[XTX]
MARKETS

MATHS EXCELLENCE PATHWAYS

PHILANTHROPY | 2023

This report aims to set out a comprehensive overview of the maths pipeline and an approach for supporting more students to achieve maths excellence, especially those from under-represented groups.

This report brings together two pieces of work. First, XTX Markets commissioned the University of Nottingham (Andrew Noyes, Christopher Brignell, Laurie Jacques, Jake Powell and Michael Adkins) to undertake a piece of original research. Their work included secondary data analysis, a review of evidence, stakeholder interviews and a mapping of interventions. Their resulting paper is ***The Mathematics Pipeline in England: Patterns, Interventions and Excellence*** (the "Nottingham Report").

Then, XTX Markets combined parts of the Nottingham Report with an overview of its own approach to supporting maths excellence, producing this second paper ***Maths Excellence Pathways*** (the "XTX Markets Report"). Large sections of the Nottingham Report have been directly reproduced, summarised, edited or lightly adapted, including the majority of the diagrams and their analyses. Many substantive points are attributable to the University of Nottingham team, who have approved the approach to repurposing their work for this publication.

Although the XTX Markets Report overlaps considerably with the Nottingham Report, it should not be taken as representing the views of the original authors or the University of Nottingham. Anyone citing this XTX Markets Report is strongly encouraged to read and acknowledge the Nottingham Report and its authors.

Contents

1. Executive Summary

This XTX Markets report, *Maths Excellence Pathways*, aims to set out a comprehensive overview of the maths pipeline and an approach for supporting more students to achieve maths excellence, especially those from under-represented groups.

The **maths pipeline** can be defined as the set of outcomes attained and courses chosen as cohorts of students progress through their education. This report uses longitudinal data to take a high-level view of the maths pipeline in England. First, as a compulsory subject from the start of reception to the end of KS4. Then, as an optional post-16 subject, studied in sixth forms, colleges and universities.

Each student follows a **pathway** through the maths pipeline. For example, some students attain low grades and choose to drop maths at 16, others attain top grades and choose to study maths at university. This report has a particular focus on the **maths excellence pathway**, the milestones for which are taken here to include top grades in KS1, KS2, GCSE and A-level maths, and completing a maths degree.

This report has four aims: (i) To describe the whole maths pipeline; (ii) To identify the extent to which different groups of students excel at each stage of the pipeline; (iii) To examine patterns of under-representation in the maths excellence pathway; and (iv) To explore how to support more students to achieve maths excellence, especially those from under-represented groups.

Sections 3 and 4 give an overview of maths education in England and explain the methodology used to describe the maths pipeline and the maths excellence pathway. Section 4 includes the majority of the quantitative analysis in this report, as well as the resulting recommendations from XTX Markets.

The analysis emphasises the importance of prior attainment in the maths excellence pathway. Attaining a top grade in A-level maths was a strong predictor of completing a maths degree and, looking further back, the students who completed A-level maths had also nearly all attained top grades in KS2 and GCSE maths.

However, thousands of students joined or left the maths excellence pathway at different stages, highlighting that students can be supported to change trajectory. For example, over 20,000 students attained below level 3 in KS1 maths in 2007/08 but went on to complete A-level maths.

The analysis also examines the distribution and retention rates of different groups of students at each stage of the maths excellence pathway, focusing on disadvantage, gender and ethnicity.

Disadvantage

Students from more deprived areas were under-represented in the top grades in maths throughout school. Compared to students in IDACI quintile 1 (the most deprived), students in quintile 5 (the least deprived) were 2.6 times more likely to attain level 3+ in KS1 maths and 2.7 times more likely to attain grade 7-9 in GCSE maths. They also were 2.5 times more likely to complete A-level maths.

Lower quintiles stand out as having smaller net growth in the number of top grades from KS2 to GCSE maths. Quintile 5 added 4,400 net students from KS2 to GCSE maths, whereas quintile 1 only added 600 net students. Lower quintiles also had higher attrition rates among previously high-attaining students. For example, 5,000 quintile 1 students who had attained level 5U-6 in KS2 maths did not go on to attain grade 7-9 in GCSE maths.

However, once prior attainment is controlled for, an interesting pattern emerges at post-16. Among all students who attained grade 7-9 in GCSE maths, the A-level maths completion rate did not vary significantly by IDACI quintile or FSM eligibility. Moreover, students from lower SECs who attained A-A* in A-level maths were 8ppts more likely to choose a maths degree, compared to those from the highest SEC (21% vs 13%).

This report calls on educators and policymakers to prioritise supporting students to join and stay on the maths excellence pathway from KS2 to GCSE. This should be sustained throughout 11-16 and focus especially on FSM eligible students who attain level 5U-6 in KS2 maths each year. (N = 13,000 in 2011/12).

This report calls for more interventions to support disadvantaged students to choose and excel in A-level maths and further maths, after which they are disproportionately likely to choose maths degrees.

This report also calls for more interventions to support disadvantaged students to succeed in maths degrees, where they currently have lower completion rates compared to their more advantaged peers.

Gender

Female students were under-represented in the top grades in primary maths but drew level in GCSE maths. From KS2 to GCSE, there was a net increase of 10,000 female students who attained top grades in maths. Overall, female students who attained level 5U-6 in KS2 maths were 4ppts more likely to attain grade 7-9 in GCSE maths than male students with the same prior attainment.

However, female students disproportionately opted out of the maths excellence pathway at A-level and degree-level. Roughly the same number of female and male students attained grade 7-9 in GCSE maths, but those female students were 20ppts less likely to complete A-level maths (41.7% vs 61.3%). Among all students who attained A-A* in A-level maths, female students were 4ppts less likely than male students to choose a maths degree (13% vs 17%).

This report calls for more interventions to positively engage female students in maths and support them to choose to study maths at A-level and degree-level. This should be sustained throughout 5-18 and develop maths as a relatable, aspirational choice.

This report also calls for further analysis around the A-level choice structure, especially as it relates to A-level maths and further maths. This should reflect on the incentives that it creates for students and schools, as well as the provision of guidance on subject and career choices.

Ethnicity

Asian, mixed and white students had fairly similar representation at level 5U-6 in KS2 maths, while black students were under-represented by around 7ppts compared to the other ethnic groups. Once at secondary school, a notably high proportion of Asian students attained grade 7-9 in GCSE maths and completed A-level maths. During that same phase, the representation of black students improved relative to mixed and white students, first narrowing the gap in grade 7-9 in GCSE maths, then achieving parity in A-level maths completion rates.

White students had the lowest retention of high-attaining GCSE students going on to complete A-level maths. However, white students had the highest maths degree completion rate, when considering the overall group. Although high-attaining Asian students had comparably high retention rates from GCSE to A-level maths, this did not translate into comparably high maths degree completion rates as an overall group. After the significant increase in attainment during secondary school, black students had relatively lower maths degree completion rates as an overall group.

This report does not draw any conclusions regarding under-representation in the maths excellence pathway by ethnicity, in part due to limited data. However, it does recommend topics for further inquiry, including parental attitudes.

Building on the earlier quantitative analysis, Section 5 further explores several themes in the maths pipeline, including: participation and attainment, maths teaching and teachers, attitudes to maths and transitions between stages. It provides additional context and reflects on why patterns of under-representation persist, drawing on the academic literature, expert feedback and case studies.

Finally, Section 6 sets out how XTX Markets is supporting maths excellence through its philanthropy, including an overview of its objectives and strategic approach. The report then concludes with a summary of XTX Markets' future plans in this space.

2. Why XTX Markets is Focusing on Maths Excellence

XTX Markets is an algorithmic trading firm, headquartered in London. It provides liquidity to markets through a fully automated electronic trading system, averaging $300bn of volume per day across multiple asset classes.

The firm's trading algorithms are developed by a quant research team that specialises in machine learning. Many employees have PhDs in maths and related subjects, including both Co-CEOs.

As well as being a leading financial technology firm, XTX Markets is also a major philanthropic donor. It aims to give effectively in several areas, including education, global development and net zero. However, above all, the strategic priority for the firm's philanthropy is maths excellence.

XTX Markets is focusing on maths excellence for two main reasons. First, as a social and economic imperative, as the world moves forward in the era of technology. Second, as an opportunity for intellectual reward and social mobility for the next generation of children and young people.

Maths is the foundation of our technological society. It underpins breakthrough discoveries and innovation. It is increasingly a source of IP creation and public goods. It is the fundamental basis of artificial intelligence, which looks set to be as transformational as fire or the wheel.

These developments are driving social and economic change. Computing power and data storage continue to grow precipitously. Technology is disrupting traditional business models, creating benefits and problems. The automation of jobs – including white collar jobs – is advancing rapidly.

To meet the scale of the challenges and opportunities ahead, XTX Markets believes that education should be reimagined to produce many more people with advanced mathematical skills.

T S Y Z E A D C O R Y L G J U T K E X P A F S Z
Q E O H F X K S G U T Y Z E S D C O R N Q K E X
B Y N D E Q S U Y X A E L F P H R Z E J X B Y D
F H B M Y D A B Q T X U V D L O P R X H K G T R
D R Y X J R S D F B Q L Y E N T K Z X A F R O V

For students, maths is an intellectually rewarding subject that prizes creativity and problem solving. It tends to develop adaptable thinkers, with a valuable grounding in foundational concepts. This is not always true of courses like data science, in which new techniques can become obsolete not long after they are taught.

Maths has low barriers to entry, other than a willingness to work hard. Studying advanced maths provides varied opportunities for growth and fulfilment in research, industry and entrepreneurship. Also, given the clearing salary for maths graduates, it is a reliable driver of social mobility too.

It is for these reasons that XTX Markets is focusing on maths excellence.

Its objective is to support more young people in the UK to progress to maths degrees, maths PhDs and careers that use advanced mathematical skills. In doing so, it focuses disproportionately on students from under-represented groups, especially disadvantaged students.

This report aims to set out a comprehensive overview of the maths pipeline and an approach for supporting more students to achieve maths excellence. Before that, though, a reflection on the maths pipeline.

This year's university graduates started primary school in 2007, the year the iPhone was launched. As they get ready to leave the education system and join the labour market, many entry-level positions are likely to be disrupted by automation driven by progress in large language models.

When this year's cohort start primary school, they will enter the classroom seeing ChatGPT as a learning tool and part of their normal daily experience. It is hard to predict what society and the economy will be like when they graduate in 2039, but it seems certain that maths skills will be even more crucial, while many of today's professions may be going extinct.

T	S	Y	Z	E	S	D	C	O	R	Y	L
G	J	T	U	L	P	A	E	X	F	S	K
A	**S**	**E**	**C**	**T**	**I**	**O**	**N**	F	**A**	O	V
Q	E	O	H	F	X	K	S	B	F	N	C
S	R	L	B	J	D	Q	Y	G	K	P	M

As noted, this XTX Markets Report uses substantial parts of a research report that it commissioned from the University of Nottingham: ***The Mathematics Pipeline in England: Patterns, Interventions and Excellence.***

Many of the substantive points in Section A of this report are attributable to the University of Nottingham team, who have approved the approach to repurposing their work for this publication. Where additional content has been incorporated in Section A of this report, attempts have been made to signpost this clearly.

3. The Maths Pipeline

Section 3 focuses on aim (i) of this report: to describe the whole maths pipeline. This section gives an overview of the pipeline and the methodology used to describe it. In doing so, it brings together two often disconnected sets of views: those of schools (up to age 18) and those of universities (beyond age 18).

As noted, the maths pipeline can be defined as the set of outcomes attained and courses chosen as cohorts of students progress through their education. This report uses the pipeline metaphor throughout, but also makes two points about its use.[1]

First, that it brings up images of flow and leaks, which tend to focus attention on points where leaks from the maths pipeline are most significant. In England, these are after GCSEs and A-levels. The Nottingham Report and this report both address these points of leakage, but also aim to take a wider view.

Second, that a focus on leaks can be limiting, as in reality many students move towards given outcomes well before 16 and are effectively 'filtered out' of the pipeline before a leak actually occurs. To reflect this nuance, the Nottingham Report refers to 'streams' within the pipeline, as well as the pipeline itself.

Instead of 'streams', this report uses 'pathways' to describe the journey that students take through the pipeline. This term emphasises that students have options and agency over their choices, and that educators can support students to excel, rather than it simply being a mechanistic process.

Section 3.1 gives an **overview of maths education in England.** This introduces some key themes in maths education, which are further developed Section 5.

Section 3.2 explains the **methodology used to describe the maths pipeline.** This describes the three cohorts of students for which longitudinal data has been analysed.

Section 3.3 provides **a visual approximation of the whole maths pipeline.** This includes two Sankey Diagrams which, taken together, run from KS1 to the end of university.

3.1 Maths Education in England

There are over 9 million students in around 24,400 schools in England, including around 16,800 state primary schools and around 3,500 state secondary schools. They are taught maths by over 250,000 primary teachers and around 35,000 secondary teachers.[2] The overall budget for maintained schools in England is over £43bn and, as a core subject, maths represents a significant share of this.[3]

Students begin studying maths in reception (age 4) and it is assessed as a compulsory subject at end of KS1 (age 7), end of KS2 (age 11) and GCSE (age 16). Some students then continue to study maths as an optional A-level subject in sixth forms and colleges, and at degree-level in universities.

The flow of students through the maths pipeline is patterned by prior attainment and social characteristics. Many of these factors are well established in the literature. For example: disadvantaged students are under-represented in the top grades throughout school and female students are less likely to choose maths post-16.

School students generally follow the national curriculum for maths. Since the early 2010s, Teaching for Mastery has been a policy priority in England, particularly in primary and lower secondary school. Since 2014 this has been supported by a network of Maths Hubs and a National Centre for Excellence in Teaching Mathematics.[4]

There has been considerable structural change in the English school system over the last decade, including a decline in local authority control and the growth of Multi-Academy Trusts (MATs). Some larger MATs have created comprehensive maths provision, such as Ark Curriculum Plus. Maths Hubs co-ordinate with MATs in varying ways, so their role is likely to evolve as the coverage of MATs continues to increase.[5]

The 2017 reforms to GCSE maths were introduced to increase the level of challenge.[6] However, the jump from GCSE to A-level maths remains considerable and only the highest-attaining GCSE students tend to attain top grades at A-level. Some critics have argued that the curriculum has led to overly procedural maths learning, and that this is exacerbated by England's high-stakes assessment and accountability culture.

