*The*
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# Future-proofing mathematics education

My Mathematical Association Presidential Address focused on maths education in the context of the current environment in England. However, many of the issues are relevant to other UK nations and maths education more widely.

There are many positives about maths education in England. There are also serious challenges. Addressing these challenges is crucial for our future society.

## *The good news*

*The government values maths education*

There is recognition across the political spectrum that high quality maths education brings national economic benefits [1] and better life chances for individuals.

- The National Centre for Excellence in the Teaching of Mathematics (NCETM) [2] has been funded by government since 2006, and the national network of Maths Hubs [3], since 2014
- The Advanced Mathematics Support Programme (AMSP) [4] and its predecessor programmes have been funded continuously by government since 2005
- The government recently announced funding for 'Early Years Maths Champions' [5]
- There are significant funding incentives for Level 3 maths uptake, through the Advanced Maths Premium [6] and the Core Maths Premium [7].

The NCETM and the AMSP resulted from the recommendations of Professor Sir Adrian Smith's 2004 review, 'Making Mathematics Count' [8]. The report highlighted the need for government to support ongoing improvement to maths education.

The NCETM coordinates the work of the Maths Hubs, helping teachers to collaborate within and between schools and colleges to improve maths teaching.

The AMSP supports Level 3 maths by providing professional development for teachers and helping to raise student participation, working collaboratively with the NCETM and Maths Hubs to improve maths education.

The government views collaboration in education as:

"The key to delivering all this, achieving and thriving for all our children." [9]

In the academic year 2024/25 the Maths Hub programme provided professional development for teachers in over 60% of primary schools and over of 60% secondary schools, and the AMSP worked with over 70% of schools and colleges offering A levels.

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*Evidence-informed pedagogy*

The work of the NCETM and the Maths Hubs has enabled England to develop a 'teaching for mastery' pedagogy for maths [10], which emphasises deep learning of key mathematical concepts and procedures.

The Maths Hubs network provides a national mechanism to help state schools to implement teaching for mastery. As I discuss later, this work has helped drive improvements in England's performance in international comparisons of maths education.

*The Observatory for Mathematical Education*

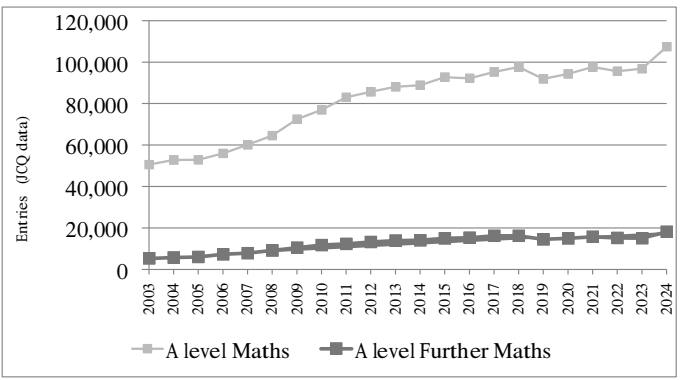
In 2024, the 'Observatory for Mathematical Education' was launched, hosted by the University of Nottingham. This has a goal to 'undertake and disseminate an outstanding programme of longitudinal research that supports the improvement of mathematics education and delivers long-term benefits for individuals and society' [11],

The Observatory has the potential to provide an unprecedented level of objective evidence to inform policies and practice in maths education.

*Increased progression to Level 3 mathematics education*

*A level Mathematics and A level Further Mathematics.*

Over the last 20 years, the AMSP and its predecessor programmes have helped A level Maths participation more than double and A level Further Maths more than treble, [12].




*Core Maths*

Despite strong growth in maths A level numbers, England's post-16 maths participation is lower than other developed nations [13]. Around 300,000 young people each year with a Level 2 pass in maths (GCSE grade 4 or above) stop studying maths at age 16.

The Core Maths qualifications [14] were designed to meet these students' mathematical needs. They build from GCSE, teaching students to apply maths to real-world contexts. All young people need these skills.

