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# Rethinking the Value of Advanced Mathematics Participation

**Final report – January 2017**

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Nuffield Foundation

# Rethinking the Value of Advanced Mathematics Participation

## Executive Summary

### Background

Participation in A-level[1] mathematics courses in England has been rising for over ten years, but concerns remain. International comparisons show England to have one of the lowest levels of post-16 mathematics engagement amongst developed countries. At the same time, several econometric analyses report increased wage returns to mathematics qualifications. These two factors, together with sustained pressure from stakeholders, led to the 2011 call from the then Secretary of State, Michael Gove, for the 'vast majority' of young people to be studying mathematics up to 18 by the end of the decade. More recently, this political aspiration was reiterated by the Chancellor in his March 2016 budget, though with a longer timescale.

The Rethinking the Value of Advanced Mathematics Participation (REVAMP) project was funded by the Nuffield Foundation and set out to investigate the value of A level Mathematics from several viewpoints. The project comprised four strands of quantitative analysis:

1. Updated research on economic returns to A level Mathematics;
2. Analysis of changing participation in A level Mathematics from 2005-13;
3. Modelling of the relationship between A level Mathematics and degree outcomes;
4. A national survey of ten thousand 17-year-olds.

The project utilised high-quality secondary datasets from the 1970 British Cohort Study (BCS), the National Pupil Database (NPD) and the Higher Education Statistics Agency (HESA). It also included a national survey of ten thousand 17-year-olds that investigated students' understandings of the value of advanced mathematics for their educational and life choices and aspirations.

These quantitative studies were complemented with a policy trajectory analysis that traced the value(s) attributed to A level Mathematics, in particular its economic value. This strand of the study included an analysis of grey literature from 2000-2015 in order to understand how key reseach ideas get taken up by policy makers and influence practice.

[1] Including AS and A levels in Mathematics and Further Mathematics, Use of Mathematics and Statistics.

## Findings

The REVAMP project has coincided with a major programme of reform in GCSE and A level Mathematics and so has much to say about the likely impact of those changes and the potential for the new post-16 Core Maths qualifications to meet the needs of over 200,000 learners in each cohort. The main findings of the project are as follows.

*On economic returns to A level Mathematics:*

- There is compelling evidence of **continued wage returns of up to 11%** to A level Mathematics. Our analysis is based upon the 1970 British Cohort Study participants when aged 34 and shows that the signalling power of A level Mathematics has been sustained over time;
- The economic benefits of A level Mathematics are overshadowed by the differences between males and females and according to where one lives. For example, for those with A level Mathematics in this sample born in 1970, **females earned around 20% less than their male contemporaries** at age 34.

*On changing patterns of A level Mathematics completion:*

- The **main driver of increased A level Mathematics participation is the rising number of A* and A grades in GCSE Mathematics**. The new GCSE 1-9 grading structure that will be implemented in 2017 is likely to have a detrimental effect on student self-perceptions and A level Mathematics uptake, in particular where students who would have achieved the top grade(s) are now less likely to do so;
- At each GCSE Mathematics grade, the proportion of students who then proceed to complete A level Mathematics has changed very little, particularly for GCSE grades A-C;
- A key factor in the increased engagement with advanced mathematics is the **rise in numbers completing AS Mathematics**, in particular girls and those attaining GCSE A and B grades. The decoupling of AS and A Level is, therefore, a threat to advanced mathematics participation;
- GCSE Mathematics A* students have been increasingly likely to study A level Mathematics or A level Mathematics with AS/A level Further Mathematics, though this is heavily biased towards boys. The decoupling of AS and A level, and changes to funding that encourage schools to focus on 3 A levels are likely to reverse this trend;
- There is continuing evidence that, all other things being equal, **girls are less likely to choose A level Mathematics**.

*On the educational value of A level Mathematics for science undergraduates[2]:*

- Whether school mathematics prepares students well for undergraduate chemistry and biology degrees is contested in the international research literature;
- There is little evidence that A level Mathematics completion has much effect on the likelihood of attaining the best degree outcomes in biology and chemistry. Those with the top grade in A level Mathematics did, however, have some small advantage;
- The effect of high attainment in A level Chemistry upon undergraduate biology degree outcomes and vice versa is clear. This may have implications for those advising students on their educational choices;
- For a given student, **the greatest influence on their chances of achieving a first class degree is the university attended**. The differences are striking and have serious implications, for example in how initial teacher education bursaries are awarded, which is a particular concern for STEM teacher recruitment.

*On young people's attitudes to studying mathematics post-16, in particular A level Mathematics or equivalent:*

- Students are generally opposed to the idea that they should be compelled to study 'some maths' post-16 (78%) but are less opposed to being 'encouraged' to do so;
- Amongst the target group for Core Maths, i.e. those not currently studying AS/A level Mathematics, **80% disagree with the idea of making mathematics compulsory post-16**.

*On the relationship between research and policy in post-16 advanced mathematics, in particular on how Dolton and Vignoles' (1999/2002) work on the wage returns to A level Mathematics in the 1958 National Child Development Survey influence policy discourses:*

- The analysis highlights the serendipitous ways in which **research impacts policy work through influential individuals who bridge political, academic and public spaces**. There are specific conditions under which research gets adopted and adapted by policy officials and in policy making processes;
- There is **clear evidence of the mutation of research ideas over time** and this needs to be understood better if research is to be usefully employed for the improvement of education and other public services.

[2] Our analysis was limited to biology and chemistry, science disciplines in which the mathematical preparedness of undergraduates is a concern, but for which very few course require A level Mathematics.

## Implications

These findings have important implications if the goal of the 'vast majority' of young people continuing their study of mathematics to 18 is to be realised. One priority is to be prepared for, and mitigate, any potential unintended consequences of the current qualifications and assessment reform processes. There are several of these:

1. The changing grade structure at GCSE was designed to increase the challenge level at the top end of the grade range. This will inevitably result in fewer students getting the top grade(s). Given the strong association between GCSE grade and A level Mathematics completion this poses a threat to post-16 participation;
2. Any perceived, or actual, increase in cognitive demand within the new A level Mathematics is likely to act as a deterrent to choosing the subject;
3. The decoupling of AS and A level and the changing funding environment are likely to reduce the numbers of students starting AS Mathematics, particularly those without the top GCSE grades.

The current reforms do have some merits, but it is also important to recognise that the changes have associated risks For example, if a drop in A level Mathematics participation materialises and coincides with strong growth in the numbers choosing Core Maths, the reasons for this need to be properly understood. It would be unhelpful for Core Maths itself to be in some way blamed for that change.

A second priority area for consideration is how to address students' negative views about further mathematical study. Over recent years there have been discussions regarding whether increased post-16 mathematics engagement should be compulsory, voluntary or incentivised in some way at the individual and/or institutional level. The evidence from this project shows that relying on a voluntary swing to mathematical study – and a big one at that – will not work to realise the government's participation goal. On the other hand, given student attitudes to mathematics, a move to make post-16 advanced mathematics of whatever form (e.g. Core Maths) compulsory, might create further antipathy to the subject and so be counterproductive.

An area for further research is mathematics at the school-university interface. The project has focused on sciences but preliminary exploratory analysis suggests that A level Mathematics performance was a much more significant predictor of degree outcomes in economics. Few would argue against the importance of mathematical competence in a range of science and social science topics, but whether the current qualifications are useful preparation is moot. Part of the present qualifications reform process is to include assessment of mathematics within new science A levels (20% in Chemistry and 15% in Biology). The implications of this embedding policy need further consideration.

Related to this, the introduction of Core Maths raises important questions about the relative merits of a) exposure to more advanced mathematics including calculus, versus b) increased competence and confidence with core GCSE Higher Tier mathematics. Despite all of the changes, what mathematics should be taught to which young people and at what point remains contested. The REVAMP project makes important contributions to this and other matters pertaining to post-16 mathematics learning.

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## 1. Background to the REVAMP Project

The number and proportion of young people participating in advanced mathematics in England's schools has been subject to a great deal of scrutiny for many years (DfE, 2011; Hawkes & Savage, 1999; Royal Society, 2008) and debates about the value of advanced mathematical study continue unabated (Norris, 2012; Noyes, Wake, & Drake, 2011; Smith, 2004). The REVAMP project builds on earlier research (Noyes, 2009; Noyes & Sealey, 2012) to reconsider the value of A level Mathematics at a critical time in the development of education policy, curriculum and assessment in England, when the calls for learners to do both more and harder mathematics have never been louder.