The 2019 reforms to A-level maths established a common curriculum including pure maths, statistics and mechanics, as well as an emphasis on problem solving and modelling. The reforms also created Core Maths, an intermediate post-16 course, which has had modest uptake to date.[7] Continuing funding for the Advanced Mathematics Support Programme reflects a sustained drive to increase participation in post-16 maths.

The level of specialist maths skills in the teacher workforce is a long-standing problem. Only 44% of secondary teachers of maths have a maths-related degree. In 2020/21, only 84% of the target of new specialist secondary maths teachers were recruited. As well as being under-recruited, specialist secondary maths teachers also leave the profession at an above average rate.

The vast majority of students drop maths at age 16, and a significant number leave school with insufficient quantitative skills and negative attitudes about maths. Studies have argued that students view post-16 maths as being for a 'clever core' or 'elite', and that female students still tend to think of STEM careers as being 'male dominated.' More generally, negative attitudes to maths tend to be greater among disadvantaged students and parents.

Despite the challenges, attainment in KS1, KS2 and GCSE maths has improved over recent years, and A-level maths is now the most chosen A-level course. Entries have grown over the last decade, from 78,950 in 2012 to 88,315 in 2022, albeit with a dip following the aforementioned qualification reforms.[8]

Around 7,000 students each year progress from schools and colleges in England to start maths degrees at UK universities. This number has remained fairly constant despite the recent growth in A-level maths entries.
Emerging research indicates that a significant shift is occurring in the distribution of maths degrees, from low- to high-tariff institutions. Indeed, some high-tariff institutions have doubled their undergraduate maths intake in recent years, since the removal of the cap on undergraduate places.[9]

3.2 Overview of the Maths Pipeline

The maths pipeline considered by this report lasts 18 years. It begins in reception (age 4) and the milestones for which there is consistent data are: end of KS1 (age 7), end of KS2 (age 11), GCSE (age 16), A-level (age 18), and the start and end of undergraduate degrees. The pipeline continues into postgraduate study and academic research and, while these are certainly areas of interest, they are mostly 'out of scope' here.

Analysing the pipeline at any single point in time will conflate the impact of different historical states and developments. For example, today's PhD students experienced the National Numeracy Strategy at primary school, whereas today's primary students are likely to be taught maths based on a version of Teaching for Mastery.

Different methods can be used to analyse the pipeline, although no one method is sufficient to understand fully its current state. One method is to select certain outcomes like GCSEs and monitor results periodically, as if watching a river from a bridge. Another method is to track students or cohorts over time, as if flowing down a river in a boat.

Using the ONS Secure Research Service, the University of Nottingham team curated three sets of linked cohort data, including data from the National Pupil Database (NPD) and the Higher Education Statistics Agency (HESA). The Nottingham Report mainly takes the approach of 'flowing down a river in a boat', but it also incorporates an element of 'watching a river from a bridge' by analysing multiple cohorts.[10]

Cohort 1 comprises a full, national cohort of students in the NPD who took their GCSEs in 2016/17.[11] Their data is linked back to the end of KS1 (2007/08) and forward to A-levels (2018/19). This cohort was chosen as the most recent cohort to have completed A-levels prior to the impact of the Covid-19 pandemic.

This cohort was the first to experience the new GCSE grading from 9-1 and the reformed A-level maths qualification, both of which placed greater emphasis on problem solving, modelling and terminal assessment. Their earlier schooling was influenced by the Primary Framework for Literacy and Mathematics and the Secondary National Strategy.

Cohort 2 comprises a HESA cohort of around 250,000 first-year undergraduates in 2015/16, many of whom will have completed their A-levels and graduated in different years. Their data is linked back to A-levels and GCSEs, and forward to undergraduate outcomes and postgraduate choices.[12] This cohort was chosen as the most recent cohort to have completed their undergraduate degrees prior to the impact of Covid-19.

This cohort took their GCSEs and A-levels before the qualification reforms introduced during Michael Gove's tenure as Education Secretary. At that time, A-levels were modular and allowed for some choice between statistics, mechanics and decision maths. Their earlier schooling was influenced by the Primary National Strategy and Secondary National Strategy.

Cohort 3 comprises a full, national cohort of students in the NPD who took their GCSEs in 2008/9. This cohort was chosen to enable additional, complementary analysis of the maths pipeline.

This cohort began school in 1997, during the early years of the national curriculum, national testing and Ofsted. Their primary schooling coincided with the sharp rise in primary maths outcomes associated with the early years of the National Numeracy Strategy.

3.3 Progression through the Maths Pipeline

3.3.1 Progression from KS1 to A-Levels

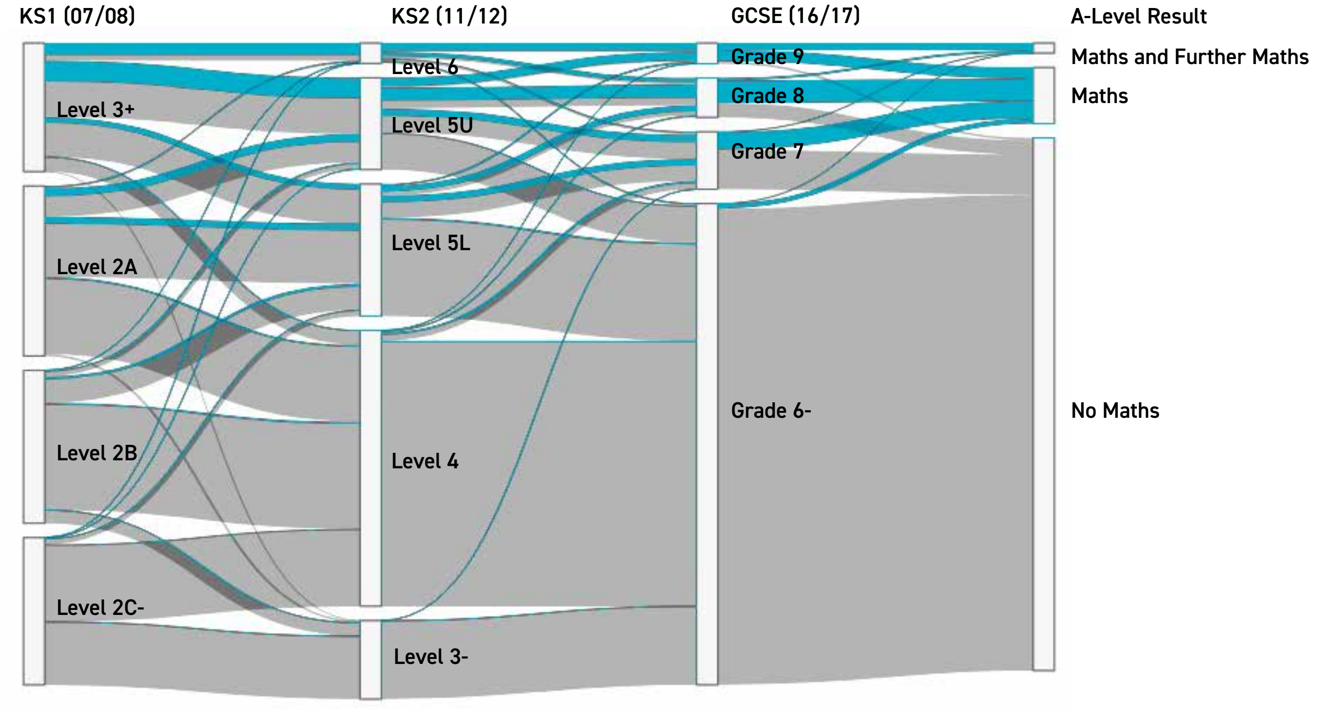
Figure 1a shows student attainment and choices in maths as Cohort 1 flowed from the end of KS1 to the end of A-level. 19.7% of students attained grade 7-9 in GCSE maths and 3.5% attained grade 9. At post-16, 9.4% of students completed A-level maths and a further 1.7% completed both A-level maths and further maths.

The students who completed A-level maths had nearly all attained top grades in KS2 and GCSE maths[*].
Even performance at the end of KS1 was a reasonably good predictor of A-level maths completion. Overall, 30.3% of students who attained level 3+ in KS1 maths progressed to A-level maths, compared to 1.3% of students who attained level 2C or below.

However, many students who attained lower grades at earlier key stages did go on to complete A-level maths.
For example, 11.0% of students who attained level 2A in KS2 maths went on to complete A-level maths.

Conversely, many students who attained grade 7-9 in GCSE maths did not go on to complete A-level maths.
12.0% of the students who attained grade 9 in GCSE maths and 36.3% of the students who attained grade 8 in GCSE maths did not go on to complete A-level maths.

Figure 1a[†]



[*] Level 5 in KS2 maths is split into upper (5U) and lower (5U) using fine grain results to identify a group that attained level 5U-6 and which represents roughly the top fifth of the cohort.

[†] Fig 1a: Sankey diagram summarising Cohort 1 student flows from the end of KS1 (2007/8) to A-levels (2018/19), with path lines to A-level maths and further maths highlighted blue. 'No maths' indicates students that did not complete advanced maths qualifications by this point. This includes 'chose but did not complete A-level maths' and 'chose A-levels but not maths'.

3.3.2 Progression from GCSEs to Undergraduate Study

Figure 1b shows the attainment and choices of the students within Cohort 2 who started their undergraduate degrees in 2015/16, as they flowed from GCSE maths to the end of their degrees.

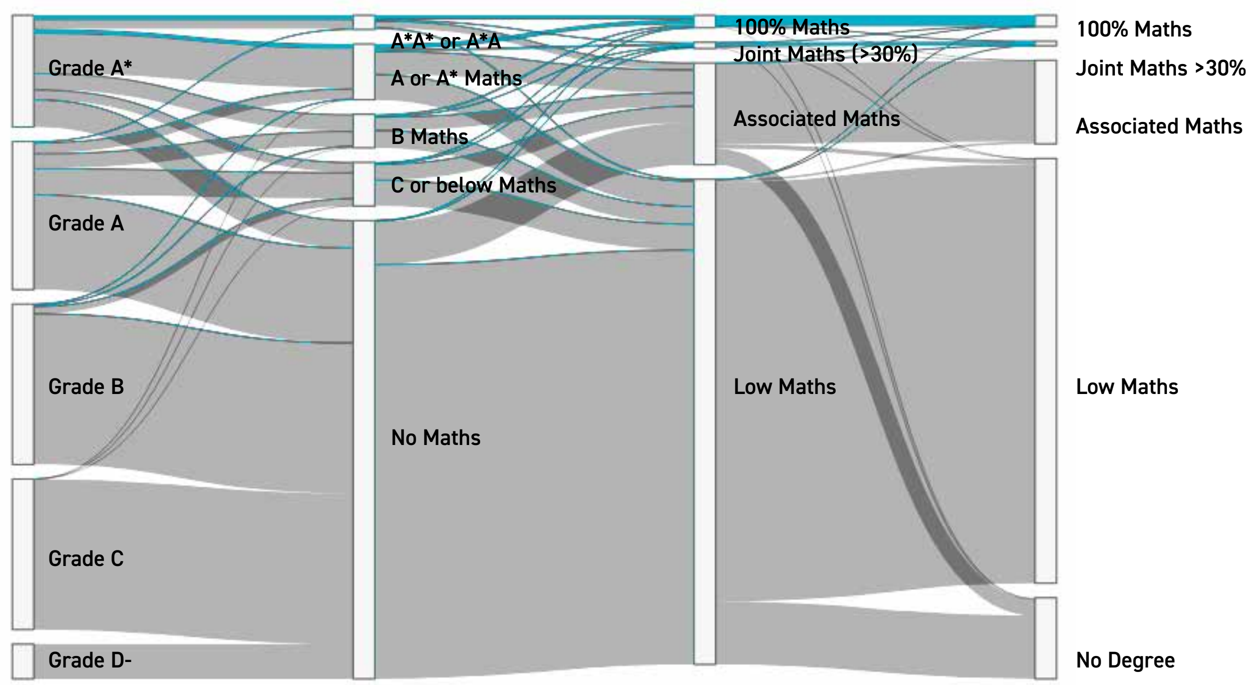
Attaining a top grade in A-level maths was a strong predictor of completing a maths degree.
11.8% of students who attained grade A-A* in A-level maths went on to complete a maths degree. Among students who attained grades A*/A+ in A-level maths and further maths, this figure rose to 37.3%.

Attaining a top grade in GCSE maths was also a good predictor of completing a maths degree. 10.3% of students who attained grade A* in GCSE maths went on to complete a maths degree. However, the figure fell sharply to 2.8% for students who only attained grade A.[13]

Many students who attained top grades in A-level maths and further maths did not complete a maths degree.
62.7% (3,840) of the students who attained grades A*/A+ in A-level maths and further maths did not go on to complete a maths degree. However, many of these students did go on to mathematically demanding degrees (see Figure 5c).

Overall, 81% of students who started a maths degree completed it. 8% transferred to a different degree with little or no maths and 11% left with no qualification. For comparison, across all subjects, 13% of students who started a degree left with no qualification.

Figure 1b*



* Fig 1b: Sankey diagram summarising Cohort 2 student flows from GCSE to degree completion (or non-completion), with path lines to undergraduate degrees in maths (single or joint) highlighted blue. The highest attaining A-level category in the diagram (A*A* or A*A) relates to students who took both A-level maths and further maths, and attained either A*A* or A*A or AA* respectively.

4. Maths Excellence Pathways

Section 4 focuses on aims (ii) and (iii) of this report: (ii) to identify the extent to which different groups of students excel at each stage of the pipeline; and (iii) to examine patterns of under-representation in the maths excellence pathway. This section includes the majority of the quantitative analysis in this report, as well as the resulting recommendations from XTX Markets.

The flow of students through the maths pipeline is patterned by prior attainment and social characteristics. Many of these factors are well established in the literature. However, the analysis in the Nottingham Report represents a new attempt to describe the whole maths pipeline, identifying the points where trends start to appear or change and highlighting the cumulative effects.

Section 4.1 defines the **maths excellence pathway.** This specifies what is meant by the 'top grades' in KS1, KS2, GCSE and A-level maths, and completing a maths degree.

Section 4.2 shows the **distribution of different groups of students across the maths excellence pathway,** focusing on disadvantage, gender and ethnicity. This identifies the extent to which these groups of students were under-represented at each stage of the pathway.

Section 4.3 examines the **rates of retention across the maths excellence pathway** for each group of students above. In doing so, this helps to give a clearer picture of who joined and left the pathway at each stage, and how other students might be supported to stay 'on track'.

