grade C

As discussed, policy-makers and some members of the STEM community would like more people with GCSE grade C to continue with mathematics post-16 (ACME, 2010; DfE, 2011a; MEI, 2011; Vorderman *et al*., 2011), but not through the traditional AS route, as we know that those with a C at GCSE struggle to make the transition. Therefore, we might seek to increase the range of mathematics provision post-16, making it broader with suitable options for learners who have achieved a grade C at GCSE. This provision already exists in the Free Standing Mathematics Qualifications and the AS Use of Mathematics. However, uptake rates for these qualifications are low (MEI, 2011), and there is debate in the mathematics community about their value (Noyes *et al*., 2011). In particular, there is a fear that the Use of Mathematics qualifications pull people away from the traditional A level courses, although analysis has shown this is not the case (Noyes *et al*., 2011). What is the case, however, is that learners with a C grade might struggle with the AS Use of Mathematics qualification, as their mathematical understanding at level 2 is not sufficient to enable smooth progress to level 3. Therefore, a further suggestion would be to offer a range of mathematics qualifications at level 2 that learners with a grade C at GCSE could take to improve their understanding post-16. Qualifications in statistics, for example, may cement the learning that has taken place at GCSE, as well as filling in some of the gaps left by the grade C. However, will it be easy to convince learners to spend curriculum time on a level 2 mathematics qualification when they have already achieved such a thing? It is unlikely unless we can convince them of the usefulness of such a course.

To engage more learners in post-16 mathematics, whether at level 2 or level 3, mathematics provision must also be viewed as useful and relevant. In order to become more engaged, learners need to see how studying more mathematics will benefit them in the future. A recent study (City and Guilds, 2012) showed that learners want mathematics to be taught more practically. There is a significant desire to learn mathematics in ways that can be applied in everyday life, or in business. In all, 45% of 14- to 16-year-olds and 54% of 16- to 18-year-olds commented, unprompted, that taught mathematics could be improved by being geared more towards real-life, relevant or practical scenarios. ACME (2011b) claimed that there are large groups of learners who would benefit from some form of post-16 mathematics but who choose not to take it. Our findings support this, with learners particularly keen to make the point that their GCSE will be all they need to progress:

> 'I don't need more after my GCSE. I want to be a primary teacher. I need a bit of maths but I don't need to do more curved graphs. That won't help me and that's what AS is.'
>
> *(Female, School B)*

> 'I think it would help me but I don't want to do it as I won't enjoy it. I think it would come in use as there is a lot of maths base in economics but I think what you do in GCSE, if you've done well, that will be enough for economics class.'
>
> *(Female, School C)*

> Maybe [it would help me] a little bit in business, like calculating profits and stuff, but we do interest and stuff at GCSE so I can just carry that on.'
>
> *(Female, School D)*

> 'I do need maths for the subject that I want to do in uni, but the thing is, I can do it with my GCSE grades. I don't really have to do it for A levels. Instead of doing maths I could do those subjects and focus on them a bit more and that would be better for uni.'
>
> *(Male, School D)*

Ways to increase the relevance of mathematics include ensuring it is contextualised within the other learning that is taking place, and also ensuring that learners are fully aware of the mathematical requirements of other subject areas.

Recognising mathematics learning within other subjects

As discussed, research into the mathematics demands within other subjects is ongoing (Nuffield, 2012a; SCORE, 2012) and it is clear that there is a great deal of arguably unrecognised mathematics learning being done post-16. Instead of focusing on learners who currently do not do any discrete mathematics qualifications post-16, perhaps we should shift that focus to recognise the large numbers of learners who are doing some mathematics study as part of other subjects. This could be done by branding all the existing mathematics learning that is currently taking place in other subjects in order that we might more accurately determine the number of learners post-16 who do not do any mathematics at all. Once these learners are taken into account, it is possible that we are already closer to reaching the government's 10-year target than is currently realised.

Learners who go on to take STEM and other degrees containing some mathematical content are often ill-prepared to deal with that content, as many have not studied mathematics since the age of 16 (Mulhern & Wylie, 2005; ACME, 2011b; Institute of Physics, 2011; Koenig, 2011). Whilst encouraging more of these learners to take A level mathematics alongside their other subjects would help this problem, this option is already available and learners are choosing not to take it. Therefore, it is unlikely that encouragement alone will lead to all learners in this situation taking A level mathematics. We need HE to be clear in the requirements for mathematics AS or A level if this truly is what learners need.

Recommendations

This analysis demonstrates:

1. the need to reconsider compulsion as a means of increasing mathematics uptake and outcomes post-16, at least within the current system (i.e. mathematics as a lone compulsory subject rather than compulsory alongside other subjects within a baccalaureate model);
2. the need for the mathematics community to decide whether greater uptake at AS or the maintenance of the higher status of mathematics is more important (as each is working against the other);
3. the need to reconsider how mathematical competence is assessed over time from primary school to degree level;
4. the need for the STEM community to be explicit in its mathematical requirements and retain as many STEM graduates and workers as possible in the sector;
5. the need to recognise all forms of mathematical learning where it takes place.