In the build-up to Curriculum 2000, Dolton and Vignoles' (1999; 2002) analysis of the 1958 National Child Development Study (NCDS) concluded that the 'economic return' to A level Mathematics (and Computing) was unique and significant: a potential 7-10% increase in earnings by age 33. This finding has subsequently seeped into educational thinking (e.g. Wolf, 2002) and policy discourses (e.g. Gibb, 2015; Kounine, Marks, & Truss, 2008; Morgan, 2014) and has been taken up by stakeholders and think tanks in their recommendations (e.g. Vorderman, Budd, Dunne, Hart, & Porkess, 2011; Wolf, 2011); school teachers even use it to recruit A level Mathematics students. The assumption of a causal relationship from that study of the baby-boomer generation, convenient though it might be for the mathematics education community, needs re-examining, firstly by analysing more recent datasets and secondly because of the different times in which we now live. Do A level Mathematics students acquire some additional human capital which is later converted in the employment market, or does the act of choosing and completing mathematics signal some prior qualities or competences?

It is impossible to know the extent to which Dolton and Vignoles' econometric research has influenced the increase in A level Mathematics completion from 2005, though it has certainly shaped policy discourses. The drivers behind the growth in A level Mathematics participation have remained unclear but need to be investigated in order to understand whether the current growth trajectory is all that it seems and whether it will address some of the longstanding concerns of the Science, Technology, Engineering and Mathematics (STEM) community. For example, are more girls now doing maths/science? Can A level Mathematics become an entry requirement for particular mathematically-demanding undergraduate programmes? The Department for Education's (DfE) analysis (2011) of mathematics and science A level participation is detailed but does not answer some of these trend questions, nor does it explore the significant variance in A level Mathematics participation between schools/colleges highlighted in earlier research (Noyes, 2013).

The furore in the mathematics education community that followed Curriculum 2000 (see Smith, 2004) might easily be forgotten by policymakers, even as we move towards the next major reform of A level Mathematics. For concerned stakeholders, the sudden drop in participation of 2001/2 that resulted from the low pass rate the challenging new AS was the final straw in a long trend of declining A level Mathematics participation. It resulted in immediate remedial action being taken by the Qualifications and Curriculum Authority (QCA) and precipitated a range of high-level calls for action.

In addition to the economic arguments for more mathematics education for all, findings from international comparison studies that show England has one of the lowest rates of post-16 mathematics participation (Hodgen, Pepper, Sturman, & Ruddock, 2010; OECD, 2010). This work has been highly influential, but so too have been calls for improved quantitative skills in a wide range of degree programmes (e.g. The British Academy, 2012) and from employer groups (CBI, 2009). Many of the key stakeholders support the notion of studying mathematics for longer. A more difficult consensus to achieve is the nature of that curriculum. Should students be learning increasingly higher levels of mathematics (e.g. A level) or developing greater confidence, fluency and competence in applying GCSE level mathematics (e.g. Core Maths)? This debate often remains hidden and is unhelpfully framed by the same notions of intellectual hierarchy that stifle the development of the models of vocational learning exemplified in the Germanic tradition. An earlier example of such an applied, accessible, post-16 mathematics pathway was AS Use of Mathematics though this was discredited by an influential yet limited analysis of what are complex educational issues (REFORM, 2010).

The research on wage returns and international comparisons precipitated the then Secretary of State Michael Gove's express intention to "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" (Gove, 2011). Although Gove's tenure as Secretary of State was not to last, this ambition continues in government as seen in the then Chancellor's March 2016 budget. Whether the current Chancellor has the same appetite for pursuing the *mathematics for all* agenda remains to be seen, especially in the light of the recent Brexit decision. It is noteworthy that the most recent champion of this cause is not the DfE but the Exchequer; the influence of the economic argument for mathematics is clear.

Although A level Mathematics numbers have been rising, concerns about the mathematical needs of over 200,000 students in each cohort who achieve a GCSE grade C or more and then stop learning mathematics remains. The value of mathematics for these young people is not necessarily the delayed gratification of future earning potential[3], the relationship of mathematics to SET (Roberts, 2002) or the utilitarian value of mathematics for accessing related undergraduate courses (J. Williams, 2012). Relevant alternative post-16 mathematics pathways, ones that are driven less by the needs of higher education and more by the desire to engage a broad constituency of level 3 learners (ACME, 2012; Noyes et al., 2011; J.

[3]See the Nuffield-funded project 'The effect of graduate earnings on 16-year-olds' subject choices' for related analysis http://www.nuffieldfoundation.org/effect-graduate-earnings-16-year-olds-subject-choices

Williams et al., 2008), are now being realised in the form of Core Maths. The coming years will show how successful this initiative has been in addressing the participation gap.

## REVAMP Objectives and Research Questions

Given this background, the REVAMP project set out to undertake various quantitative analyses of three secondary datasets in order to provide different perspectives on the value of advanced level mathematics. Alongside this, a policy trajectory analysis of 14-19 mathematics education since Curriculum 2000 was undertaken. Finally, a large-scale survey of around ten thousand 17-year-olds was conducted in over 100 schools and colleges (i.e. Year 12) in order to understand their evolving attitudes towards post-16 mathematical study.

The project's umbrella research question - what is the value of A level Mathematics today? - was explored through these intersecting strands. These five *work packages* are set out overleaf with key questions, the data sources and other issues.

| WP | Research Questions | Dataset |
|---|---|---|
| 1 | Is there still a 'return' to A level mathematics and, if so, how great is it?<br>Do Dolton and Vignoles' findings hold in more recent datasets? | 1970 British Cohort Study |
| 2 | Who is doing A level Mathematics now?<br>How have participation patterns changed; by social category, by school type, etc? | National Pupil Database; A level cohorts 2005-2013, matched to prior attainment and census data |
| 3 | What is the relationship between A level participation and attainment and degree outcomes? | 2012 HESA outcomes data, matched to prior qualifications |
| 4 | How have mathematics education reports/policy/etc, taken up the economic and other value discourses since Curriculum 2000? | New dataset comprising all relevant papers, reports, policy documents. |
| 5 | What do 17-year-olds think is the value of post-16 advanced mathematical study and how does it relate to their current and future choices and aspirations? | New dataset from large scale survey |

Table 1: REVAMP project research questions and data sources

> "Winning the battle of the maths economy will be critical to the UK's future success. Current Government policy is too small scale to deal with the pressing nature of the problem. Radical measures have to be taken to move mathematics from "geek to chic". Rigour must be central to this approach." (REFORM, 2008, p. 5)

## 2. REVAMP Project Methodology and Findings

### 2.1 Economic value: Returns to A level Mathematics

In the late 1990s a review of 16-19 education in England (Dearing, 1996) had called for research to better understand declining participation in mathematics and science subjects (see also Hawkes & Savage, 1999). In response to this call, Dolton and Vignoles (1999; 2002) undertook research to provide better labour market evidence on the economic return of A levels. Their research utilised the 5th wave of the National Child Development Study (NCDS), as well as the 1980 Graduates and Diplomates Survey, and suggested that A level Mathematics was unique in terms of its economic return. The extent of this wage return was 7-10% at age 33.

There were several caveats discussed in the original research. The NCDS participants were all male due to analytical decisions to drop female participants; they were born in 1958, took their A levels in 1976, and were 33 at the time of the survey in 1991. Analysis of females was based upon the Graduate and Diplomates survey at a point six years after graduation but this is a different population subset. The researchers combined mathematics and computing as a single category, yet the computing element has generally been forgotten or ignored. They also discussed the uncertainty inherent in all statistics, though this idea has also disappeared in general usage of their research (see 2.4).

The project set out to update Dolton and Vignoles' work for a number of reasons. There has been considerable change in the educational and economic landscape between 1974 (i.e. the year in which the 1958 cohort chose their A levels) and today: A level Mathematics has undergone reform over that time and whether standards have been maintained is unlikely (Jones, Wheadon, Humphries, & Inglis, 2016); the numbers taking A levels has varied; the proportion of people completing their education at 18 has grown; higher education has become more market-oriented; the economy is substantially different with the rapid expansion of the service sector and a substantial decline in traditional industries. In light of these changes it is not clear that Dolton and Vignoles' results would be seen in the later dataset.

The analysis was with Wave 7 (2004) of the 1970 British Cohort Study. Six single-level log-linear models of increasing complexity were developed. A null model was used to estimate the overall average pay and then a set of demographic variables were added for Model 2 (sex of respondent, marital status, whether the respondent has any children, their occupational class and region of residence). Model 3 added basic qualifications up to the age of 18 controlling for subjects completed rather than level of attainment. Model 4 added the remaining post-18 qualifications available: NVQ, higher education diploma, degree and professional qualification. Model 5 took the form of a replication of Dolton and Vignoles' (2002) model, as far as it was possible, adding work experience variables and age 10 ability scores. Finally, model 6 addressed the issue of omitted variable bias as far as the available data allowed. Full details of the approach can be found in Adkins and Noyes (2016).