Building on the analysis in Section 4, XTX Markets identifies some priority areas for supporting more students to achieve maths excellence, especially those from under-represented groups. It also makes a series of recommendations for future action, which are further developed in Section 6.

The recommendations are highlighted in blue boxes to signpost that this material was provided by XTX Markets and not taken from the Nottingham Report.

4.1 Defining the Maths Excellence Pathway

This longitudinal study analyses three cohorts of students (see Section 3.2). Some outcomes were assessed in different ways across the cohorts. For example, GCSE grades were measured 9-1 for Cohort 1 and A*-U for cohorts 2 and 3. Moreover, the cohorts have been composed in slightly different ways, due to varying availability of longitudinal data.

Working within these parameters, Section 4.1 specifies what is meant for cohorts 1 and 2 by the 'top grades' in KS1, KS2, GCSE and A-level maths, and completing a maths degree. The tables below should be used as the point for reference for terminology throughout this report.

Cohort 1 comprises a full, national cohort of students in the NPD who took their GCSEs in 2016/17. For Cohort 1, the maths excellence pathway at each stage consists of students that attained:

Assessment	Grade	Written As	Notes
KS1 maths SATs	Level 3 or above	Level 3+	-
KS2 maths SATs	Level 5U or above	Level 5U-6	Level 5 is split into upper (5U) and lower (5L) using fine grain results to identify a group (Level 5U-6) that represents roughly the top fifth of the cohort.
GCSE maths	Grade 7 or above	Grade 7-9	Grades 7-9 are taken here as being broadly equivalent to grades A-A* in the older GCSE maths qualifications.

Cohort 2 comprises a HESA cohort of around 250,000 first-year undergraduates in 2015/16. For Cohort 2, the maths excellence pathway at each stage consists of students that attained:

Assessment	Grade	Written As	Notes
GCSE maths	Grade A or above	A-A*	-
A-level maths	Grade A or above	A-A*	While the definition does not include A-level further maths, many students did take both courses. Where applicable, grades are shown in the form X/Y+. For example, A*/A+ means grade A* in A-level maths and grade A or above in A-level further maths.
Undergraduate degree	Completion	Completion	This includes undergraduate degrees at level 6 (bachelor's) and level 7 (integrated master's) of the Frameworks for Higher Education Qualifications (FHEQ). A single degree is one that is entirely within the mathematical sciences. A joint degree is one that includes at least 30% maths content.

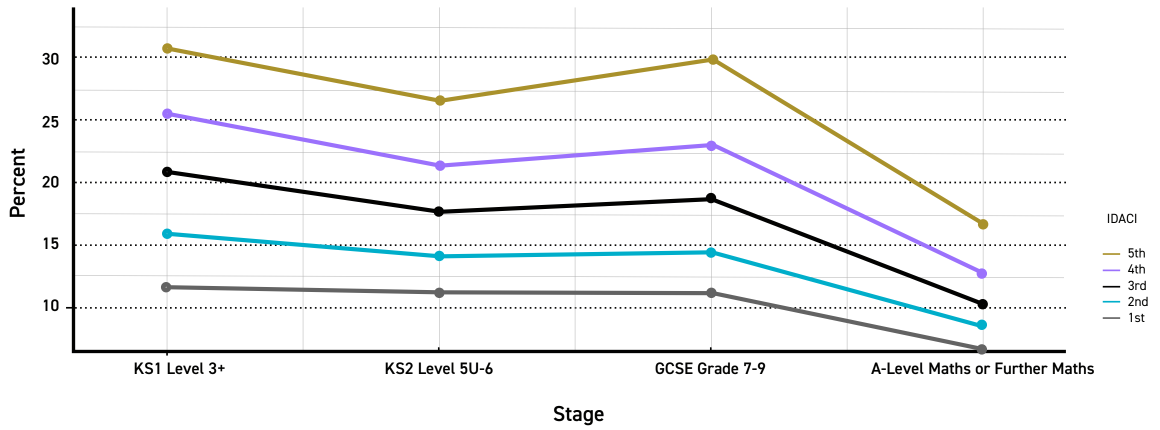
4.2 Maths Excellence Pathways: Student Distribution

4.2.1 Disadvantage

Students from more deprived areas were under-represented in the top grades in maths throughout school.
As Figure 2a shows, Cohort 1 students in IDACI quintile 5 (the least deprived) were 2.6 times more likely to attain level 3+ at the end of KS1 than students in quintile 1 (the most deprived). This ratio remained fairly constant in later stages of the pipeline. Students in quintile 5 were 2.7 times more likely to attain grade 7-9 in GCSE maths than students in quintile 1 and 2.5 times more likely to complete A-level maths. In the earlier Cohort 3, students in quintile 5 were 2.3 times more likely to complete A-level maths than students in quintile 1, suggesting that the A-level maths completion gap may have widened in recent cohorts.

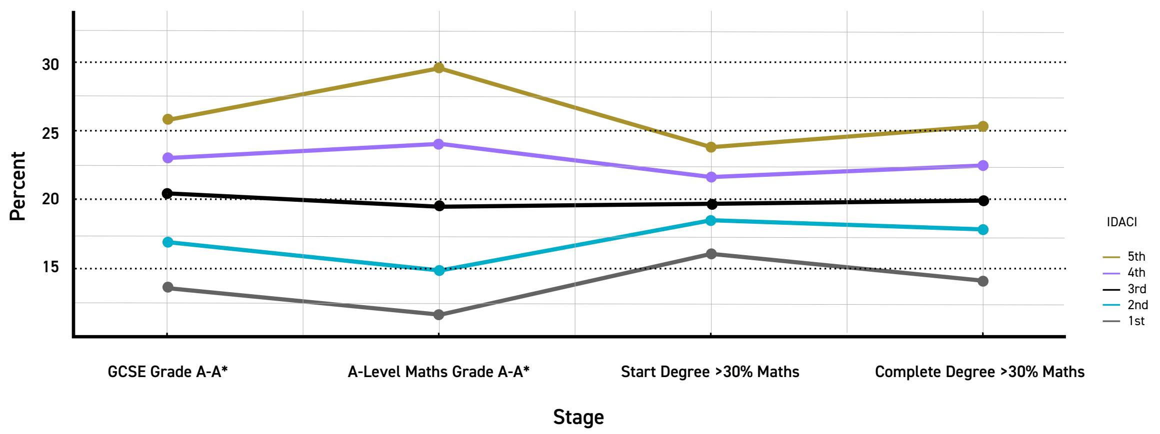
Lower quintiles stand out as having smaller net growth in the number of top grades from KS2 to GCSE maths.
As Figure 2a shows, every quintile except quintile 1 increased the percentage of students attaining top grades in maths from the end of KS2 to GCSEs. In net terms, quintile 5 added 4,400 grades 7-9 in GCSE maths to its baseline number of level 5U-6 in KS2 maths. In comparison, quintile 1 only added 600 top grades.

Figure 2a*



Students from more deprived areas narrowed the gap at the start of university, but it widened again by the end.
As Figure 2b shows, Cohort 2 students in lower quintiles were under-represented in the top grades in GCSE and A-level maths. This under-representation continued to degree-level, although the gap did narrow somewhat. However, the gap widened again by the end of undergraduate study, as students from lower IDACI quintiles were relatively less likely to finish a maths degree.

Figure 2b†



* Fig 2a: The % of Cohort 1 students in each IDACI quintile who attained level 3+ in KS1 maths, level 5U-6 in KS2 maths, grade 7-9 in GCSE maths and completed at least one of A-level maths or further maths

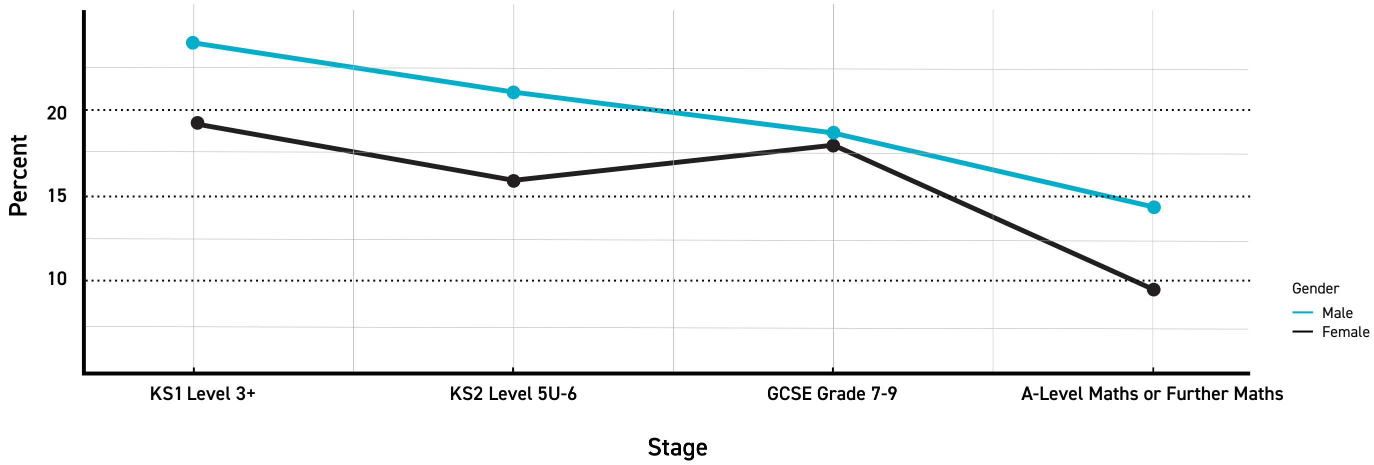
† Fig 2b: The composition by IDACI quintile of students in Cohort 2 who attained grade A-A* at GCSE, grade A-A* in A-level maths, and who started and completed an undergraduate degree in which maths comprised >30%.

4.2.2 Gender

Female students were under-represented in the top grades in primary maths, but drew level in GCSE maths.
Figure 3a shows that 19.0% of female students in Cohort 1 attained level 3+ at the end of KS1, compared to 23.7% of male students. This gender gap continued to the end of KS2 but narrowed to near zero at GCSE. It then widened again at A-level, with 9.6% of female students in the cohort completing A-level maths, compared to 14.6% of male students.

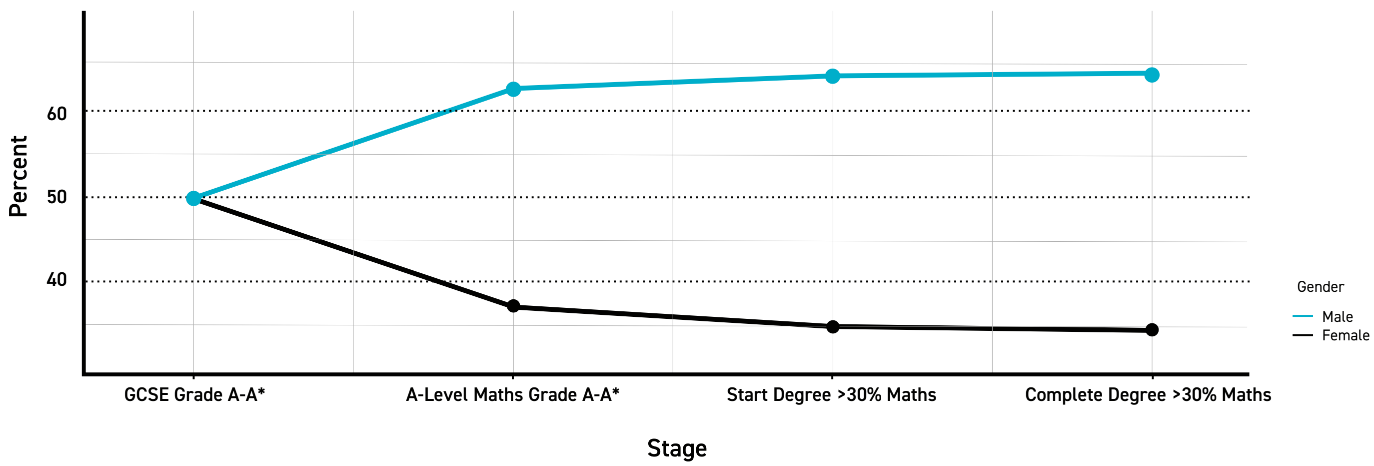
In the earlier Cohort 3, A-level maths completion rates were 8.9% for female students and 12.7% for male students. This highlights the fact that although A-level maths completion has increased in recent cohorts, this has been much more the case for male students than female students.

Figure 3a*



Female students were again under-represented on the maths excellence pathway at A-level and degree-level.
Figure 3b shows that roughly equal numbers of male and female Cohort 2 students attained grades A-A* in GCSE maths. However, only 37% of the students who attained grade A-A* in A-level maths were female. By the end of undergraduate study, the composition of the cohort had skewed to be 65% male and 35% female.

Figure 3b†



* Fig 3a: The % of male and female Cohort 1 students who attained level 3+ in KS1 maths, level 5U-6 in KS2 maths, grade 7-9 in GCSE maths and completed at least one of A-level maths or further maths.

† Fig 3b: The composition by gender of Cohort 2 students who attained grade A-A* in GCSE maths, grade A-A* in A-level maths, and who started and completed an undergraduate degree in which maths comprised >30%.