As the government is keen to increase the mathematical skills and capabilities of young people, as well as participation in the subject post-16, it must consider ways to do this that will not be at the expense of general learner engagement. A policy move towards compulsion would not necessarily increase mathematical outcomes if learners were disengaged, and might lead to higher truancy rates and negative attitudes towards learning in general. Furthermore, the usual progression route from GCSE (grade C and above) is to AS, something that is not currently available to large groups of learners. The mathematics community has demonstrated how mathematics is included within other subject areas and we believe that more could be done to utilise these inter-subject links. Consequently, our recommendations offer ways to increase learner engagement with mathematics to drive up post-16 participation and also ways to identify the amount of unrecognised mathematics learning that is currently taking place embedded within other subject areas.

Compulsion

Evidence from the learner focus groups showed that compulsion and the removal of choice could lead to further disengagement from mathematics and also to disengagement from education more widely. Internationally, where mathematics is compulsory to 18, it is always alongside other subjects that are also compulsory (Hodgen *et al.*, 2010). Therefore we recommend:

1. The government should not seek to implement compulsory mathematics learning for all post-16 learners unless it is introduced as part of a wider compulsory baccalaureate model containing a range of subjects.

However, we support the need to increase participation in mathematics after the age of 16. How, then, might this be achieved without compulsion?

Increasing engagement

The focus on the C grade in mathematics at GCSE is leading to a range of harmful practices, including early entry, multiple re-sits (ACME, 2011a; DfE, 2011a) and focusing on learners at the C/D boundary at the expense of either higher or lower achievers (Ofsted, 2008). However, even when learners achieve a grade C at GCSE, they are often dissuaded from continuing with the subject at AS level because a B or above at GCSE mathematics is viewed as a minimum requirement for learners to do well at AS. Large groups of learners who do have top GCSE grades and the option to take mathematics at AS are choosing not to do so even where it may be useful for them. Therefore we recommend:

2. The government should continue its move against early entry to GCSE mathematics (except in the case of learners who will start an AS programme in year 11).
3. The government and mathematics community should consider whether they believe it is more important for mathematics to remain as a 'hard' subject at AS and A levels, or whether it is more important that participation numbers rise significantly. We believe that the AS qualification suffers from low participation partly because mathematics is viewed and experienced as an elitist subject. We believe the AS should be redesigned and opened out to be fully accessible for learners with a C at GCSE (or the mathematics community will have to accept that the subject will remain the preserve of a 'clever core').
4. A new way of reporting mathematical progress through GCSE and AS level should be introduced. Learners should take ongoing low-stakes interim assessments throughout their GCSE course that log the competencies demonstrated. GCSE exams would be taken in the usual way, but alongside a single-grade result, learners would receive detailed information on their achievement throughout the course. All awarding organisations would need to follow the same process and it would need to be fully supported by, and demanded from, government. Equally, university admissions departments would need to be familiar with and request the mathematics reports that such a scheme would generate.
5. HE departments and employers in the STEM sector should demand more mathematics from their entrants (whether this is a full A level or results from smaller level 3 qualifications would be a decision for HE and employers). Whilst this may have an initial impact on numbers of HE applications in the first instance, our analysis shows that to increase mathematics uptake, it is vital that learners see the demand for and relevance of the subject.

Recognition of mathematical learning

We know about the government's aspiration for the vast majority of learners to study some form of mathematics up to the age of 18 over the next decade. The STEM community is clear that mathematics supports a range of subjects both in the STEM sector and beyond (ACME, 2011b; Vorderman *et al.*, 2011). Therefore we propose a shift in the focus of determining what it means to be studying mathematics post-16. We recommend:

6. Where mathematics content features in other subject areas at levels 2 and 3, this learning should both be emphasised *within* that qualification and should also be recognised *outside* of it. This type of embedded mathematics learning should count towards the government's 10-year target.

Improving career retention in the STEM sector

With concerns about England's ability to compete on a global scale in the STEM sector, it is important that STEM degrees are internationally competitive. We believe this will be made easier if a higher mathematics demand is placed on university applicants (see recommendation 5). However, once graduates have their STEM degrees, large numbers are choosing to work in other sectors (BIS, 2011). Therefore we recommend:

7. More should be done by the STEM sector to identify why the number of people with STEM degrees choose not to work in the subject. Once the reasons are uncovered, we advise that moves are taken to reverse the trend. Arguably, it would be easier to retain those with a love of mathematics and STEM subjects than to convert those who, ordinarily, would have chosen a different route.

Further research

Finally, we recommend that the research into wage returns for A level mathematics is carried out once more in order to test whether the 10% increase in wages for those who took A levels 40 years ago holds true today.

This report has attempted to sift the evidence underlying the heated debate about post-16 mathematics participation in England. It has sought to provide measured reflection on the evidence and implications for different approaches. We hope our findings and recommendations will contribute positively to the shared aim of encouraging mathematics efficacy and progression rates.

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