### *2.1a Findings*

Based on a series of models of earnings for those completing at least one A level in the 1970 BCS:

1. mathematical skills, whether measured as ability scores at age 10, qualification grades at age 16 or completion of A level Mathematics, have strong and positive association with earnings at age 34;
2. wage returns to A level Mathematics for children born in 1958 and 1970 are broadly similar;
3. Only mathematics and computing A levels are associated with a wage premium at age 34, as in the earlier study;
4. the premium on A level Mathematics varies between 2 and 21% of income but is further dependent upon a range of other factors;
5. Females in the sample born in 1970 earned around 20% less than their male contemporaries at age 34. Simulations suggest that difference between men and women with A level Mathematics is somewhere in the region of £11000-15000. However, the return for men with and without maths is around £4500-5500 compared to women with and without maths being around £4200-6400. There is some statistical uncertainty with these predictions;
6. Regional variations in earnings are substantial with those outside London receiving considerably lower pay at age 34.

### *2.1b Implications and recommendations*

This analysis highlights the economic value of good mathematical skills and of higher level qualifications. For this group of A level students from 1988, mathematical competence at age 11 and O level grades at age 16 predicted later earnings, whether people had A level Mathematics or not.  However, although A level Mathematics was associated with higher incomes for both the 1958 and 1970 birth cohorts, there is no guarantee that this will be so for today's 16-year-olds making choices in different times, particularly those persuaded to study A level Mathematics on the basis of this research.

The reasons for the 'return' are unclear. Is there something intrinsic about the learning gains from A level Mathematics that get rewarded (see Attridge & Inglis, 2013), or does the qualification signal pre-existing qualities and competences to the employment market?  What is clear is that mathematical competence matters and so the development of new, engaging post-16 Core Maths qualifications is a worthy project if it encourages a significant upturn in post-16 mathematical study.

One of the striking features of the research is the differential income of males and females even with A level Mathematics. When this is compounded by the reduced likelihood of girls choosing to study mathematics post-16 (see below), this remains one of the outstanding challenges of increasing mathematics participation and ensuring fairer economic and therefore life chances.

> "People with an A level in maths go on to earn 7 to 10% more than similarly educated people without the qualification and it opens doors to a whole range of interesting careers"
>
> Nick Gibb, Minister of State for Schools, 2015.

**2.2 Valued by whom? Understanding changing patterns of participation**

*Reporting A level Mathematics uptake*

The widely cited report Making Mathematics Count (Smith, 2004) described the Curriculum 2000 reforms as "a disaster for mathematics" because of the impact they had on participation rates. Following recommendations made in the aftermath of those reforms, A level Mathematics entries turned a corner in 2003/4 and have been rising ever since. By 2006, media coverage was positive with the Guardian newspaper reporting that "Mathematics has become the third most popular A level subject, with a 5.8% increase in entries and a 22.5% increase in pupils taking further mathematics" (A. Smith, 2006). Three years later, in 2009, Mathematics in Education and Industry (MEI) reported that "something special is happening in mathematics" with a 12.2% increase in those taking A level (Porkess & Lee, 2009).

In 2011, with entries for A level Mathematics continuing to rise, one journalist suggested that the phenomena was due in part to 'the Brian Cox effect' (Vasagar, 2011). Examiners also attributed the rise to the financial recession. One complicating factor is that many students repeated modules making accurate trend analysis, and discussions of causality, difficult. In the same year, Plus Magazine reported, under the title "People keep falling in love with mathematics":

> Who said that people don't like maths? Numbers of entries to maths A and AS levels across the UK have again increased this year. The number of students taking maths A level has risen by 7.8% compared to last year (from 77,001 to 82,995) and A level further maths entries have risen by 5.2% (from 11,682 to 12,287). At AS level maths has seen an increase of 25.3% compared to last year (from 112,847 to 141,392) and further maths an increase of 24.7% (from 14,884 to 18,555). The number of students taking A level maths is now higher than it has been for almost two decades. (https://plus.maths.org/content/maths-levels-rise-again)

Three years later in 2014, the Wellcome Trust reported that "Science and maths popularity continues to increase" (August 2014). Elsewhere the Times Educational Supplement reported that "Maths has overtaken English for the first time in more than a decade to become the most popular A level taken this year…maths has steadily grown in popularity, from 52,788 entries in 2004 to 88,816 this year" (Exley, 2014).

These examples are selective but broadly representative. The resounding message over recent years is one of good news. For those championing greater engagement with advanced mathematics these rising numbers are welcome, but there has been little attempt to thoroughly investigate and explain the changes and understand the underlying patterns. Sometimes, changes in mathematics numbers are contrasted with other subjects as in the case of English above, but this is about as complex as the analysis gets. The percentages of students doing A level Mathematics still leaves participation post-16 falling very short of the desired 'vast majority'.

*Three metaphors for post-16 mathematics uptake*

Three metaphors are often used in discussions of upper secondary mathematics engagement: pipeline, pathway and participation. The metaphors are compelling as they align well with the broad thesis of contemporary metaphor theory (Lakoff, 1993) and the notion of root metaphors that can be traced back to early sensory-motor experiences: force (c.f. *pipeline*), movement (c.f. *pathway*) and containment (c.f. *participation*). The metaphor of *participation* speaks of belonging to a community of learners and taking part in the social activity of learning mathematics. The idea of *pathways*, with their associated networks and junctions, denotes movement and, perhaps more importantly, choices.

The metaphor which seems to be more prevalent in the US and is growing in use in England is *pipeline*. This metaphor implies force and focuses on the *supply* of suitably qualified mathematicians and scientists to science, industry and commerce (and DfE, 2011; two examples of this notion of 'supply' are Roberts, 2002). The thing being supplied – in this case students – is pushed (or pulled) along a pipe or channel in order to meet a perceived demand. Here the key concepts are not choice (as in pathways) or interaction (as in participation) and 'leaks from the pipeline' are broadly conceptualised as wasteful and needing to be plugged. The language used to talk about A level Mathematics is important because, according to the theory, metaphors have generative power.

This *pipeline* metaphor imagines students as flows of human resources. In keeping with this, the REVAMP approach was to better understand the characteristics of this flow. Normally, A level entries are reported once a year as a single number and these numbers are compared year on year. However, it is not clear who is being counted and compared: are they all of the same age/cohort? Does this include overseas students who have come to the UK for sixth form study? Does it include retaking students? Depending upon the answers to these and other questions, the annual entry statistics might be interpreted differently.

The REVAMP approach took subsequent cohorts of young people aged 16 and tracked them over the following three years to find out what post-16 mathematics outcomes they achieved. The analysis subsets the cohort by the strongest predictor of participation, prior GCSE attainment level at age 16 (Noyes, 2009).

*The NPD dataset*

The analysis was based on seven consecutive cohorts of Year-11 (age 16) GCSE students in England from 2004-2010, with linked post-16 A level data from 2005 through to 2013. This amounts to just over 4.5 million 16-year olds. During this period, the proportion of young people continuing to advanced study (i.e. those that might possibly consider A level Mathematics) rose from around 52% to 63% and similarly, those getting a GCSE Mathematics grade C or above rose from just under 50% to just under 60% over the period.

A proportion of students take three years to complete their A level studies so it was important to include this longer-term data. It was also the case that not all students certificated at AS level and some were re-examined and so can be double counted in the data. Tracking each cohort and limiting an individual's inclusion in the working dataset to a single, highest and/or final outcome provides a clearer understanding of what is happening. One of the drawbacks of this approach is the delay in developing this participation analysis. For example, A level entry figures released in August 2016 included students from the GCSE cohorts of 2013/14/15 but not all of the 2015 cohort will have completed their A level studies until 2018, with the NPD release for this group being January 2019.