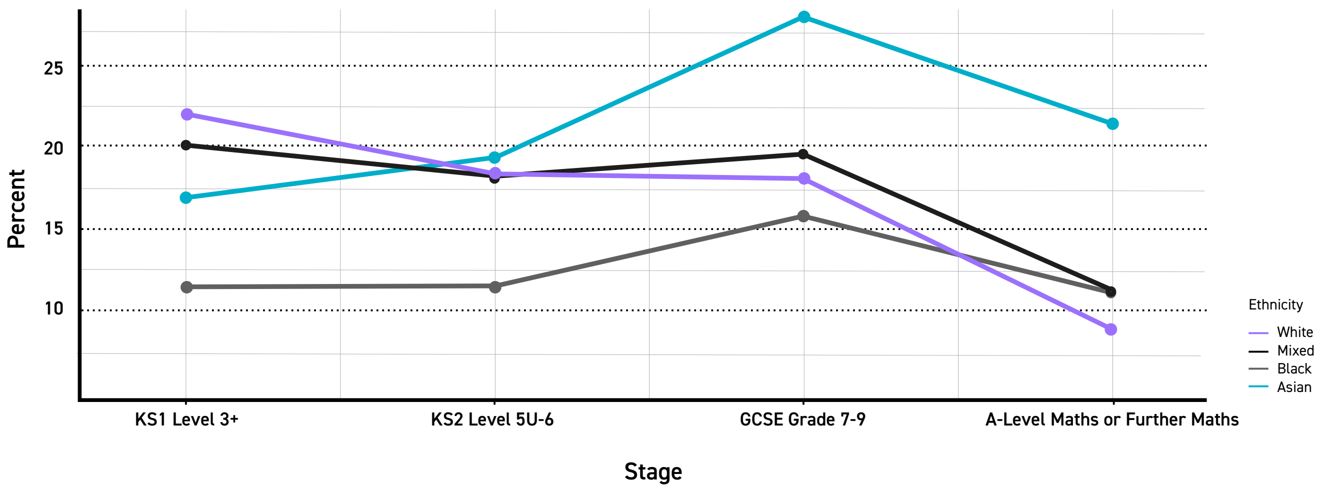
4.2.3 Ethnicity

Asian, mixed and white students had fairly similar representation at level 5U-6 in KS2 maths.
Figure 4a shows that there was a wider spread between these ethnic groups in KS1 maths, but that this converged in KS2 maths. However, black students were under-represented by around 7ppts, compared to the other ethnic groups.

A notably high proportion of Asian students attained top grades in GCSE maths and completed A-level maths.
10.6% of Cohort 1 students were Asian, but they comprised 15.6% of the students who attained grade 7-9 in GCSE maths and 21.2% of the students who completed A-level maths. During that same phase, the representation of black students improved relative to mixed and white students, first narrowing the gap in grade 7-9 in GCSE maths, then achieving parity in A-level maths completion rates.

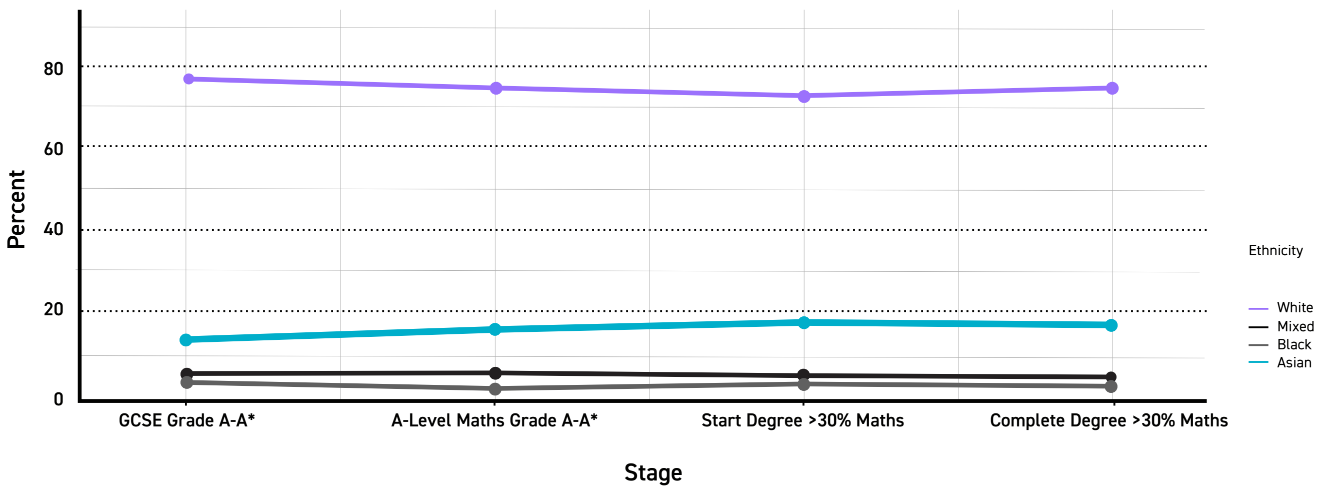
From the earlier Cohort 3 to Cohort 1, A-level maths completion rates increased by 1.8ppts for black students and stayed fairly constant for Asian (+0.2 ppts) and white students (+0.4 ppts). Mixed students were the only ethnic group for which the A-level maths completion rate decreased (-1.1 ppts).

Figure 4a*



Asian students were again over-represented on the maths excellence pathway at A-level and degree-level.
More generally, Figure 4b shows that the composition by ethnicity of Cohort 2 maths undergraduates was similar to the earlier composition of Cohort 2 high-attaining students in GCSE and A-level maths.

Figure 4b†



* Fig 4a: The % of Cohort 1 students from each ethnic group who attained level 3+ in KS1 maths, level 5U-6 in KS2 maths, grade 7-9 in GCSE maths and completed at least one of A-level maths or further maths.
† Fig 4b: The composition by ethnicity of Cohort 2 students who attained grade A-A* in GCSE maths, grade A-A* in A-level maths, and who started and completed an undergraduate degree in which maths comprised >30%.

4.3 Maths Excellence Pathways: Student Retention

Section 4.3 examines the rates of retention across the maths excellence pathway for different groups of students, focusing on disadvantage, gender and ethnicity.

The following table highlights the four transitions that are examined:

The proportion of Cohort 1 students who attained level 5U-6 at the end of KS2 and then went on to attain grades 7-9 in GCSE maths.

▼

The proportion of Cohort 1 students who attained grades 7-9 in GCSE maths and then went on to complete A-level maths.

The undergraduate degree courses chosen by Cohort 2 students who had already attained grade A-A* in A-level maths.

▼

The completion rates of all Cohort 2 students who enrolled on an undergraduate maths degree, irrespective of their A-level attainment.

This analysis helps to give a clearer picture of who joined and left the pathway at each stage, and how they might be supported to stay 'on track.' Building on this, XTX Markets has identified some priority areas and made a series of recommendations for future action. These are intended as the beginnings of an approach for supporting more students to achieve maths excellence, especially those from under-represented groups.

4.3.1 Disadvantage

Progression from End of KS2 to A-Level Maths (Cohort 1)

As noted, students from more deprived areas were under-represented in the top grades in maths throughout school. Lower quintiles stand out for having smaller net growth in the number of top grades from KS2 to GCSE maths.

Lower quintiles also had higher attrition rates among previously high-attaining students.
As Figure 5a shows, only 52.1% of IDACI quintile 1 students who attained level 5U-6 in KS2 maths went on to attain grade 7-9 in GCSE, maths compared to 73.5% of those in quintile 5.

Overall, the education system failed to retain over 30,000 students on the maths excellence pathway between the end of KS2 and GCSEs. In particular, 5,000 quintile 1 students who attained level 5U-6 in KS2 maths did not go on to attain grade 7-9 in GCSE maths.

However, controlling for prior attainment, disadvantaged students chose A-level maths at the same rate as others.
Students in lower IDACI quintiles were under-represented at grade 7-9 in GCSE maths and in A-level maths completion. Figure 5b shows something important, though. Once students attained grade 7-9 in GCSE maths, the A-level maths completion rate did not vary significantly by IDACI quintile or FSM eligibility.

Progression from A-Level Maths to Maths Degrees (Cohort 2)

High-attaining students from lower socio-economic classes (SECs) disproportionately chose maths degrees.
Among students who attained A-A* in A-level maths, there was a strong relationship between degree subject and socio-economic class. Figure 5c shows that 21% of students from lower SECs who attained grade A-A* in A-level maths chose a maths degree, compared to 13% of those from the highest SEC.

This may reflect that students from lower SECs were more risk-averse in their degree subject choices, opting for courses perceived to have lower social and cultural barriers. It may also be the case that some students from higher SECs chose A-level maths to enhance their applications to other selective courses, rather than with the intention to choose a maths degree.

However, disadvantaged students were relatively less likely to finish a maths degree that they had started.
Despite high-attaining students from lower SECs disproportionately choosing maths degrees, Figure 5d shows that maths degree completion rates were relatively lower for disadvantaged students as an overall group. This held true whether measuring by IDACI quintile or socio-economic status.

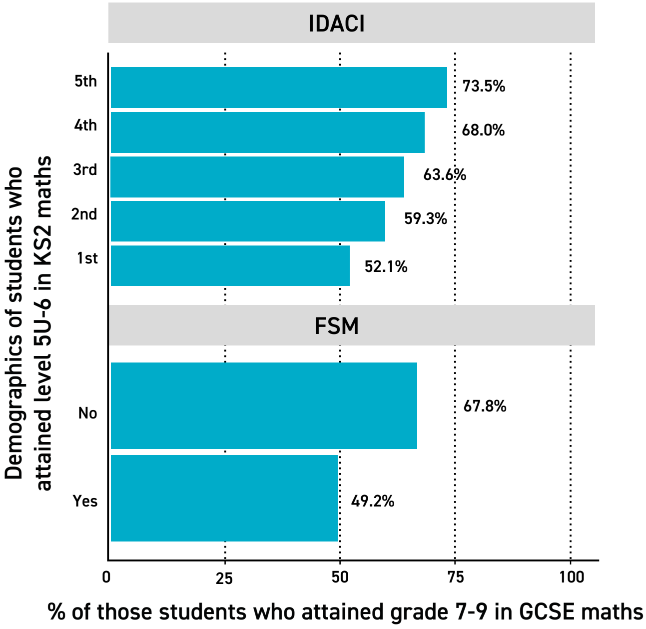
This report calls on educators and policymakers to prioritise supporting students to join and stay on the maths excellence pathway from KS2 to GCSE. This should be sustained throughout 11-16 and focus especially on FSM eligible students who attain level 5U-6 in KS2 maths each year. (N = 13,000 in 2011/12).

This report calls for more interventions to support disadvantaged students to choose and excel in A-level maths and further maths, after which they are disproportionately likely to choose maths degrees.

This report also calls for more interventions to support disadvantaged students to succeed in maths degrees, where they currently have lower completion rates compared to their more advantaged peers.

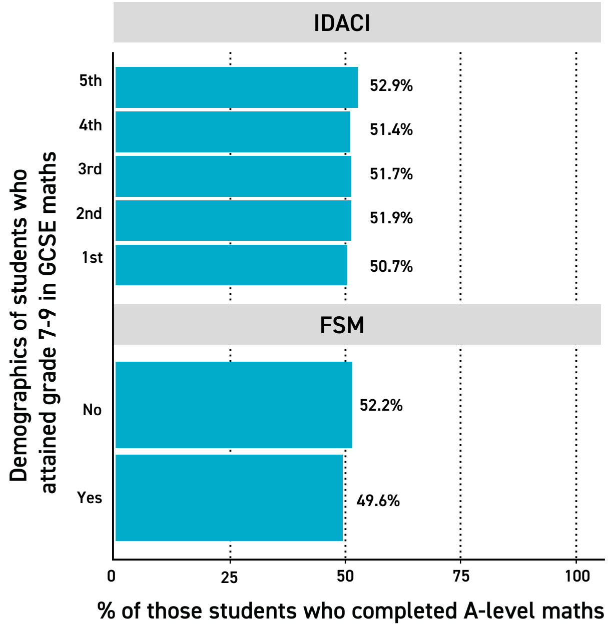
Lower IDACI quintiles had higher attrition rates among previously high-attaining students

Figure 5a*



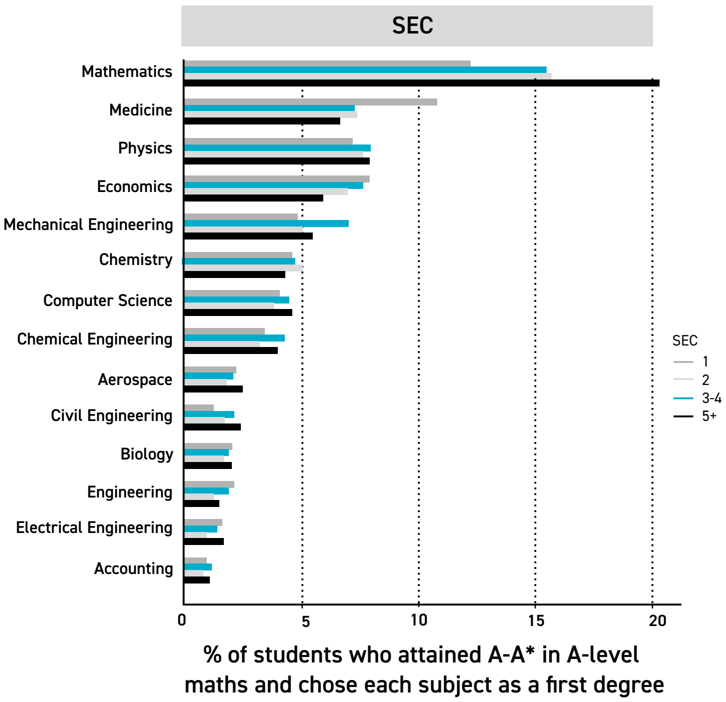
Controlling for prior attainment, disadvantaged students chose A-level maths at the same rate

Figure 5b†



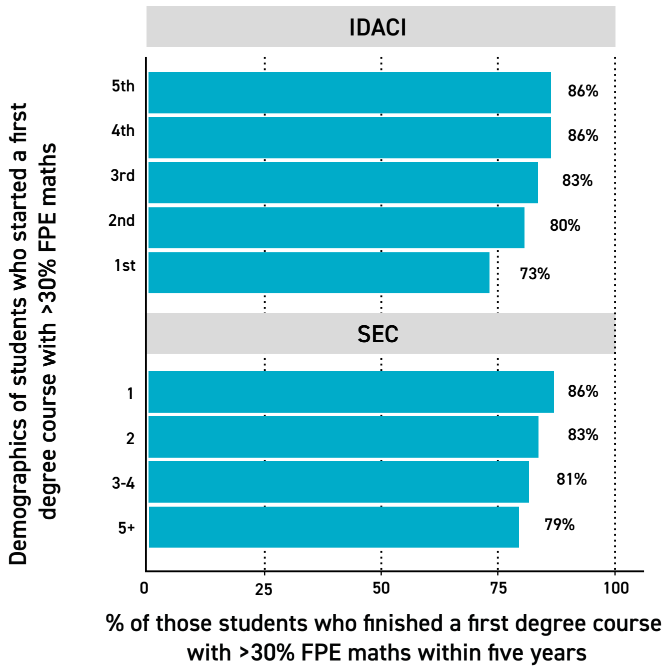
High-attaining students from lower SECs (5+) disproportionately chose maths degrees

Figure 5c‡



Disadvantaged students were relatively less likely to complete a maths degree

Figure 5d§



* Fig 5a: The % of Cohort 1 students who attained level 5U-6 in KS2 maths and went on to attain grade 7-9 in GCSE maths, by IDACI and FSM.