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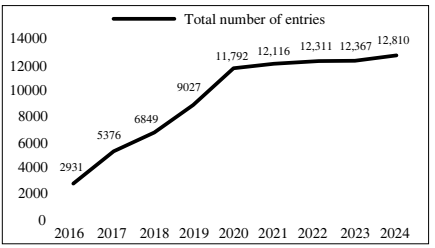
Growth in Core Maths numbers slowed during the Covid-19 pandemic, but there are now encouraging signs of further growth. In 2024, the government introduced a specific ‘Core Maths premium’ funding premium to encourage greater uptake.

| Year | Total number of entries |
|---|---|
| 2016 | 2931 |
| 2017 | 5376 |
| 2018 | 6849 |
| 2019 | 9027 |
| 2020 | 11,792 |
| 2921 | 12,116 |
| 2022 | 12,311 |
| 2023 | 12,367 |
| 2024 | 12,810 |




Core Maths entries 2016-2024

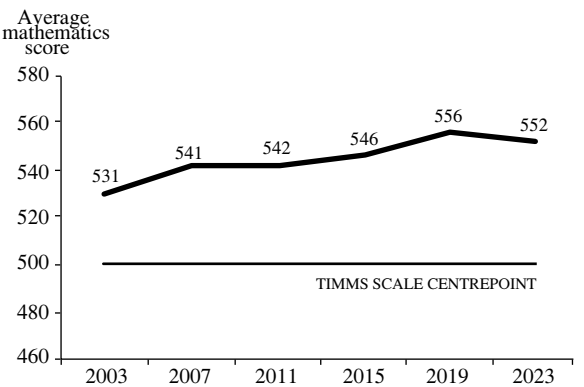
Increasing numbers of universities are explicit about encouraging prospective undergraduates to take Core Maths if they are not studying A level Maths [15].

*Improved performance in international comparisons of maths education*

Trends in International Mathematics and Science Study (TIMSS) test children's maths skills at age 9 and age 13. The most recent results were published in December 2024.

The graph below shows TIMSS scores in maths for England’s year 5 pupils (age 9) over the past 20 years [16].

Figure 1: Trend in average year 5 mathematics score (England)




Source: IEA TIMSS International Report 2023

Note 1: Response rates for TIMSS in England were relatively low in 2003.

Since 2003, the trend is consistently positive. The slight decrease in 2023 is not statistically significant. In the context of Covid-19, I consider this a positive result.

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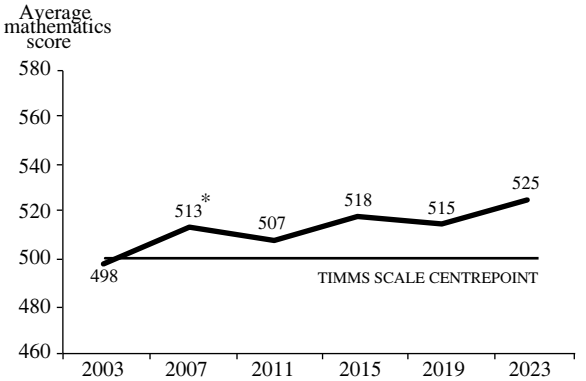
The graph below shows TIMSS scores in maths for England's year 9 pupils (age 13) over the past 20 years.

Figure 3: Trend in average year 9 mathematics score (England)




Source: IEA TIMSS International Report 2023

Note 1: Response rates for TIMSS in England were relatively low in 2003.
Note 2: Scores that represent a significant increase on the previous TIMSS cycle are marked with an asterisk (*).

The 10-point increase between 2019 and 2023, while not statistically significant, is encouraging given the Covid-19 pandemic.

The OECD administers a Programme for International Student Assessment (PISA) [17] for 15-year-olds. The two most recent PISA maths tests (2018 and 2022) show positive outcomes for England.

The 2018 score was England's highest ever. The 2022 score was significantly lower than 2018, but most countries' scores fell after the Covid-19 pandemic. England's results were less severely affected than most other countries. Between 2018 and 2022, our PISA maths league table position rose from 17th to 11th, our highest ever position.