Table 2 below shows the breakdown of A level Mathematics completion, by GCSE Mathematics grade and for each of three years from the full dataset. Table 3 delves further into this data to show the differences between boys and girls. The full analysis of the data can be found in Noyes and Adkins (2016b).

| GCSE Maths Grade | Year | No maths | At least AS maths | At least A level maths | At least A level maths and AS further maths | A levels in maths and further maths | Total |
|---|---|---|---|---|---|---|---|
| | 2004 | 6204 (23%) | 21131 (77%) | 19308 (71%) | 6136 (22%) | 4308 (16%) | 27335 |
| A* | 2007 | 4647 (17%) | 22719 (83%) | 20956 (77%) | 7890 (29%) | 5504 (20%) | 27366 |
| | 2010 | 5474 (15%) | 31055 (85%) | 27740 (76%) | 10023 (27%) | 7197 (20%) | 36529 |
| | 2004 | 24853 (51%) | 23720 (49%) | 17185 (35%) | 1782 (4%) | 902 (2%) | 48573 |
| A | 2007 | 29463 (47%) | 33889 (53%) | 24031 (38%) | 2810 (4%) | 1440 (2%) | 63352 |
| | 2010 | 33454 (44%) | 42236 (56%) | 26946 (36%) | 3266 (4%) | 1740 (2%) | 75690 |
| | 2004 | 81735 (85%) | 14404 (15%) | 6294 (7%) | 229 (0%) | 70 (0%) | 96139 |
| B | 2007 | 85276 (85%) | 15196 (15%) | 6387 (6%) | 270 (0%) | 76 (0%) | 100472 |
| | 2010 | 78752 (82%) | 17553 (18%) | 5577 (6%) | 194 (0%) | 85 (0%) | 96305 |
| | 2004 | 89247 (98%) | 2054 (2%) | 414 (0%) | 20 (0%) | 5 (0%) | 91301 |
| C | 2007 | 99333 (99%) | 1552 (2%) | 369 (0%) | 16 (0%) | 5 (0%) | 100885 |
| | 2010 | 116405 (99%) | 1245 (1%) | 235 (0%) | 14 (0%) | 10 (0%) | 117650 |

Table 2: Changing patterns of AS/A level Mathematics participation, by GCSE grade, for year 11 leaving cohorts in 2004, 2007 and 2010. Percentages are included in parentheses. N.B. This includes all students at each GCSE grade, irrespective of whether they progressed to A levels.

| GCSE Grade | Year | No maths | | At least AS maths | | At least A level maths | | At least A level maths and AS further maths | | A levels in maths and further maths | | Total male | Total female |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | F | M | F | M | F | M | F | M | F | | |
| A* | 2004 | 16% | 30% | 84% | 70% | 78% | 62% | 29% | 15% | 22% | 9% | 14493 | 12842 |
| | 2007 | 12% | 22% | 88% | 78% | 83% | 70% | 37% | 21% | 27% | 13% | 13821 | 13545 |
| | 2010 | 10% | 20% | 90% | 80% | 83% | 68% | 36% | 19% | 27% | 12% | 18773 | 17756 |
| A | 2004 | 41% | 62% | 59% | 38% | 45% | 26% | 5% | 2% | 3% | 1% | 24118 | 24455 |
| | 2007 | 37% | 56% | 63% | 44% | 47% | 29% | 6% | 3% | 3% | 1% | 31210 | 32142 |
| | 2010 | 34% | 54% | 66% | 46% | 44% | 27% | 6% | 2% | 4% | 1% | 37761 | 37929 |

Table 3: The percentages of Male/Female students with GCSE grades A* and A in the Year 11 leaving cohorts of 2004, 2007 and 2010 who completed particular levels of post-16 mathematics.

In his March 2016 budget, the Chancellor committed to "….ensure the future workforce is skilled and competitive, including looking at the case and feasibility for more or all students continuing to study maths to 18, in the longer-term."

### *2.2a Findings*

1. GCSE Mathematics grades are the strongest indicator of whether a student will complete AS/A level Mathematics;
2. The GCSE cohorts from 2004 to 2010 saw the numbers of students with A* and A grades rise by 34% and 56% respectively. This is the key driver of growth in AS/A level Mathematics uptake;
3. Of those awarded A level Mathematics from the 2010 GCSE cohort, over 90% had attained an A* or A grade at GCSE;
4. Only around 1% of GCSE Mathematics grade C students completed AS/A level Mathematics;
5. The proportion of GCSE Mathematics grade B students attaining AS/A level Mathematics increased from 15 to18% over the period. This is all explained by increases at AS level - the proportion of GCSE grade B students completing a full A level Mathematics has fallen slightly;
6. Only GCSE A* students have increased their likelihood of completing A level Mathematics and/or Further Mathematics.

### *2.2b Implications and recommendations*

The percentages of students completing AS/A level Mathematics, by GCSE Mathematics grade has not changed significantly over the period in question, with a few exceptions. The increase in A level Mathematics numbers has been driven by the growing proportion of A* and A GCSE grades.

A reformed GCSE Mathematics is now being taught and includes a new grading structure (1-9) that will be implemented for the first time in 2017. One of the goals of the reforms is to make GCSE Mathematics more demanding. This could produce unintended consequences. If students achieve less than the top grades in Mathematics alongside strong grades in other subjects, A level Mathematics uptake will probably reduce.

Secondly, the recent decision to decouple AS and A levels is likely to have a negative impact on the growth in GCSE A and B grade students completing AS Mathematics. Some of those exiting with an AS Mathematics started their post-16 studies open to the idea of completing the full A level. As students are increasingly being encouraged to start only 3 A levels that they will see through to completion, some of these students will now not risk starting what is widely considered to be a more demanding A level. So, although all subject numbers should reduce if the number or entries per person decreases, it might well be that mathematics is impacted more strongly due to the historically high level of AS participation. Careful monitoring of the impact of these reforms is needed.

There remains a need for the new Core Maths qualification to provide attractive mathematics pathways for the GCSE B and C grade students who are no more likely to complete A level Mathematics now than they were 10 years ago. It could also provide an attractive additional element to the portfolio of those GCSE Mathematics A* and A students for whom A level Mathematics is not sufficiently attractive.

## 2.3 Academic value: Predicting degree outcomes

This section considers the extent to which school mathematics qualifications predict undergraduate success in science, in particular biology and chemistry. Many researchers point to a problematic gap between school mathematics and university applications of mathematics within the disciplines (Groen et al., 2015; Heck & Van Gastel, 2006; Tai, Sadler, & Loehr, 2005). Such studies support a general consensus that success in undergraduate science is built upon ‘two pillars’ (Sadler & Tai, 2007): the level of prior mathematics and discipline-specific science knowledge, though some studies demur from this position.

The level of mathematical and scientific competence amongst England's school and university graduates has come under the spotlight in recent years (for example, CBI, 2015). At the same time, a growing body of work has reported the benefits of STEM to individuals and the economy. Gordon Brown called science the 'bedrock' of the economy and ensuing governments have maintained this position through the protection of the science budget and a strong focus on STEM participation in schools and universities. The question that this project sought to answer was whether claims regarding the educational value of attaining A level Mathematics before proceeding to STEM degrees is warranted. The original intention was to undertake this analysis for a wide range of mathematically-demanding subjects but, due to methodological challenges, the focus here is on undergraduate biology and chemistry.

The Royal Society's report on the transition from school/college to university study of STEM subjects urged greater uptake of mathematics at A level in order to facilitate the wide range of science, engineering and technology studies available (see also Hulme & Wilde, 2014). Whilst the logic of this argument seems eminently sensible, there is an underpinning assumption that A level Mathematics per se will enable learners to acquire the sorts of knowledge and skills necessary for undergraduate SET studies.

At this point we foreground a double bind that results in part from the increasingly competitive quasi-market of higher education in England. Given the aforementioned pattern of A level participation in mathematics, many UK undergraduate programmes - even in SET - do not require applicants to have completed A level Mathematics as this would reduce the applicant pool. Departments include mathematics in their programmes, e.g. 'maths for chemists'. This action might be interpreted in two ways. Either universities are resigned to issues of poor mathematics preparation because they can teach discipline-specific mathematics to students with a stronger motivation to learn and they recognise the problem of transfer from school to scientific degree study, mediating this accordingly. Alternatively, universities might consider this teaching as remedial and unnecessary if all students had completed A level Mathematics. Disentangling these two positions is not easy.

The research question is as follows: does having A level Mathematics increase the probability of gaining a first-class degree in biology or chemistry in England's universities? We were also interested to know whether the level of achievement in A level Mathematics matters, and whether any effect of having A level Mathematics varies by university. Consider, for example, two 16-year-old girls from similar schools and social backgrounds. They have near identical GCSE grade profiles including an A grade in mathematics. Jane proceeds to study A levels in Chemistry, Biology and Psychology whilst Alice chooses Mathematics, Chemistry and Geography and they both gain grades AAB. They meet each other at university as they start their Chemistry degrees. Will the fact that Alice completed A level Mathematics make her any more likely to achieve a first class degree? The models below are not concerned with any one pair of such students but rather the averages. The multiple other factors - many of them unknowable or unmeasurable - that make Alice and Jane unique will of course have more influence on their degree outcome than just possessing A level Mathematics.