† Fig 5b: The % of Cohort 1 students who attained grade 7-9 in GCSE maths and went on to complete A-level maths, by IDACI and FSM.

‡ Fig 5c: The 14 most popular degree subject choices of Cohort 2 students who attained grade A-A* in A-level maths, by HESA SEC.

§ Fig 5d: The completion rate of all Cohort 2 students who started a maths degree, by IDACI and HESA SEC.

4.3.2 Gender

Controlling for prior attainment, female students were more likely to stay on the maths excellence pathway at GCSE. Figure 6a shows that Cohort 1 female students who attained level 5U-6 in KS2 maths were 4ppts more likely to attain grade 7-9 in GCSE maths than their male peers. This suggests that if the more female students can be supported to attain top grades in KS2 maths, this should translate into more top grades in GCSE maths.

However, female students disproportionately opted out of the maths excellence pathway at A-level. Figure 6b shows that 41.7% of Cohort 1 female students who attained grade 7-9 in GCSE maths went on to choose A-level maths, compared to 61.3% of male students. This low conversion of high-attaining female students to A-level maths explains why the course is male-dominated, rather than prior attainment.

High-attaining female students were also less likely to choose maths degrees. Figure 6c shows that maths was the most popular degree among Cohort 2 students who attained A-A* in A-level maths. Of these, 13% of female students and 17% of male students chose a maths degree. Female students chose subjects in the life sciences more often than male students, who were more likely to stay within maths or related subjects. Across Cohort 2 as a whole, there was no gender gap in the maths degree completion rate.

Figure 6a*

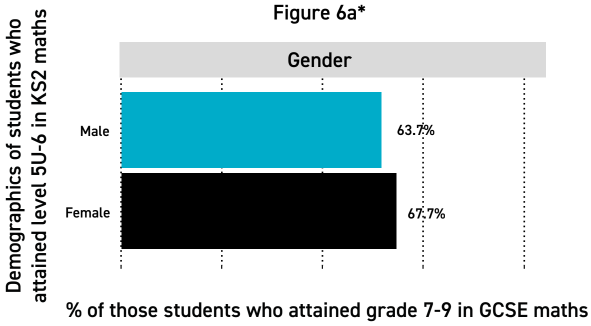


Figure 6b†

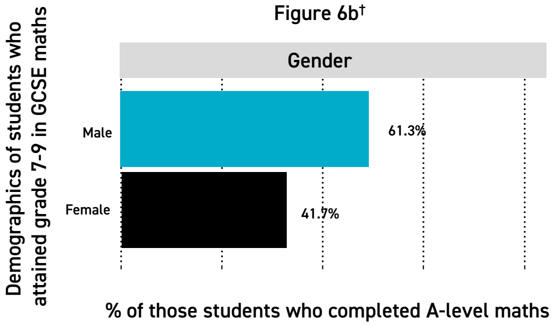


Figure 6c‡

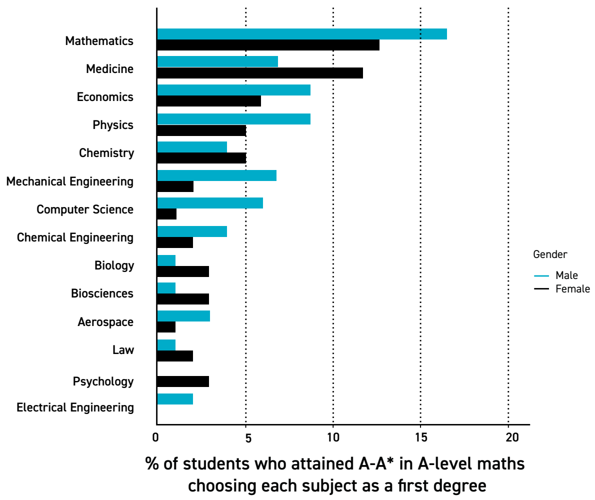
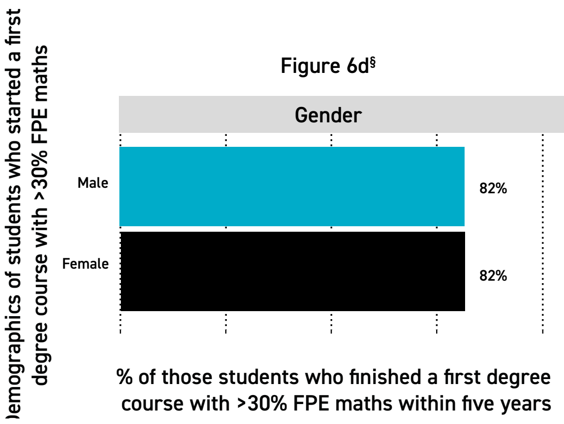


Figure 6d§



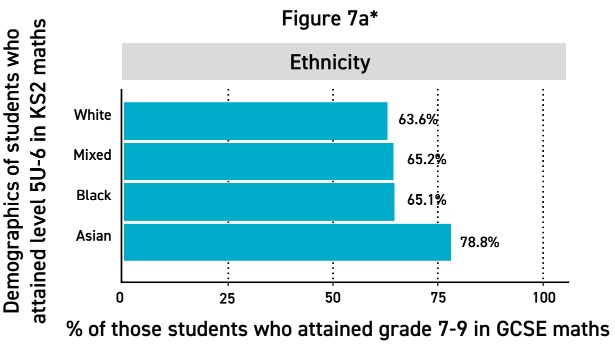
This report calls for more interventions to positively engage female students in maths and support them to choose to study maths at A-level and degree-level. This should be sustained throughout 5-18 and develop maths as a relatable, aspirational choice.

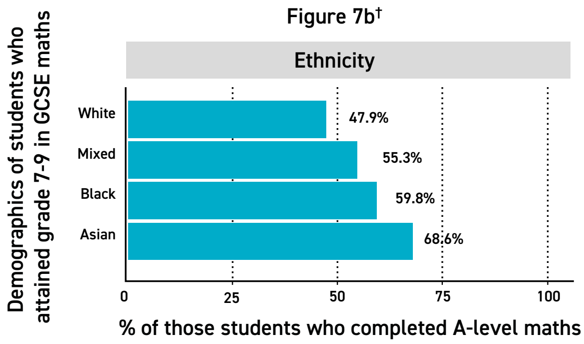
This report also calls for further analysis around the A-level choice structure, especially as it relates to A-level maths and further maths. This should reflect on the incentives that it creates for students and schools, as well as the provision of guidance on subject and career choices.

* Fig 6a: The % of Cohort 1 students who attained level 5U-6 in KS2 maths and went on to attain grade 7-9 in GCSE maths, by gender.
† Fig 6b: The % of Cohort 1 students who attained grade 7-9 in GCSE maths and went on to complete A-level maths, by gender.
‡ Fig 6c: The 14 most popular degree subject choices of Cohort 2 students who attained grade A-A* in A-level maths, by gender.
§ Fig 6d: The completion rate of Cohort 2 students who started maths degrees, by gender.

4.3.3 Ethnicity

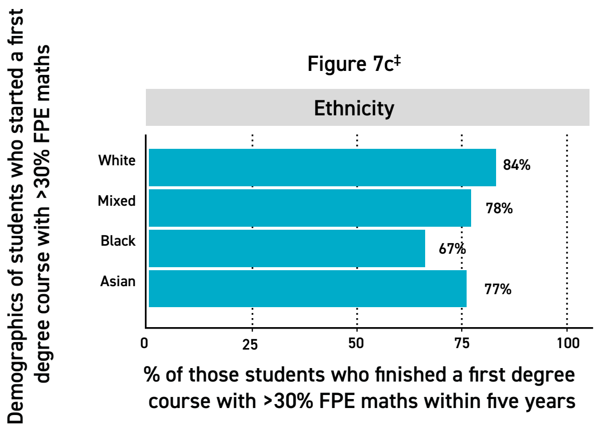
Asian students were disproportionately likely to stay on the maths excellence pathway during secondary school. Figure 7a shows that retention rates among high-attaining students from KS2 to GCSE maths were broadly the same for Cohort 1 students in other ethnic groups. Figure 7b shows a wide spread of retention rates of high-attaining GCSE students by ethnicity. Once again, Asian students were particularly likely to stay on the pathway from GCSE to A-level. White students were the least likely to stay on the pathway during this stage.





When analysing Cohort 2 students who attained A-A* in A-level maths, the data only supported weak inferences about the relationship between degree subject choice and ethnicity. In particular, the total number of black and mixed students was relatively small, so analysing percentages on that basis may be misleading. As such, there is no equivalent diagram for degree subject choices by ethnicity.

Maths degree completion rates show different patterns than earlier stages of the maths excellence pathway. Figure 7c shows maths degree completion rates for Cohort 2 students by ethnicity. White students had the highest completion rate as an overall group. Although high-attaining Asian students had comparably high retention rates from GCSE to A-level maths, this did not translate into comparably high maths degree completion rates as an overall group. After the significant increase in attainment during the secondary phase, black students had relatively lower maths degree completion rates as an overall group.



This report does not draw any conclusions regarding under-representation in the maths excellence pathway by ethnicity, in part due to limited data. However, it does recommend topics for further inquiry, including parental attitudes.

* Fig 7a: The % of Cohort 1 students who attained level 5U-6 in KS2 maths and went on to attain grade 7-9 in maths GCSE, by ethnicity.
† Fig 7b: The % of Cohort 1 students who attained grade 7-9 in GCSE maths and who went on to complete A-level maths, by ethnicity.
‡ Fig 7c: The completion rate of Cohort 2 students who started a maths degree, by ethnicity.

5. Themes in the Maths Pipeline

Section 5 focuses on aims (i) and (iv) of this report: (i) to describe the whole maths pipeline; and (iv) to explore how to support more students to achieve maths excellence, especially those from under-represented groups. This section uses qualitative data, expert feedback and case studies to provide further context, and to reflect on why patterns of under-representation persist in the maths pipeline..

As well as the quantitative analysis in sections 3 and 4, the Nottingham Report also synthesised a range of other data sources to better understand key themes in the maths pipeline. This included a review of literatures and a series of interviews with experts.

The Nottingham Report reviewed academic and grey literatures, as well as statistical releases that present trends over time. Given the large number of academic studies that have investigated the maths pipeline, systematic reviews and meta-analyses were prioritised. Four questions guided the review, focusing on: student engagement, patterns of attainment, maths teaching and historical changes.

The Nottingham Report also included findings from a group of 19 interviewees, categorised into four groups: system thinkers, educational leaders, intervention facilitators and enrichers. The interviews were designed to explore perspectives on the motivations for and effectiveness of interventions, awareness of other interventions and future thinking for the maths pipeline.

Section 5.1 – Participation and Attainment

Section 5.2 – Maths Teaching

Section 5.3 – Maths Teachers

Section 5.4 – Attitudes to Maths

Section 5.5 – Transitions between Stages

To supplement the analysis in Section 5, XTX Markets has included some case studies to provide further context within each theme. These case studies mostly refer to programmes that have received funding from XTX Markets. They are included to highlight relevant interventions across the maths excellence pathway, although it should be emphasised that there are many other examples of good practice too.

The case studies are highlighted in blue text to signpost that this material was provided by XTX Markets and not taken from the Nottingham Report.

5.1 Participation and Attainment

This report takes a long, high-level view of the maths pipeline in England. First, as a compulsory subject from the start of reception to the end of KS4, with the milestones being end of KS1 (age 7), end of KS2 (age 11) and GCSE (age 16). Then, as an optional post-16 subject, studied in sixth forms, colleges and universities, with the milestones being A-level (age 18), and the start and end of undergraduate degrees.

In England, the points where leaks from the maths pipeline are most significant are after GCSEs and A-levels. Prior attainment at GCSE is the strongest predictor of progression to A-level maths. Once GCSE attainment is included in predictive models, the effects of socio-economic status all but disappear. Social class differences are thus 'baked-in' to GCSE outcomes by the time students choose their A-levels.[1] This is important because it means that social patterns of underachievement formed at earlier points in the pipeline most likely contribute to students avoiding A-level maths and other post-16 maths options.[2]

By age 16, a cumulative attainment gap of 19 months across all subjects has formed between disadvantaged students and their more advantaged peers. Roughly 40% of this general attainment gap can be accounted for during the pre-school years, 20% during primary school and 40% during secondary school.[3] 2022 provisional results for the end of KS2 maths suggest that the pandemic has had a negative impact on the attainment gap, with 12% of disadvantaged students achieving higher than the expected level, compared with 27% of students not known to be disadvantaged.[4]

Geographical analysis of GCSE maths outcomes indicates that a larger proportion of the top grades are achieved in the south of England.[5] Subsequent rates of A-level maths participation vary significantly across England, with a clear North-South divide. In 2015/16, the 10 local authorities with the lowest A-level maths participation rates were all in the north of England, and in each less than 20% of the students who attained A*-C in GCSE maths went on to study A-level maths.[6] That said, it is worth noting that A-A* grades in A-level further maths were more evenly distributed nationally.

In 2022, around 88,000 students completed A-level maths and around 14,000 students also completed A-level further maths. 42,000 students attained grade A-A* in A-level maths, indicating that they would be capable of continuing to study a maths degree. In fact, just under 7,000 students from England apply for and are offered places on mathematical sciences degree courses each year. Despite efforts by universities to widen participation for students from under-represented groups, the higher education phase of the maths pipeline still has significantly lower representation of low-SES students compared to the wider population, and indeed, the rest of the higher education sector.[7]

A maths degree can be a driver of social mobility. 42.5% of maths graduates who previously qualified for FSM are in the top quintile of earners.[8] Around 4% of maths undergraduates are eligible for FSM at age 16, compared to 6% for all undergraduates and 12.5% for the population.[9] Generally speaking, low-SES students are less likely to complete their degree course and less likely to achieve a higher degree class.[10] These gaps in participation and attainment have a knock-on effect into postgraduate study and employment outcomes.

The Stoke-on-Trent Maths Excellence Partnership was launched in 2016 as a collaboration between local schools, with support from the city council and the Stoke-on-Trent Opportunity Area, as well as local donors, local universities and various education charities, including MEI.

The programme aims to increase participation and attainment in advanced maths. It includes a combination of teacher development and student interventions, including additional tutoring and enrichment. In particular, it seeks to promote collaboration, maths curriculum leadership and professional networks, and a positive culture around maths.