The dataset for this analysis started from an National Pupil Database request including all pupils in England in the Year 11 (age-16) cohort of 2005/6 along with their AS and A level results in years 2006/7 through to 2008/9. This group was linked to the Higher Education

Statistics Agency (HESA) database up to the academic year 2012/2013. The dataset included ethnicity, the Income Deprivation Affecting Children Index (IDACI) and the free school meal indicator at age 16. The HESA data included the title and category of the degree, degree classification, level of study, institution, gender, ethnicity, socio-economic classification and POLAR3, a postcode-based measure of the level of participation in higher education. Following careful data cleaning, a final sample of 6464 students with Biology degrees (including Genetics, Microbiology, Molecular Biology, Biophysics, Biochemistry and Zoology) from 96 universities, and 1980 with Chemistry degrees from 61 universities was used in the analysis.

Multilevel models were developed for each of the two sciences showing the effects of various changes in demographic and educational background data[4]. Figure 1 presents a summary of the model parameter estimates for biology and chemistry graduates. The parameter values are shown by estimates and credible intervals (95%).

#### *2.3a Findings*

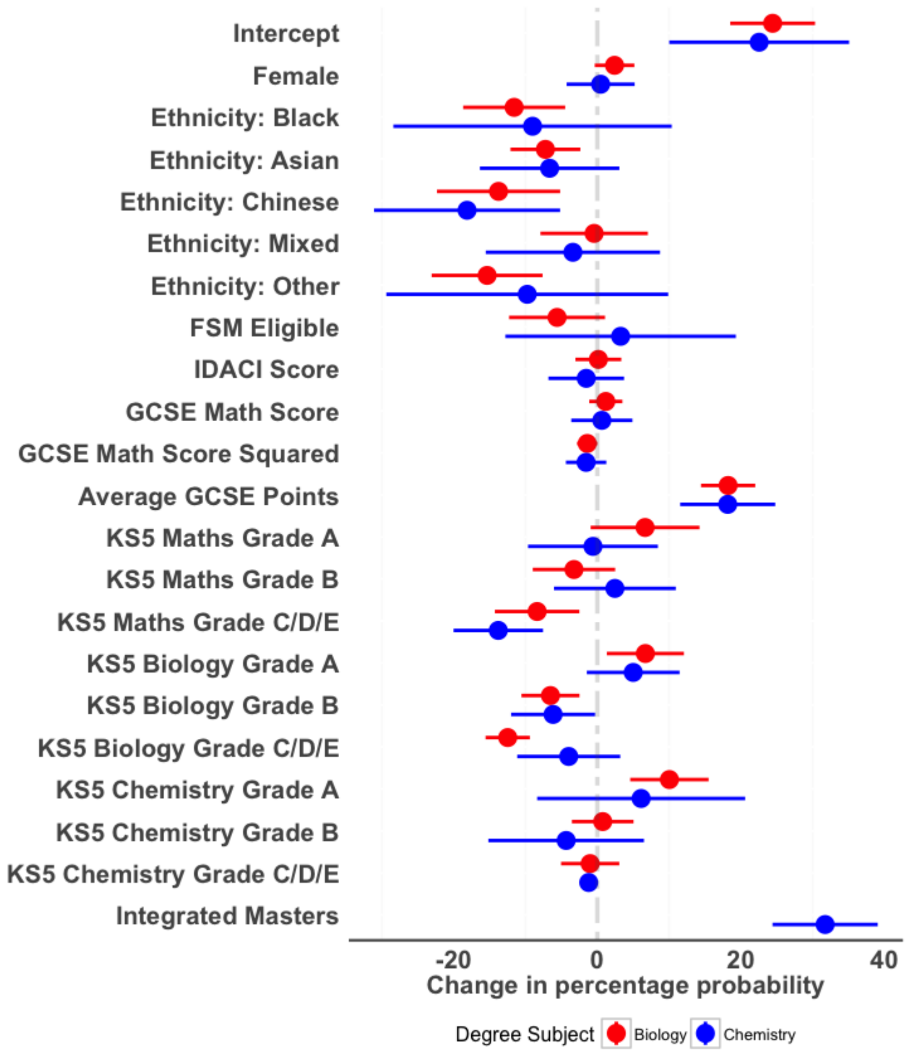
Based on analysis of the above dataset the following conclusions can be drawn:

1. Having A level Mathematics does not consistently predict degree outcomes in biology and chemistry. Only biology students with top grades in A level Mathematics are more likely to achieve the better degree classifications than those without A level Mathematics, though the effect is a small one;
2. Those with low grades in A level Mathematics (C-E), achieve lower degree outcomes than those without A level Mathematics;
3. High attainment in A level Chemistry (i.e. grade A) is associated with higher chances of gaining a first class degree in biology and vice versa, though the evidence is less compelling for the effect of A level Biology grade A on undergraduate chemistry;
4. Ethnic minority students on biology and chemistry undergraduate programmes in England are substantially less likely to attain a first class degree than White groups in nearly all cases;
5. In biology, females have a small increased chance (2.4%) of attaining a first class degree. There is not a clear gender difference in chemistry;
6. Social class differences in attaining a first class degree are not particularly clear, though there is some evidence that for biology degrees those from lower socioeconomic status backgrounds do a little less well;

[4] Further details of the dataset, the data cleaning, imputation and modelling processes can be found in a working paper at https://www.nottingham.ac.uk/research/groups/crme/projects/revamp.aspx

7. General academic attainment, as evidenced in the average GCSE score, is a strong indicator of likely performance at degree level, but there is no evidence that GCSE Mathematics attainment can be distinguished from general attainment at that age as a predictor;
8. The university attended has a much greater bearing upon a student's chances of attaining a first class degree than does their participation, or attainment, in A level Mathematics. For the reference group this probability can range from around 7 to 51% in biology and 5-48% in chemistry degrees.

Figure 1: Parameter estimates for the model variables indicating the percentage change in the probability of attaining a first class degree (A level here shortened to KS5, Key Stage 5)



At first glance, these results may seem counterintuitive. Possible explanations include the following:

- mathematical aptitude is more important that specific qualifications. Those with good general academic ability at GCSE (including mathematics) have sufficient intellectual resources to handle the mathematics that they encounter in their degree programmes;
- A level Mathematics content and techniques might not be that relevant or easily transferred to the undergraduate biology or chemistry context;
- there are differences in undergraduate module pathways and course experiences, both within and between universities. Less mathematically confident students chose, or are directed to, less mathematically demanding pathways;
- universities are better placed to teach discipline-specific mathematics and do it more effectively with better motivated students. Any initial differences in A level completion are smoothed, but underlying mathematical competence and confidence remains important;

### *2.3b Implications and recommendations*

Educational transitions are complex and the mathematical needs of learners moving between school and university SET programmes are no exception. Recent A level qualification reforms have mandated that a proportion of new science qualifications must assess relevant mathematical applications within that discipline (DfE, 2014). It remains to be seen whether this mathematical *embedding* strategy will improve mathematical continuity into undergraduate SET studies.

The government’s commitment to ensuring continued study of mathematics up to the age of 18 for all young people is laudable. New Core Maths qualifications are key to realising the government’s ’maths for all’ vision, especially for students on academic study pathways. This strand of the REVAMP project raises questions over what the most appropriate mathematics preparation is for undergraduate study in a range of disciplines. There has long been a view that A level Mathematics is the best preparation for mathematically-demanding courses of study, but our evidence suggests that this needs further consideration.

> “We recommend that...the Government make studying maths in some form compulsory for all students post-16. We recommend also that maths to A2 level should be a requirement for students intending to study STEM subjects in HE.”
>
> House of Lords' Select Committee on Science and Technology (2012, paragraph 32)

### 2.4 Political value: Policy and public discourses of the value of mathematics

Much has been written about the relationship between social research and public policy (e.g. Nutley, Walter, & Davies, 2007) and this includes a sustained discussion in education (see Lingard, 2013; Lubienski, Scott, & DeBray, 2014; Orland, 2009; Saunders, 2007, for more recent examples). This strand of the REVAMP project explored how econometric research in mathematics education (i.e. Dolton and Vignoles' work) that was dormant for many years become topical and was reframed to suit policy.

Using a theatrical metaphor, Carol Weiss argued that research is a "supporting player in the drama of policy making. The empirical question is under what conditions research gets on the stage at all, and when it does, what consequences it has for the unfolding action" (1991, p. 308). We use this post-16 mathematics case to illuminate the setting - staged and/or improvised - of this particular policy drama. Although this is a case of policy-informing research, Dolton and Vignoles' work was originally policy-driven research, what Lingard (2013) terms 'research *for* policy'. So, whilst it is the reappearance onto the policy stage that was of interest, the motivation for the original research shouldn't be forgotten.

It would seem, based on experience in and around research and policy advisory work, that research has limited chance of impact without brokerage across pre-existing or emerging networks. These tangled webs of 'bridgers and brokers' (Ball & Exley, 2010) or 'boundary spanners' (P. Williams, 2002), which nowadays includes a diverse array of researchers, think tanks, advocacy groups, philanthropists and the like, are part of the new forms of networked governance (Ball, 2008, 2009; Ball & Junemann, 2012) that make the analysis of policy work challenging.

There have been numerous reports from government departments, charities, learned societies and think tanks since Curriculum 2000 that have tried to understand and/or offer recommendations on how to tackle the challenge of increasing mathematics uptake post-16. This aspect of the project began with the grand aim of exploring the changing discourses in these literatures in order to understand how the current policy discussions are framed. In the end we investigated this framing by focusing on one important piece of research – Dolton and Vignoles econometric analysis – in order to understand how this idea became *adopted* and *adapted* by various stakeholders.

A database of reports, statements, press releases, media coverage, government papers and the like that pertain – directly or indirectly - to upper secondary school mathematics (14-19) was compiled. We drew upon policy sociology to develop a critical interpretation of the trends in post-16 mathematics education policy and advisory work. By tracing these discourses over the years we aimed to understand how the key influencers and influences have framed the debates and likely future of post-16 mathematics. The full version of the analysis is reported in Noyes and Adkins (2016a).

*The big picture*

**1999** New Labour Government (from 1997) has continued neoliberal education policy direction from previous Conservative government; national review of 16-18 qualifications led by Lord Dearing (1996) has precipitated major reform, i.e. Curriculum 2000; Dolton and Vignoles' research first published.

**2000-2004** Curriculum 2000 impacts qualification landscape; 'disastrous' (Smith, 2004) reduction in A level Mathematics numbers requires immediate remediation; increasing number of reports on importance of STEM to economic security (Roberts, 2002); Wolf cites Dolton and Vignoles' research in 'Does Education Matter' (2002).

**2004** Tomlinson Report (DfES, 2004) recommendations on 14-19 education rejected; Smith Report (Smith, 2004) on post-14 mathematics published and will lead to flurry of activity; A level Mathematics participation rising gradually.

**2004-2010** The Maths Pathways Project (following 'Smith') produces lengthy programme of curriculum and qualification development but ultimately has little impact; The Reform Group publishes 'The Value of Mathematics' (Kounine et al., 2008); A level Mathematics numbers rising, mainly as a result of larger cohorts and higher proportion of top grades at GCSE.

**2010** General election and new coalition government; Wolf Report (2011) on vocational education commissioned; Nuffield Foundation publishes widely cited 'Outliers' report (Hodgen et al., 2010) on post-16 mathematics participation.

**2011** Conservative-commissioned Vorderman Report (2011) published; Michael Gove's (2011) Royal Society speech sets out vision that "within a decade the vast majority of pupils are studying maths right through to the age of 18".

**2012** Truss becomes junior minister at the Department for Education; during a short term in office Truss advocates strongly for mathematics, particularly A level and new Core Maths qualifications.

### *2.4a Findings*

Weiss (1991) describes 'the extraordinary concatenation of circumstances' by which research impacts policy. She suggests that research can shape policy as 'data, ideas or argument' and these can all be seen in this case. More recently, Orland (2009, p. 136) identified three conditions for research to be used in policymaking: *rigour, relevance and usefulness* and we want to expand on these ideas*.*

This case study highlights how key players, relationships, and conditions have been important in the influence of this research on policy. We synthesise the various points from the analysis into a typology of ways in which this particular research has been *adopted* but also *adapted*.

There are six reasons why Dolton and Vignoles work was adopted by policymakers:

1. The main research findings are simple and/or simplifiable:
2. The research is persuasive**;**
3. Key connections are made;
4. The research harmonises with policy ideology;
5. The implications of the research are workable;
6. The research has interested champions**.**

In addition to these six conditions for research *adoption*, this research was *adapted* when it interacted with policy priorities. These are more general principles and can either be intentional in the form of omissions and distortions or accidental through the 'Chinese whispers' that occur as ideas and people flow across policy networks.

Four main themes of *adaptation* can be identified from this case and we are confident that these are characteristic of the research-policy interface in other areas:

1. Decontextualisation: ignorance of the historical, economic and cultural context

   The policy discourse around this research does not acknowledge the historical context. Social research is temporally and culturally framed and losing sight of this increases the risk of misapplication.

2. Partiality: only using the convenient parts of the research

   a) The elision of mathematics and computing in the original research has been lost. Although this is not surprising it could be considered a missed opportunity now that ministers are concerned to re-establish computing (i.e. programming) in schools.

   b) Partiality can also consist in selective use of statistical results. The ranges reported in the original research have disappeared and the 'return' is now a fixed 10%, or 'around 10%' and reflects a bias towards a more politically expedient result. Moreover, there is a tendency to strip out the inherent uncertainty in any such statistical analysis, for example confidence intervals. So it is that "the original research findings are reduced to a simple 'story', qualifying statements are lost, and the conclusions are often stretched beyond the findings of the study" (Weiss, 1991, p. 311)

3. Overgeneralisation**:**

   *a) To time*: Nicky Morgan's claim about earnings over lifetimes is an example of overgeneralization (see over). All that can be said is that in 1991, amongst a small sample of men born in 1958, those who had completed an A level in mathematics or computing in 1975 were earning, on average, between 7 and 10% more than their A level peers who had not taken mathematics or computing.

b) *To other subjects*: Dolton and Vignoles' work identified A level Mathematics as having a unique effect. It is particularly interesting that science A levels did not have any wage return (although it is likely that physics and biology behave very differently in this regard).

4. Misinterpretation**:**

   Misinterpretation is a potential consequence of research being simple and simplifiable. In this present case, the notion of causality is a pertinent example. What cannot be implied from this research is that a young person aged 16 in 2016 who is persuaded to change their A level choices to include mathematics on the basis of this research will, as a result, be earning 7-10% more than their non-A level Mathematics peers in 2033. Yet this is the tenor of the politicians' position.

### *2.4b Implications and recommendations*

The concerns addressed in this strand of the REVAMP project were in large part motivated by our position as researchers: how does one stimulate engagement with one's research and maximise the chances of its subsequent impact. This case highlights the unpredictable nature of this knowledge transfer dynamic and offers a framework for considering the likely impact of research upon policy.

The analysis highlights a more fundamental problem with the ways in which social research findings – which are almost always complex and nuanced – get *adapted* in the process of reducing them to easily communicable and catchy sound bites that are useful for rationalising policy decisions.

> "…maths, as we all know, is the subject that employers value most, helping young people develop skills which are vital to almost any career. And you don't just have to take my word for it – studies show that pupils who study maths to A level will earn 10% more over their lifetime" (Morgan, 2014).

### 2.5 Perceived value: student attitudes and ascription of value

This final section reports the findings from the national survey. In order to ensure good response rates to our survey, we worked closely with key contacts at over 100 schools/colleges across England. This sample was created from an initial random selection of around 10% of the schools/colleges offering A level Mathematics (with N<10 removed). Only around half of those agreed to participate in the study. The full population in each of these colleges is not known or whether the pattern of missingness is biased against those not studying mathematics. That said, the final dataset of around 10000 had similar patterns of engagement to those reported in Section 2.2 above.

Through several iterations of the survey and advice from the project's advisors, a pilot-ready version was developed. It was kept as short as possible to increase completion rates and minimise void responses with a maximum completion time of 10 minutes, i.e. short enough to be completed in a registration period at the start of the day. Further details about the process can be found in Noyes and Adkins (2016c).

The survey gathered students' examination data at age 16 (GCSE level); their current pattern of study and the qualifications being undertaken; whether they had moved institution following GCSEs; and, their aspirations for education or work beyond school/college. Basic demographic data were collected and included ethnicity and a social class measure (i.e. parental level of education). The survey made use of items from TIMSS, the Trends in International Mathematics and Science Survey (Sturman, Burge, Cook, & Weaving, 2012). This had the advantage of working with pre-tested items and also allowed for some comparison, where appropriate, with those surveys. Some of the items required minor modification because of the different target age group.

One of the design difficulties when surveying this sample is that, unlike in TIMSS, these students now have different relationships to mathematics. Students might be studying A level Mathematics, or they might have failed their GCSE and so be retaking that qualification, or, they might not be studying mathematics at all. These are very different categories of respondent and because we are interested in attitudes to advanced mathematics study we removed the GCSE retake students from the data frame. That left two groups: those actively engaged in AS/A level Mathematics and those who have, for whatever reason, ceased their study of the subject.