Between 2017 and 2019, the rate of students in Stoke-on-Trent attaining grade 7-9 in GCSE maths increased from 11% to 15%. The number of students progressing to A-level maths increased from 125 to 209. The proportion of subject specialists teaching in secondary schools in the areas has grown from 50% to 88% today.

5.2 Maths Teaching

Curriculum and Assessment

Student attainment in maths is assessed in statutory tests and examinations at age 5 (Early Learning Goals), age 7 (KS1 SATs), age 11 (KS2 SATs) and age 16 (GCSEs). Then, for those students choosing to study advanced maths qualifications, at age 18 (e.g. A-level maths). Moreover, since 2021, students have also been required to demonstrate competence in the Multiplication Tables Check at age 9.[11]

The current national curriculum was launched in September 2014. It intended to "embody high expectations" and it was "designed to raise standards for children age 5-16, especially the poorest."[12] This reflects the belief that a curriculum can be simultaneously 'for excellence' and 'for all', enabling students to excel irrespective of their mathematical and socio-economic background.

Providing a common curriculum for all students throughout the pipeline is problematic. It implies some homogeneity in capability, motivation, potential and future interests, and that there is a single purpose for maths education. However, student outcomes are clearly neither homogenous, nor equitable. Some students race along the excellence pathway, others progress slowly through the pipeline and others drop maths at age 16.

While GCSE outcomes are important for individual students, schools are also held to account through collective student outcomes at several points in the pipeline. This has created a high-stakes assessment culture for both individuals and institutions. Such assessments arguably obey Campbell's Law and have led to negative effects for students, such as experiencing a narrowing of the curriculum.*

This pattern of national testing risks over-emphasising individual performance on timed, written tests. In maths especially, this can mean that students spend a lot of time on routine and practice tasks to develop fluency in solving exam questions. This stresses procedural knowledge over the problem solving and reasoning capability that supports conceptual understanding. While this may suit the broad purposes of maths for employment and citizenship, it is less likely to produce the kinds of mathematical thinkers that admissions tutors in universities are looking for.

Nunes (2009) showed that primary students from more advantaged backgrounds showed better mathematical reasoning than their disadvantaged peers, arguing that: "improving reasoning through instruction could make an important contribution to reducing socio-economic status inequalities."[13] A narrow maths curriculum, like the one outlined above, may compound the disadvantage gap and limit access to the excellence pathway.

Recent reforms have sought to redress this imbalance of mathematical purposes, particularly for students on the excellence pathway. The new GCSE maths qualification, introduced for first assessment in 2017, was designed to increase the level of challenge for students.[14] The reforms to A-level maths, two years later, established a common curriculum including pure maths, statistics and mechanics, as well as a greater emphasis on problem solving and modelling.

Curriculum and assessment are less constrained in the higher education stage of the maths pipeline, where there is a wide range of undergraduate maths curricula offered by a variety of universities. Some common elements include calculus and linear algebra. Different branches of maths are covered to different depths, for example: analysis, mathematical modelling, mathematical physics, number theory, probability, scientific computation and statistics. In contrast to the high-stakes, paper-based tests in GCSE and A-level maths, other types of assessment such as computing, presentation and written reporting are more common at university.

*"The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor." (Campbell, 1979).

Ark Curriculum Plus provides a carefully sequenced mathematics curriculum from KS1 to KS3, including planning guidance, lesson resources, and assessment and intervention tools. It also provides a professional development programme that supports teachers with implementation.

Originally conceived as Mathematics Mastery, the programme was founded by Dr Helen Drury, who drew inspiration from high-performing systems, including Finland, Hong Kong, Massachusetts and Singapore. Its work was influential in the DfE's adoption of a wider mastery approach to teaching mathematics, including NCETM's Teaching for Mastery.

Ark Curriculum Plus helps teachers to develop mathematics fluency among students, and to quickly identify and address knowledge gaps to achieve better attainment. Two randomised control trials funded by the EEF indicated that the programme caused 1-2 months of additional progress.

A notable case study is Ark Conway Academy in White City. In 2014, 100% of students attained Level 3 in KS1 maths. The headteacher credited the school's success in maths to "a combination of factors... [including applying] the Mathematics Mastery approach faithfully and rigorously."

Enrichment and Stretch

One of the challenges in curriculum design is deciding what maths to teach when, and how interest in further study might be stimulated by exposure to some topics earlier and in greater depth. Adapting a curriculum for high-attaining pupils is one option. This is attempted to a degree in the current GCSE curriculum, where content is expanded in some mathematical topics for high-attaining students.

One interviewee commented on how they were thinking about this:

"You cannot just do it all up at Level 3, because it is what happens to them before that really has an impact. So, we started to develop a series of [extension and enrichment] courses...within GCSE higher tier, to start getting teachers to think about the continuation of certain topics that they might study...through to A-level maths and further maths." (Intervention Facilitator)

One interviewee explained how their intervention offered high-attaining students experience of familiar topics like geometry in greater depth, or topics not included in the curriculum such as combinatorics:

"When we [provide] support to the most able students, we are not actually getting in the way. We are never finding ourselves irritating school teachers...we are teaching them something that they wanted to teach them." (Enricher)

Mathematics Education for Social Mobility and Excellence (MESME) is a charity that is bringing Maths Circles to UK secondary schools. Maths Circles are a special out-of-class maths club, inspired by the Russian mathematics tradition.

MESME Maths Circles is a guided enrichment programme. Students that are part of a 'circle' meet regularly with an experienced, knowledgeable mentor. Together, they grapple with intriguing problems, explore exciting mathematical ideas and learn to think like university mathematicians. MESME provides all curriculum resources at zero cost and either supports teachers or supplies expert mentors to run the circles.

MESME Maths Circles is not an acceleration programme that introduces content from later stages of the curriculum. Nor is it a self-study programme that students work through independently. Instead, MESME Maths Circles employ a carefully sequenced and connected curriculum to gradually develop students' mathematical thinking and problem solving in a challenging but fun setting

MESME takes a long-term view of the maths pipeline. MESME Maths Circles are available from age 11 and the goal is to instil an enjoyment of mathematics that motivates students to excel throughout school and on to study a maths degree. Ultimately, MESME aims to double the number of mathematical sciences PhD students at UK universities by 2035, with a particular emphasis on students from disadvantaged backgrounds.

5.3 Maths Teachers

There are around 250,000 (FTE) teachers teaching maths in state-funded nursery, primary and secondary schools in England.15 This is over half of all the teachers in the country. There is significant variation in the qualifications held by these teachers and there are multiple routes into the profession.

The government has pledged to create a 'world-class' initial teacher education market and to provide a 'golden thread of teacher development' at every stage of a teacher's career.[16] Primary teachers are required to have attained at least grade 4 in GCSE maths. Formerly they required at least grade C. In the majority of cases, this is their highest maths qualification. Around 44% of secondary teachers of maths have a maths-related degree.[17]

The supply of secondary maths teachers has been a policy concern for successive governments.[18] In 2020/21, only 84% of the target enrolment for new secondary maths teachers was reached, continuing a longstanding trend of under-recruitment.[19] Retention is also a major problem. The rate of secondary maths teachers leaving the profession is above the average and has increased year-on-year.[20]

Teacher shortages are managed locally by schools. Senior leaders tend to deploy maths teachers in secondary schools by placing better qualified and more experienced teachers at GCSE and A-level, where the stakes are higher. As a result, "the shortage … is being felt most keenly at KS3."[21] Furthermore, in schools located in more deprived areas, there are often insufficient teachers with appropriate professional experience and qualifications to prepare students for these high-stakes assessments.[22]

Teachers' mathematical knowledge was frequently mentioned by interviewees as being an important aspect of teacher quality. Studies on the maths teacher workforce have shown a lack of agreement about what it means to be a 'specialist teacher' of mathematics.[23] Teachers can access maths-specific CPD through Maths Hubs, the NCETM and other providers, including MATs. Since 2015, the NCETM has supported seven cohorts of mastery specialist primary teachers, over 1,000 teachers in total.[24] Participating in high-quality CPD also has the potential to increase the likelihood of teachers remaining in the profession for longer.[25]

One interviewee reflected on this in the context of a primary teacher who had attained grade C in GCSE maths on their fourth attempt:

"[It is] all action and energy and passion when she is talking about English or geography, [but] maths is very much stifled and constrained. That is inevitably going to influence the experience pupils get." **(System Thinker)**

One interviewee, a system thinker, referred to how a school had attempted to address the challenge of teacher subject knowledge gaps by producing lesson scripts for 'non-specialist' teachers. These included questions for the teacher to ask and a flow chart of common pupil responses and teacher responses. Despite this scaffolding, they noted that these teachers still missed good learning opportunities, due to their limited mathematical knowledge.

Ambition Institute

Ambition Institute helps teachers and school leaders to keep getting better, in the classroom and across their school or trust. It is a national charity offering training and professional development, based on the most rigorous research and evidence about what really works.

Ambition Institute is piloting a subject-specific Early Career Teacher (ECT) programme in maths. Teachers follow the usual ECT programme structure, including conferences, mentoring and StepLab modules. However, working as a subject-specific cohort, they focus on mathematical content and examples, rather than generic material. For instance, the programme includes questions to test for misconceptions in topics like congruence and squaring.

Given the challenges around recruiting specialist maths teachers, the pilot aims to develop a teacher development model that will support retention. The theory of change is informed by evidence that professional development for teachers is proven to support retention and that this is particularly significant over the first five years.

5.4 Attitudes to Maths

Positive attitudes to mathematics are important because they are associated with increased attainment in the subject.[26] In pre-school years, children experience mathematical ideas through natural curiosity about their environments. Sustaining this curiosity and interest can contribute to better maths outcomes later.[27] Family attitudes to maths can an important role in this. However, negatives attitudes to maths tend to be greater among disadvantaged students and parents.[28]

In the 2019 TIMMS tests, a majority of Year 5 students reported liking maths, with significantly more boys than girls indicating that they very much liked maths.[29] This echoes similar gender patterns at later points in the maths pipeline, where male students appear to have a stronger preference for maths than female students.

Attitudes to doing maths influence student choices to study the subject post-16.[30] Perceived difficulty, boredom and lack of relevance were among reasons given by Year 10 students for not choosing the subject. Conversely, intrinsic motivation influenced Year 12 students' intentions to study maths at university.[31] The older secondary students get, the more negative their attitudes to maths become.[32] This decline tends to be greater for female students than male students.

Nurturing positive attitudes to maths is complex, requiring sustained effort from those who influence students. When done well, it can help to create communities of like-minded students, where maths is viewed positively. One interviewee referred to the importance of this type of community:

"... a significant impact on [student] self...who they are and who they want to be...the most common thing you will find from our students is excitement around mathematics and a sense of finding their tribe." **(Educational Leader)**

Several interviewees led interventions which aimed at improving student attitudes to maths, with the longer-term goal of encouraging post-16 study of maths:

"We are not just trying to get [students] through the exams, but to make them confident, engaged...to enjoy maths, to see it as something that is worthwhile and that is beneficial, whatever they end up doing in their future lives. Some will enjoy it and be engaged enough to consider mathematics as a career, maybe as a teacher [or] a researcher." **(Enricher)**

This sense of belonging has been shown to motivate undergraduates to stick with studying maths. Conversely, a sense of not belonging risks students being marginalised, or perceiving the subject to be dull or irrelevant. One interviewee outlined how their intervention addressed this through exposure to positive role models:

If you can see it, you can be it...the idea of having a role model that uses maths which challenges those conscious and unconscious biases...around what the mathematician is, what a mathematician does, where they come from, what they look like...improves [student] awareness of potential careers and...[benefits] the educator in the classroom as well." **(Intervention Facilitator)**

STEMettes

Stemettes is an award-winning not-for-profit that works to engage, inspire and connect young women and non-binary people into STEM careers. Dr Anne-Marie Imafidon founded Stemettes in 2013, with the idea of providing free, fun, food-filled experiences.

Keeping this idea at its core, Stemettes has built an authentic community of thousands of young people age 5-25, supported by mentors and role models. It runs a wide range of purposeful events, often in partnership with leading STEM businesses. It publishes relatable content, including bios and case studies of STEM leaders. It also offers long-term cohort programmes, including mentoring and industry-registered qualifications in areas such as cyber-security.

Stemettes makes a concerted effort to design interventions that reach young people from a wide range of cultural, ethnic and socio-economic backgrounds. Its approach is youth-centred and the voices of beneficiaries are central to everything it does. Over the past decade, Stemettes has supported over 60,000 girls, young women and non-binary people on their journey to become future leaders in STEM.

5.5 Stages and Transitions

School

The most recent TIMSS data indicates that primary students in England attain highly and make good progress in maths, compared to other stages of the maths pipeline in England and to other countries generally.[33] This holds true even when factors such as disadvantage are considered. However, multiple studies have shown that the primary-secondary transition is a crucial point in the maths pipeline, where attainment and attitudes drop.[34]

Back in 2015, Ofsted termed KS3 the 'wasted years', observing slow progress and a lack of challenge for the 'most able' pupils in maths.[35] Several interviewees also identified 11-16 as a much-needed area of attention. One interviewee explained that school leaders needed encouragement to think about the maths journey from Year 7 onwards to increase later participation:

"[They] should be thinking from Year 7 that all these students are going to choose A-level, or will need to study something post-16 that has got maths in it, so what are they doing with them at various stages through KS3 and KS4?... In the future, schools would really think carefully about a systematic program. And that might involve us. Or it might involve other people."
(Intervention Facilitator)

Many studies have explored patterns of post-16 maths.[36] These have identified several patterns: (i) students with higher grades in GCSE maths are more likely to choose A-level maths and attain a top grade, (ii) given similar grades in GCSE maths, students from disadvantaged backgrounds have a similar likelihood of continuing to A-level maths, although they are much less likely to initially attain a top grade at GCSE, and (iii) given similar grades in GCSE maths, female students are less likely to choose A-level maths than male students.

In 2022, around 88,000 students completed A-level maths. 47.3% of those attained grade A-A*. Around 14,000 students also took A-level further maths. 64.7% attained grade A-A*.

Of the total A-level maths cohort, there were around 33,000 female students, a relatively low proportion. This corresponds with the earlier analysis of Cohort 1, in which female students represented 38.5% of A-level maths students and 27.4% of A-level further maths students. Other studies have also suggested that students view post-16 maths as only being for a 'clever core' or 'elite', and also that females still tend to think of STEM careers as being 'male dominated'.[37]

In 2011, the Government announced its intention to create a network of specialist maths sixth forms to support maths excellence. These maths schools have been established in partnership with leading maths universities, which provide expertise, governance and sponsorship.

The first maths schools opened in 2014: Exeter Mathematics School and King's College London Mathematics School. They were joined by University of Liverpool Mathematics School (2020) and Lancaster University School of Mathematics (2022). Three new maths schools will open in 2023 (Cambridge, Imperial and Leeds) and a further four are pencilled in, including Aston, Durham and Surrey, with one more to be confirmed.

Maths schools provide a deep, immersive mathematical education for students, routinely including A-level maths, further maths and physics. In addition, maths schools offer curriculum enrichment and exposure to university-style teaching. Maths schools have so far delivered exceptionally high attainment and progress scores. For example, in 2022, 99.6% of A-level grades at King's College London Mathematics School were A-A* and 33% of leavers went to Oxbridge. According to the latest national data, both King's College London Mathematics School and Exeter Mathematics School have exceptionally high value added scores, at +0.93 and +0.79 respectively.

As small, specialist institutions, maths schools are eligible for additional funding from the DfE. They also commit to supporting the wider system, including outreach programmes for local students and schools. As the university maths school network comes together more formally, the schools are collaborating internally and externally to develop outstanding practice in maths teaching and learning, and to explore how to support maths excellence in all schools.

University

In 2022, around 42,000 students attained grade A-A* in A-level maths, indicating that they would be capable of continuing to study a maths degree. However, just under 7,000 students from England apply for and are offered places on mathematical sciences courses each year. Around 4% of maths undergraduates are eligible for FSM at age 16. This compares to 6% for all undergraduates and 12.5% for the population.[38]

In 2015, a UCAS survey of undergraduate applicants found that "the earlier young people understand about the opportunities available through higher education, the more likely they are to be motivated to apply."[39] Students from disadvantaged backgrounds are the most likely to have adopted that goal much later in their education.

One interviewee described the importance of their intervention a positive influence for primary students, particularly those from disadvantaged backgrounds:

***"It is long-term because we think that being a kind of stable presence in [students'] lives is important...a lot of what we do is based on the relationships that we form with [students]... All the people that work in centres have gone to university, so this gives [students] who may be the first in their family to go to university...a person that they know who has been...who can talk positively about it."* (Intervention Facilitator)**

Supporting disadvantaged students to make the school-university transition is important to prevent leaks from the maths pipeline. Students leave maths degree courses before completion for several reasons, including diminishing success and enjoyment of the subject, isolation due to living at home and limited study skills.[40] Moreover, lower-income students may be more likely to need to balance studies with paid employment.

One of the interviewees described a new programme designed to address some of these factors:

***"It is sort of a six-month period...at the beginning...they will meet [a tutor] at key points...where we think there might be moments of doubt... After you get your first assignment back, you are used to always getting A grades. Suddenly you've got a thing called a third and you didn't know what that [is]. And you think, 'Oh my gosh, I'm gonna have to leave the university. It's not for me'... Making sure that there is a touch point then."* (Intervention Facilitator)**

The Sutton Trust was founded by Sir Peter Lampl in 1997 to address the UK's low social mobility. It is distinctive in that it delivers effective programmes, carries out influential research and has a major impact on government policy.

The trust partners with 13 highly selective universities to provide Sutton Trust Summer Schools. These are residential programmes that include university-style teaching led by academics, wider enrichment activities and advice on how to prepare for the admissions process.

In 2022, the Sutton Trust provided 226 places on its maths summer schools. 50% of the students were eligible for free school meals and 77% would be the first in their family to go to university. The trust produced an internal evaluation on recent cohorts across all subjects, using data from UCAS Strobe and additional propensity score matching, This found that participants were 8ppts more likely than a comparison group to have an accepted place at a high-tariff university.

While supporting access to higher-tariff universities is a positive, emerging research indicates that a significant shift is occurring in the distribution of maths degrees, from low- to high-tariff institutions: "Preliminary UCAS data suggests that in 2011 high-tariff institutions accounted for 63% of places and low-tariff institutions 13.5%... [By 2021]... high-tariff institutions [accounted for] 78% and low-tariff ones... 4.5%."[41]

All HEIs that require grade B or C in A-level maths now appear to enrol fewer than 50 students per year.[42] Some universities have cancelled undergraduate maths courses altogether, including Birkbeck College and Brighton University.[43] Given that disadvantaged students are relatively less likely to attend university outside their local area, 'maths deserts' may emerge if undergraduate maths courses are too small to be viable.

The final stage in the maths pipeline is postgraduate study, where it is increasingly a requirement that students can access master's degrees in order to prepare for PhD programmes.[44] Undergraduate master's degrees (MMath) offer one such route, with capped tuition fees and access to student loans.

For standalone master's degrees (MSc), the introduction of student loans in 2015 helped to narrow the gap in participation between different socio-economic classes. However, studies show that, after controlling for prior attainment and undergraduate institution, students from disadvantaged backgrounds are less likely to progress to master's degrees.[45] Other studies show a similar picture at PhD-level.[46]

One interviewee highlighted student attitudes to debt aversion:

"I think [the funding situation has] improved, but a lot of the students I talked to say well, I am already sort of £40,000 in debt. I am not sure I want to get another 10 grand in debt." **(Educational Leader)**

The Martingale Foundation has been established to find, fund and support a new generation of STEM postgraduates. Through its Martingale Scholarships, it supports students to undertake postgraduate study at some of the UK's leading research universities.

Postgraduate degrees are increasingly associated with academic and career advancement. However, student loans often fall short of tuition fees, never mind the cost of living. This can put postgraduate study out of reach for many who cannot fund their studies through family income. The Martingale Foundation was created because it believes that family income should not be a barrier to the pursuit of excellence.

Martingale Scholars are given full funding for a master's and a PhD, including all tuition fees and a tax-free stipend to cover living costs, equivalent to an annual salary of up to £25,000. They study at world-class institutions and benefit from outstanding career development opportunities. They also join a pioneering community of postgraduate students and gain access to a network of leading universities and businesses, including research and industry internships.

The Martingale Foundation has recruited an inaugural cohort of scholars in mathematics, who will commence their postgraduate studies from September 2023. The pilot was launched in partnership with five universities: Cambridge, Imperial, King's, Oxford and UCL. The foundation intends to grow the partnership to include new universities nationally from September 2024 and to explore new STEM subjects from September 2025.

At PhD-level, the main constraint on the maths pipeline is funding. In 2017, the Bond Review called for a tripling of public-sector funding for mathematical sciences research, as well as the creation of at least 100 additional PhD places per year.[47] Despite some initial progress in the early-2020s, this appears to have now stalled.

In 2020, the Government pledged £300m additional funding for the mathematical sciences.[48] However, as of November 2022, only £124m of this funding had been committed, including on institutes, research grants, and doctoral and postdoctoral awards.[49] £176m has not yet been allocated and BEIS advised that: "The UKRI Board took the difficult decision to advise BEIS Ministers not to hypothecate a further uplift for the mathematical sciences at this stage."[50]

Protect Pure Maths is an award-winning public campaign that unites mathematicians, educators, businesses and policymakers to protect pure maths and support all mathematical sciences. It is overseen by the London Mathematical Society.

Protect Pure Maths was founded in June 2021 after the University of Leicester closed its pure maths research group. The campaign continues to support mathematics departments to resist detrimental restructures and cuts to maths teaching, such as those threatened at Birkbeck College and Brighton University.

The campaign has also held the Government to account regarding the £300m funding for the mathematical sciences. This has included parliamentary questions, select committee appearances and a Westminster Hall debate focused on mathematics. As well as this, the campaign had lobbied for the inclusion of pure maths within R&D credits, a policy which was later announced by the then Chancellor of the Exchequer, Rishi Sunak, in the 2022 Spring Statement.

T S Y Z E S D C O R Y L
G J T U L P A E X F S K
A **S E C T I O N** F **B** O V
Q E O H F X K S B F N C
S R L B J D Q Y G K P M

As noted, this XTX Markets Report uses substantial parts of a research report that it commissioned from the University of Nottingham: ***The Mathematics Pipeline in England: Patterns, Interventions and Excellence.***

Section B of this report includes an overview of XTX Markets' philanthropic funding for maths excellence. Where this section draws on research by the University of Nottingham, this is referenced in the text.

6. How XTX Markets is Supporting Maths Excellence

Section 6 focuses on aim (iv): to explore how to support more students to achieve maths excellence, especially those from under-represented groups. This section includes an overview of XTX Markets' objectives and strategic approach, and concludes with a summary of its future plans in this space.

XTX Markets is focusing on maths excellence for two main reasons. First, as a social and economic imperative, as the world moves forward in the era of technology. Second, as an opportunity for intellectual reward and social mobility for the next generation of children and young people.

To meet the scale of the challenges and opportunities ahead, XTX Markets believes that education should be reimagined to produce many more people with advanced mathematical skills.

Its objective is to support more young people in the UK to progress to maths degrees, maths PhDs and careers that use advanced mathematical skills. In doing so, it focuses disproportionately on students from under-represented groups, especially disadvantaged students.

Section 6.1 outlines XTX Markets' **objectives and strategic approach** in its philanthropic funding for maths excellence. This emphasises the importance of the 'impact journey' in particular.

Section 6.2 reflects on the **venture philanthropy mindset.** This outlines the main tenets of XTX Markets' approach to providing funding and wider support for partners.

Section 6.3 concludes with a summary of XTX Markets' **future plans.** This builds on the priority areas and recommendations for future action that were outlined earlier in this report.

6.1 Objectives and Strategy

Objectives

As well as being a leading financial technology firm, XTX Markets is also a major philanthropic donor. It aims to give effectively in several areas, including education, global development and net zero. However, above all, the strategic priority for the firm's philanthropy is maths excellence.

Its objective is to support more young people in the UK to progress to maths degrees, maths PhDs and careers that use advanced mathematical skills. In doing so, it focuses disproportionately on students from under-represented groups, especially disadvantaged students.

XTX Markets has additional aims in this space too, although they sit outside the scope of this report. For example, it is interested in identifying and developing exceptional mathematical talent globally, including through preparation for Olympiads. It is also interested in supporting excellence in STEM subjects more widely.

Approach

XTX Markets' philanthropy has a specific focus on maths excellence. However, the approach that it takes in pursuing this objective is relatively broad.

Support students from any background but especially target students

This report shows that disadvantaged students have lower gains and higher attrition throughout the maths excellence pathway. While XTX Markets focuses disproportionately on students from under-represented groups, it is open to working with organisations that provide support for students from any background to excel. Rather than limit funding only to organisations that are highly concentrated on disadvantaged students, XTX Markets seeks a balance across its portfolio.

Support students across all stages of the maths excellence pathway but especially at key points

This report shows that prior attainment is a strong predictor of completing A-level maths and a maths degree, so it is therefore important to support students of all ages. This report also shows that students join and leave the maths excellence pathway at different stages, highlighting that students can be supported to change trajectory. Nonetheless, this report identifies some key points of focus, including attaining top grades at 11-16, choosing A-level maths and further maths, and completing maths degree courses.

Support students across multiple themes within maths excellence

There is no single solution that enables students to achieve maths excellence. The themes in the Nottingham Report are complex, inter-related and affect different students in different ways. XTX Markets is working with partners across these themes: (i) Participation and attainment, (ii) Maths teaching, (iii) Maths teachers, (iv) Attitudes to maths, and (v) Transitions between stages.

Support various types of organisation that are committed to impact

XTX Markets aims to have system-level impact by supporting a large number of students across various stages of the maths excellence pathway. To do so, it will be necessary to work with a wide range of organisations, including charities, schools and universities, as well as researchers, policymakers and others. While XTX Markets is open to working in flexible ways with different partners, the common factor is that all partners must be strongly committed to impact.

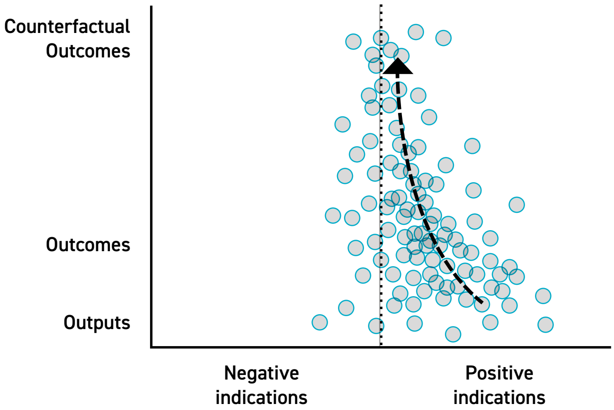
Focus on impact

Charities often talk about delivering "impact at scale." While this is a good mantra, it tends to simplify two things. First, that what is meant by 'impact' is crucial. Second, that there are significant trade-offs between impact and scale.

First, XTX Markets understands impact in terms of having high standard of evidence that a programme has caused positive counterfactual outcome, i.e. outcomes that would otherwise not have occurred.

There are various frameworks to assess standards of evidence. XTX Markets normally uses a version of the Maryland Scientific Methods Scale, adapted from the What Works Centre for Local Economic Growth. This sets out five levels of evidence, ranging from simple cross-sectional correlations (Level 1) to randomised control trials (Level 5).

The due diligence and selection process for funding from XTX Markets is built around the idea of the 'impact journey'. This is a generalisation of the journey that programmes tend to take as they move from a Level 1 to a Level 5 standard of evidence.



The impact journey has several stages, each with descriptors for scale, consistency of delivery, data capability, evaluation capability and standard of evidence. In short, programmes start at a small scale, with positive indications but low standards of evidence. Over time, they progress to be larger scale and, while the indications tend to revert to the mean, the standard of evidence tends to increase.

It is worth noting that the highest level of the 'impact journey' is a very high bar to reach. In 2022, XTX Markets reviewed the directory of Education Endowment Foundation effectiveness trials and found that that only 13 out of 44 RCTs reported a positive effect.

Second, XTX Markets focuses on impact over scale.

When charities talk about delivering "impact at scale" there is often an implicit assumption not just that they are generating impact but also that it will increase linearly with scale. However, programme delivery is dependent on context and execution. It is rarely as simple as administering a vaccination or manufacturing a product, for example. Marginal impact tends to vary as charities develop their operations and deploy funds to new areas. More broadly, charities do not always stay 'on track'. It is fairly common for charities to start with a strong delivery focus but then drift into additional areas as they scale, for example research or policy influencing.