### *2.5a Findings*

1. Students are generally opposed to the idea that they should be compelled to study 'some maths' post-16 (78%) but are less opposed to being encouraged to do so.
2. 80% of the target group for Core Maths, i.e. those not currently studying AS/A level Mathematics, disagree with the idea of making mathematics compulsory post-16.
3. Students who have taken A level Mathematics are more likely to report finding their GCSE Mathematics experience to have been interesting, enjoyable and relatively easy.
4. The vast majority (94%) recognise that it is important to do well in mathematics.
5. High proportions of students in the sample who are planning to proceed to STEM degrees are studying A level Mathematics (Physics 93%, Engineering 89%, Chemistry 82%, Medicine 77%, Computing 62% and Biology 49%)

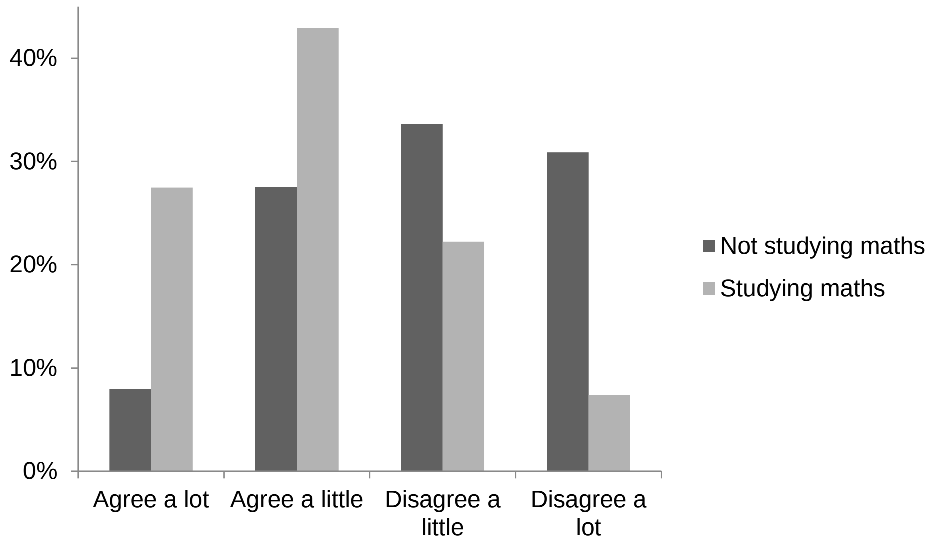



Figure 2: Percentage responses to the question ‘All students should be **encouraged** to study some maths up to age 18’, split according to whether studying advanced mathematics or not in Year 12.

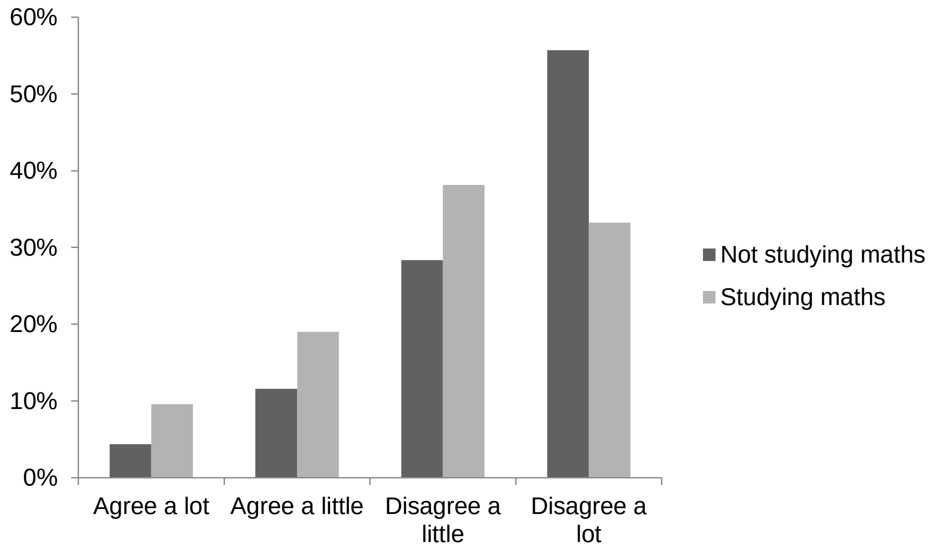



Figure 3: Percentage responses to the question ‘All students should **have** to study some maths up to age 18’, split according to whether studying advanced mathematics or not in Year 12.

“Government needs to ensure that all young people, regardless of what route they choose, study some form of maths or numeracy education after 16” (CBI, 2009)

### *2.5b Implications and recommendations*

Those studying AS/A level Mathematics report more positive views of GCSE Mathematics and were happier with their GCSE results than those not studying A level. With the GCSE Mathematics grade being the strongest predictor of AS/A level completion, the importance of good experiences in GCSE mathematics and the need for alternative pathways are clear.

The reformed GCSE that will first be examined in 2017 is intended to be more demanding and might well impact negatively upon attitudes and experiences and thereby post-16 engagement. When students make their post-16 choices the options are not ‘maths versus not-maths’ but ‘maths versus other subjects’. As long as students have a choice of study pathways their experiences of, and grades in, GCSE Mathematics will have a major impact upon post-16 mathematical engagement.

The ‘maths for all to 18’ goal will not be realised whilst students can choose to *not* study mathematics. Well-designed strategies need to be enacted to effect this change, whether in the form of new curricular structures (e.g. a baccalaureate) or incentives at the individual or institutional level. Investment in staffing and professional development as well as funding for mathematics to be studied as a fourth subject is needed to ensure the success of this step-change in post-16 mathematics education.

A parsimonious range of attractive and engaging mathematics qualifications for all learners needs to have *use value* for learners and *exchange value* for employers and higher education. If university admissions tutors are not persuaded of the usefulness of new Core Maths qualifications they are unlikely to succeed.

There are clear links between students’ attitudes towards mathematics, their ongoing engagement with the subject and their educational, career and life trajectories. The quality of GCSE Mathematics is central to the project of increasing mathematical competence. The impact of new GCSE and AS/A level qualifications need to be monitored in order to mitigate the risks of unintended consequences on uptake.

## 3. Project Publications

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

Noyes, A. & Adkins, M. (2016). Reconsidering the rise in A level mathematics participation. *Teaching Mathematics and its Applications*. 35(1), 1-13. DOI: 10.1093/teamat/hrv016

Noyes, A. & Adkins, M. (2016). Studying advanced mathematics in England: findings from a survey of student choices and attitudes. *Research in Mathematics Education.* 18(3), 231-248.  DOI: 10.1080/14794802.2016.1188139

Noyes, A. & Adkins, M. (2016). The Impact of Research on Policy: A Case of Qualifications Reform. *British Journal of Educational Studies*, 1-17. doi:10.1080/00071005.2016.1159654

Adkins, M. & Noyes, A. (2017). Do Advanced Mathematics Skills Predict Success in Biology and Chemistry Degrees? *International Journal of Science and Mathematics Education, in press.*

The project website www.nottingham.ac.uk/research/groups/crme/projects/revamp.aspx contains links to these papers and other project documentation.

## 4. References


ACME. (2012). *Post-16 Mathematics: a strategy for improving provision and participation*. Retrieved from London: http://www.acme-uk.org/media/10520/20121217acme_post_16_strategy.pdf

Adkins, M., & Noyes, A. (2016). Reassessing the economic value of Advanced level Mathematics. *British Educational Research Journal, 42*(1), 93-116.

Attridge, N., & Inglis, M. (2013). Advanced mathematical study and the development of conditional reasoning skills. *PLoS ONE, 8*(7). doi:10.1371/journal.pone.0069399

Ball, S. (2008). New Philanthropy, New Networks and New Governance in Education. *Political Studies, 56*(4), 747-765. doi:10.1111/j.1467-9248.2008.00722.x

Ball, S. (2009). Privatising education, privatising education policy, privatising educational research: network governance and the 'competition state'. *Journal of Education Policy, 24*(1), 83-99. doi:10.1080/02680930802419474

Ball, S., & Exley, S. (2010). Making policy with 'good ideas': policy networks and the 'intellectuals' of New Labour. *Journal of Education Policy, 25*(2), 151-169.

Ball, S., & Junemann, C. (2012). *Networks, new governance and education*. Bristol: The Policy Press.

CBI. (2009). *Stronger together: businesses and universities in turbulent times*. Retrieved from London: https://globalhighered.files.wordpress.com/2009/09/cbi_he_taskforce_report.pdf

CBI. (2015). *Inspiring growth: CBI/Pearson education and skills survey 2015*. Retrieved from London:

Dearing, R. (1996). *Review of Qualifications for 16-19 Year Olds*. Hayes, Middlesex: SCAA Publications.