The Stanford Social Innovation Review paper ***What's Your End Game?*** highlights six options for charities as they scale: (i) sustained service, (ii) open source, (iii) replication, (iv) commercial adoption, (v) government adoption, and (vi) mission achievement. The typical assumption charities make is that they will continue to scale and deliver a sustained service. However, as the paper notes: "Most non-profits will struggle to reach the full-scale stage. For that reason, non-profit leaders should shift their focus from the scale of their organisation to the impact that their organisation can help to achieve."

6.2 Venture Philanthropy Approach

XTX Markets adopts a 'Venture Philanthropy' mindset for much of its maths excellence funding. This involves applying certain approaches from venture capital to philanthropy. There are three basic components:

1) Ventures – Venture capital supports businesses to grow through defined stages and funding rounds - seed, series A, series B etc – to become successful, enduring organisations. XTX Markets takes the same approach in its philanthropy. For many charities, these stages broadly map on to the impact journey.

2) Capital – Venture capital tends to provide large investments designed to help ventures to scale rapidly. Likewise, XTX Markets looks to make donations that will enable charities to invest significantly in their programmes and organisational infrastructure, with the goal of achieving a sustained return.

3) Return – In venture capital, the intended return is sustained profit or a successful sale and exit. For XTX Markets, the goal of philanthropy is sustained outcomes, based on a repeatable funding model. This may include long-term funding from XTX Markets, on a case-by-case basis.

Overall, XTX Markets aims to make philanthropic investments in high potential programmes and organisations, and to support them to grow, achieve impact and sustain their performance.

As well as these three basic components, there are other ways in which venture capital investing is relevant to XTX Markets' approach:

1) Due diligence – XTX Markets looks for high potential leadership teams with great ideas and / or provably effective organisations. The due diligence process focuses intensively on the impact journey, including several sessions on impact, funding and growth plans and leadership. As such, XTX Markets does not normally solicit funding applications.

2) Funding – Wherever possible, XTX Markets tries to make significant unrestricted donations that give charities the resources and the confidence to invest for impact. Restricted funding or project funding is generally avoided, although there are instances where this is favoured. Overall, the goal is to find brilliant organisations and leaders with shared objectives, and then support and hold them accountable to ambitious high-level objectives

3) Funding Plus – While funding is of course crucial, XTX Markets also aims to provide additional value to its partners. One way it does this is through offering strategic challenge and support, which tends to be more hands on for new ventures and more light touch for larger 'evergreen' programmes. Another way is through making connections with other charities and funders, as well as building a community of like-minded leaders.

4) Governance and Grant Management – XTX Markets does not typically seek to influence partners by taking board seats, either as a trustee or an observer. It does try to influence charities but in an open-minded way, where challenge is reciprocal. XTX Markets' grant management process focuses on high-quality discussions informed by relevant data, not line-by-line budgets or monitoring reports. For example, redacted board papers are preferred to bespoke 'impact reports'.

Bringing all this together, XTX Markets takes a portfolio approach to its maths excellence funding. Partners in the portfolio have a common focus on the objective to support more young people in the UK to progress to maths degrees, maths PhDs and careers that use advanced mathematical skills. The portfolio approach allows for diversification in approaches, as well as the potential for complementarity and community among partners.

One way of conceptualising the XTX Markets portfolio is as a grid with themes and stages. As noted, the themes are broadly consistent with those outlined in the Nottingham Report. The stages encompass both the partner's current stage of development and the type of support that XTX Markets typically offers.

	"Early-stage" (Seed)	"Scale up" (Series A or B)	"Sustained scale" (Evergreen)
	For early-stage partners, XTX Markets supports as a 'venture builder', focusing on laying the foundations for impact	For scale up partners, XTX Markets provides challenge and support, focusing on advancing on the impact journey	For sustained scale partners, XTX Markets supports mostly by making connections and building community
Participation and attainment			
Maths teaching			
Maths teachers			
Attitudes to maths			
Transitions between stages			

6.3 Future Plans

This report calls on educators and policymakers to prioritise supporting students to join and stay on the maths excellence pathway from KS2 to GCSE. This should be sustained throughout 11-16 and focus especially on FSM eligible students who attain level 5U-6 in KS2 maths each year. (N = 13,000 in 2011/12).

This report is clear that attainment in GCSE maths is critical in determining future trajectories, but that disadvantaged students have lower gains and higher attrition on the maths excellence pathway from KS2 to GCSE. Therefore, providing funding and support throughout 11-16 will be a priority for XTX Markets.

As a starting point, XTX Markets is setting out plans for a new Maths Excellence Fund. This will trial and evaluate a new programme for schools, informed by the approach taken by the Stoke-on-Trent Maths Excellence Partnership.

This report calls for more interventions to support disadvantaged students to choose and excel in A-level maths and further maths, after which they are disproportionately likely to choose maths degrees.

The Nottingham Report highlights some existing interventions in this space, including AMSP and Imperial College London's MA*ths programme. XTX Markets will review current provision and new opportunities, with a view to expanding support throughout 16-18.

Policymakers can support by reviewing how to better track students who start A-level maths and further maths, not just those who enter exams. This would help to understand patterns in who chooses and drops the subject.

This report also calls for more interventions to support disadvantaged students to succeed in maths degrees, where they currently have lower completion rates compared to their more advantaged peers.

In recent years, universities have seen a shift in emphasis from 'widening access' to 'student success'. XTX Markets is interested to explore these possibilities further. One potential model is the Posse Foundation, a US charity that supports students not just to get into university, but also to complete their degrees.

As above, policymakers can support by reviewing how to better track university students. This includes both the school-university transition and the undergraduate-postgraduate transition.

This report calls for more interventions to positively engage female students in maths and support them to choose to study maths at A-level and degree-level. This should be sustained throughout 5-18 and develop maths as a relatable, aspirational choice.

While there has been a welcome growth in interventions to support girls and young women into STEM subjects, few are specifically focused on maths. XTX Markets is keen to connect with organisations already working in this space and identify further opportunities for support.

This report also calls for further analysis around the A-level choice structure, especially as it relates to A-level maths and further maths. This should reflect on the incentives that it creates for students and schools, as well as the provision of guidance on subject and career choices.

XTX Markets would support research to better understand how students and schools respond to the A-level choice structure. In particular, there is a worry that some students may be discouraged from taking A-level further maths and encouraged to stick with 'safer' or 'more rounded' choices.

This question will overlap with the current review of 16-18 maths. In XTX Markets' view, it is crucial that any reform to 16-18 maths increases incentives for students to choose maths A-level, rather than an intermediate option like Core Maths. For example, as a signal of academic excellence to universities.

Further Areas for Exploration

While this XTX Markets report has given some specific recommendations and future plans, it still has many unknowns and further areas for exploration. One line of inquiry, which has not been covered in detail in this report, is how to support primary school students on the maths excellence pathway. Another line of inquiry is how to co-ordinate activities and interventions to better enable students to achieve maths excellence. XTX Markets is strongly interested in both these areas.

In terms of primary schools, this has perhaps been less of a priority given the general improvement in primary maths over recent years. There are some interesting questions, though. These include how to harness and support education technology use in the classroom and at home, and how to build positive attitudes to maths.

In terms of co-ordination, schools are well-placed to identify talented maths students and to provide or at least signpost interventions. However, schools may benefit from further support to co-ordinate this work effectively, including finding the right interventions. Outside schools, it appears that there are fewer scouting and talent development structures for maths, compared to areas like sport and the arts.

Further Research Questions

XTX Markets is grateful to have partnered with the University of Nottingham on this project, both for the original commissioned research and for their significant contribution to this report. The intention is that this work will represent a first step towards a better understanding of the issues and a pro-active agenda for change.

XTX Markets is interested in commissioning further research to support maths excellence pathways, including but not limited to the questions raised in the Nottingham Report:

How could different approaches to pedagogy and assessment encourage engagement and participation?
How could area-based co-ordination programmes support maths excellence?
How do some groups of students and schools buck the trends in maths excellence?
What are the preferences and choices of students making the transition from undergraduate to postgraduate?
How can we improve mapping access to interventions and initiatives?
How could further longitudinal cohort studies enhance our understanding of the maths excellence pathway?
How does the maths pipeline compare to other STEM subjects?
How do attitudes to maths differ in mixed and single-sex schools?
How can parents better supports students to excel in maths?

Summary

This XTX Markets report has set out a comprehensive overview of the maths pipeline and an approach for supporting more students to achieve maths excellence, especially students from under-represented groups. Hopefully, the analysis and recommendations in this report will make a helpful contribution to the evidence, and to wider discussions around maths excellence.

For XTX Markets, this report represents the first steps in a long-term commitment to help reimagine education so that it produces many more people with advanced mathematical skills. In the years ahead, XTX Markets looks forward to working collaboratively with schools, universities, charities and anyone else with an interest in this work on maths excellence pathways.

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7. Citations and Endnotes

As noted throughout, this XTX Markets report uses substantial parts of a research report that it commissioned from the University of Nottingham ***The Mathematics Pipeline in England: Patterns, Interventions and Excellence.*** Wherever this report has used material from the Nottingham Report that itself included a citation or a footnote, it has endeavoured to replicate the original here. Any errors or omissions herein were made on the part of XTX Markets.

This report uses **footnotes** to clarify or support meaning in the text. It uses **endnotes** for three reasons:
(i) To provide citations from the Nottingham Report, which are given in basic form here and in full form in the original;
(ii) To provide supplementary reference material from the Nottingham Report; and
(iii) To provide citations for new material, which are signposted **(XTX Markets)** in the endnote.

3. The Maths Pipeline

1 For a discussion of the pros and cons of pipeline, pathways and participation metaphors, see Noyes and Adkins (2016).

2 https://www.gov.uk/government/statistics/school-workforce-in-england-november-2021

3 This does not include the considerable sums spent in private and shadow education. For a recent discussion of this, see https://www.suttontrust.com/wp-content/uploads/2019/12/Shadow-Schooling-formatted-report_FINAL.pdf

4 https://www.ncetm.org.uk/maths-hubs

5 https://www.gov.uk/government/publications/opportunity-for-all-strong-schools-with-great-teachers-for-your child Although the Government has since changed its position on the policy as a whole in early 2023, the likelihood of a move to a self-improving MAT-organised system seems very likely.

6 For example, see https://www.gov.uk/government/speeches/oral-statement-on-education-reform

7 https://eprints.whiterose.ac.uk/168941/1/PolicyLeeds-Note1_Core-Maths.pdf

8 https://analytics.ofqual.gov.uk/apps/Alevel/Outcomes

9 "Mathematics Undergraduate Enrolment at UK Universities." Prof Cathy Hobbs, 2022. **(XTX Markets)**

10 For a detailed explanation of the data used, see the Nottingham Report (p.12).

11 Although a full national cohort is around 660,000 students (at age 16), the analysis is based on those students for whom the full record from 4-16 (and beyond) is available. For further detail, see the Nottingham Report (p.11).

12 For Cohort 2, the Nottingham Report included undergraduate students who had previously taken GCSEs and A-levels in order to focus on students who had come through the English or Welsh education system.

13 The Nottingham Report focused on those attaining A-A* in A-level maths given that this is a differentiating factor in recruitment to maths degrees in so called selecting universities. For further detail, see the Nottingham Report (p.14).

1 Boylan et al., 2016; Noyes, 2009.
2 Mcmaster, 2017; Noyes and Adkins 2017.
3 Huchison et al., 2016.
4 https://explore-education-statistics.service.gov.uk/find-statistics/key-stage-2-attainment/2021-22
5 https://analytics.ofqual.gov.uk/apps/GCSE/County
6 Smith, 2017 (p.53).
7 Sutton Trust, 2021.
8 Sutton Trust, 2021.
9 Sutton Trust, 2021.
10 Crawford, 2014.
11 https://www.gov.uk/government/collections/multiplication-tables-check
12 https://www.gov.uk/government/news/new-curriculum-will-make-education-system-envy-of-the-world
13 Nunes, 2009 (p.5).
14 https://www.gov.uk/government/speeches/reformed-gcses-in-english-and-mathematics
15 https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england
16 https://www.gov.uk/government/publications/opportunity-for-all-strong-schools-with-great-teachers-for-your-child
17 Allen & Sims, 2018. Note that this was using data from 2016.
18 Long & Danechi, 2021.
19 Worth & Van den Brande, 2019.
20 Worth & Van den Brande, 2019.
21 Allen & Sims, 2018.
22 Allen & Sims, 2018.
23 Allen & Sims, 2018; The Royal Society, 2007.
24 Personal communication between the University of Nottingham and Debbie Morgan, NCETM, 30 August 2022.
25 Worth & Van den Brande, 2019.
26 Richardson et al., 2020.
27 Shah et al., 2018.
28 Quaye & Pomeroy, 2022.
29 Richardson et al., 2020.
30 Sheldrake et al., 2015.
31 Brown et al., 2008.
32 Hodgen, Küchemann et al., 2010.
32 Richardson et al., 2020.
34 Brown et al., 2003; Jindal-Snape et al., 2020; Kaur et al., 2022.
35 Ofsted, 2015 (p.5).
36 ACME, 2012; Hillman, 2014; Noyes & Adkins, 2017.
37 Matthews & Pepper, 2007; Nardi & Steward, 2003; Cassidy et al., 2018.
38 Sutton Trust, 2021.
39 UCAS, 2016 (p.7).
40 Brown et al., 2005.
41 "Mathematics Undergraduate Enrolment at UK Universities." Prof Cathy Hobbs, 2022. **(XTX Markets)**
42 "Mathematics Undergraduate Enrolment at UK Universities." Prof Cathy Hobbs, 2022. **(XTX Markets)**
43 https://www.lms.ac.uk/news/birkbeck-letter **(XTX Markets)**
44 Dixon & Vittle, 2014.
45 Wakeling & Mateos-Gonzalez, 2021.
46 Sutton Trust, 2021; Institute for Fiscal Studies, 2020. **(XTX Markets)**
47 Bond, 2017.
48 www.gov.uk/government/news/boost-for-uk-science-with-unlimited-visa-offer-to-worlds-brightest-and-best **(XTX Markets)**
49 https://committees.parliament.uk/oralevidence/10422/pdf **(XTX Markets)**
50 Correspondence between George Freeman MP and Protect Pure Maths **(XTX Markets)**