DfE. (2011). *Maths and science education: the supply of high achievers at A level*. London: Department for Education.

DfE. (2014). *GCE AS and A level subject content for biology, chemistry, physics and psychology*. London Department for Education.

DfES. (2004). *14-19 Curriculum and Qualifications Reform: final report of the working group on 14-19 reform.* London: Department for Education and Skills.

Dolton, P., & Vignoles, A. (1999). *The economic case for reforming a levels (CEPDP, 422)*. London: Centre for Economic Performance, London School of Economics and Political Science.

Dolton, P., & Vignoles, A. (2002). The return on post–compulsory school mathematics study. *Economica, 69*(273), 113-142.

Exley, S. (2014, 14th August 2014). A-level results 2014: Maths overtakes English to become most popular subject. *TES*. Retrieved from https://www.tes.co.uk/news/school-news/breaking-news/a-level-results-2014-maths-overtakes-english-become-most-popular

Gibb, N. (2015). School Reform Minister Nick Gibb speaks to the London Thames Maths Hub Primary Conference. Retrieved from https://www.gov.uk/government/speeches/nick-gibb-speech-on-governments-maths-reforms

Gove, M. (2011). Michael Gove speaks to the Royal Society on maths and science. Retrieved from http://www.education.gov.uk/inthenews/speeches/a00191729/michael-gove-speaks-to-the-royal-society-on-maths-and-science

Groen, L., Coupland, M., Langtry, T., Memar, J., Moore, B., & Stanley, J. (2015). The mathematics problem and mastery learning for first-year, undergraduate STEM students. *International Journal of Learning, Teaching and Educational Research, 11*(1).

Hawkes, T., & Savage, M. (1999). *Measuring the mathematics problem*. London: The Engineering Council.

Heck, A., & Van Gastel, L. (2006). Mathematics on the threshold. *International Journal of Mathematical Education in Science and Technology, 37*(8), 925-945.

Hodgen, J., Pepper, D., Sturman, L., & Ruddock, G. (2010). *Is the UK an Outlier?* London: Nuffield Foundation.

Hulme, J., & Wilde, J. d. (2014). *Tackling transition in STEM disciplines: Supporting the Science, Technology, Engineering and Mathematics (STEM) student journey into higher education in England and Wales.* Retrieved from York:

Jones, I., Wheadon, C., Humphries, S., & Inglis, M. (2016). Fifty years of A-level mathematics: have standards changed? *British Educational Research Journal, 42*(4), 543-560. doi:10.1002/berj.3224

Kounine, L., Marks, J., & Truss, E. (2008). *The Value of Mathematics*. London: REFORM.

Lakoff, G. (1993). The contemporary theory of metaphor. In A. Ortony (Ed.), *Metaphor and Thought* (2nd ed., pp. 202-251). Cambridge: Cambridge University Press.

Lingard, B. (2013). The impact of research on education policy in an era of evidence-based policy. *Critical Studies in Education, 54*(2), 113-131. doi:10.1080/17508487.2013.781515

Lubienski, C., Scott, J., & DeBray, E. (2014). The Politics of Research Production, Promotion, and Utilization in Educational Policy. *Educational Policy, 28*(2), 131-144. doi:10.1177/0895904813515329

Morgan, N. (2014). Nicky Morgan speaks at launch of Your Life campaign. Retrieved from https://www.gov.uk/government/speeches/nicky-morgan-speaks-at-launch-of-your-life-campaign

Norris, E. (2012). *Solving the maths problem: international perspectives on mathematics education*. London: RSA/OCR.

Noyes, A. (2009). Exploring social patterns of participation in university-entrance level mathematics in England *Research in Mathematics Education, 11*(2), 167-183.

Noyes, A. (2013). The effective mathematics department: adding value and increasing participation? *School Effectiveness and School Improvement, 24*(1), 87-103.

Noyes, A., & Adkins, M. (2016a). The Impact of Research on Policy: A Case of Qualifications Reform. *British Journal of Educational Studies*, 1-17. doi:10.1080/00071005.2016.1159654

Noyes, A., & Adkins, M. (2016b). Reconsidering the rise in A-level mathematics participation. *Teaching Mathematics and its Applications, 35*(1), 1-13.

Noyes, A., & Adkins, M. (2016c). Studying advanced mathematics in England: findings from a survey of student choices and attitudes. *Research in Mathematics Education, 18*(3), 231-248.

Noyes, A., & Sealey, P. (2012). Investigating participation in Advanced level mathematics: a study of student drop out *Research Papers in Education, 27*(1), 123-138.

Noyes, A., Wake, G., & Drake, P. (2011). Widening and increasing post-16 mathematics participation: pathways, pedagogies and politics. *International Journal of Science and Mathematics Education, 9*, 483-501.

Nutley, S., Walter, I., & Davies, H. (2007). *Using Evidence: how research can inform public services*. Bristol: Policy Press.

OECD. (2010). *PISA 2009 Results: What students know and can do: student performance in reading, mathematics and science (Volume I)*. Retrieved from Organisation for Economic Cooperation and Development: http://www.oecd.org/pisa/pisaproducts/48852548.pdf

Orland, M. (2009). Separate orbits: The distinctive worlds of educational research and policymaking. In G. Sykes, B. Schneider, D. Plank, & T. Ford (Eds.), *Handbook of education policy research* (pp. 113-128). New York: Routledge.

Porkess, R., & Lee, S. (2009). *A Level Mathematics & Further Mathematics: an investigation into the reasons for increased uptake in 2009*. Retrieved from http://www.mei.org.uk/files/pdf/a_level_uptake.pdf

REFORM. (2010). *The Misuse of Mathematics*. London: Educators for Reform.

Roberts, G. (2002). *SET for success: The supply of people with science, technology, engineering and mathematics skills*. London: Department for Education and Science.

Royal Society. (2008). *Science and mathematics education 14-19: A 'state of the nation' report on the participation and attainment of 14-19 year olds in science and mathematics in the UK*. London: The Royal Society.

Sadler, P. M., & Tai, R. H. (2007). The two high-school pillars supporting college science. *SCIENCE, 317*(5837), 457.

Saunders, L. (2007). *Educational research and policy-making: exploring the border country between research and policy*. London: Routledge.

Smith. (2004). *Making Mathematics Count*. London: The Stationery Office.

Smith, A. (2006). Maths fuels rise in top grades at A-level. *The Guardian*. Retrieved from http://www.theguardian.com/education/2006/aug/17/schools.alevels

Sturman, L., Burge, B., Cook, R., & Weaving, H. (2012). *TIMSS 2011: mathematics and science achievement in England*. Slough: NFER.

Tai, R. H., Sadler, P. M., & Loehr, J. F. (2005). Factors influencing success in introductory college chemistry. *Journal of Research in Science Teaching, 42*(9), 987-1012.

The British Academy. (2012). *Society Counts: quantitative skills in the social sciences and humanities*. London: BA.

Vasagar, J. (2011). A-levels boom in maths and science credited to 'Brian Cox effect'. *The Guardian*. Retrieved from http://www.theguardian.com/education/2011/aug/18/a-levels-boom-maths-science

Vorderman, C., Budd, C., Dunne, R., Hart, M., & Porkess, R. (2011). A world-class mathematics education for all our young people. Retrieved from http://www.tsm-resources.com/pdf/VordermanMathsReport.pdf

Weiss, C. (1991). Policy research: data, ideas or arguments? In P. Wagner & C. Weiss (Eds.), *Social sciences and modern states: national experiences and theoretical crossroads* (pp. 307-332). Cambridge: Cambridge University Press.

Williams, J. (2012). Use and exchange value in mathematics education: contemporary CHAT meets Bourdieu's sociology. *Educational Studies in Mathematics, 80*(1), 57-72.

Williams, J., Wake, G., Black, L., Davis, P., Hernandez-Martinez, P., Hutcheson, G., & Nicholson, S. (2008). TLRP Research Briefing No 38: Keeping open the door to mathematically demanding programmes in Further and Higher Education. Retrieved from http://www.lta.education.manchester.ac.uk/TLRP/Research%20Briefing.pdf

Williams, P. (2002). The competent boundary spanner. *Public Administration, 80*(1), 103-124. doi:10.1111/1467-9299.00296

Wolf, A. (2002). *Does Education Matter? Myths about education and economic growth*. London: Penguin.

Wolf, A. (2011). Review of Vocational Education - the Wolf Report. Retrieved from https://www.education.gov.uk/publications/eOrderingDownload/The%20Wolf%20Report.pdf