These positive indications suggest that England's national approach may have helped to mitigate the impact of the pandemic. They certainly reflect the commitment and expertise of teachers of maths in our primary and secondary schools.

## *The Challenges* (*and how they might be addressed*)

*Attitudes to maths*

There is a widespread view that people in the UK have negative attitudes to maths, but research from Axiom Maths [18] found that attitudes to maths in England are not as negative as many might assume. We can, however, do more to improve attitudes to maths.

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*Maths is a crucial tool for life and work*

Maths is useful. Pupils sometimes question why they should have to study the subject. I do not subscribe to the view that mathematical ideas should be introduced through contexts, since this can distract novice learners from the maths they need to learn [19]. However, we can reinforce and consolidate mathematical learning through application in meaningful contexts. This helps students integrate new knowledge into their existing schemas (*ibid*), emphasises the value of maths, and is motivational.

Maths also stimulates cognitive development. Research evidence suggests that stopping learning maths at age 16 is disadvantageous [20], potentially reducing adult cognitive potential.

*Maths is enjoyable and beautiful*

I suspect just about everyone reading this agrees that maths is enjoyable and beautiful, but a large proportion of people don't think this way. It may not be possible to persuade everyone to our point of view, but maths teaching should enable everyone to understand that maths is hugely useful and so be motivated to master the fundamentals needed for life and work.

We should also inspire those who can find maths beautiful and help them thrive. We have some great things to offer, including the MA's Primary Mathematics Challenge [21], the UKMT Mathematical Challenges [22], NRICH [23] and Axiom Maths [24]. Teachers should be encouraged to make use of these and other opportunities in their teaching. Used in the right way, maths competitions can motivate all students, not just the highest attainers. MEI's FE Maths Challenge [25] is an excellent illustration, with over 30,000 GCSE Mathematics resit students taking part last year and 96% stating that the experience was ‘Good’ or ‘Excellent’. I suspect many young people have a latent potential to enjoy maths that we fail to ignite.

*Access to brilliant, varied careers*

Many young people are unclear about the careers maths can lead to, or how ‘mathematical and data education’ (to use the title promoted by the Royal Society's Mathematical Futures programme [26]) is necessary for many careers.

We should ensure that teachers understand the importance of maths in careers and communicate that to students. The Institute of Mathematics and its Applications (IMA) has a careers website [27] with excellent information on a wide range of careers.

*Teaching for mastery*

The ‘teaching for mastery’ pedagogy seems to be having a positive impact on children's experience of maths and, as a result, their attitudes to the subject. Teaching for mastery assumes everyone can learn and enjoy maths. Students are encouraged to engage deeply, reason and make connections. Careful curriculum design ensures a coherent sequence of essential content is covered over time.

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When the NCETM/Maths Hubs began developing teaching for mastery in 2014, it was common for children in primary schools to be grouped on tables according to their perceived 'ability' and taught accordingly. Less confident and articulate children (often children from disadvantaged backgrounds) can seem less able, and children are sensitive to the expectations of their teachers, leading to a 'self-fulfilling prophecy'.

Teaching for mastery emphasises whole class teaching, resulting in many children who might otherwise have been labelled as weak enjoying and learning maths more successfully.

Pedagogy affects attitudes to maths: Feeling you understand something is enjoyable and empowering. Trying to learn an ever-growing set of facts and rules is dull and stressful, and may disadvantage girls more than boys (more on this later). The example below illustrates the teaching for mastery approach.

Which of these fractions is bigger?

$$\frac{4}{13} \text{ or } \frac{5}{16}$$

Can you think of alternative approaches? Teachers should encourage discussion, ask questions:

Why does that work? Convince me, convince the person next to you. Is there a better way? If so, what makes it better?

*Common denominator*?

$\frac{4}{13} = \frac{4 \times 16}{13 \times 16} = \frac{64}{208}$

$\frac{5}{16} = \frac{5 \times 13}{16 \times 13} = \frac{65}{208}$

How does this help decide which is bigger?

This is the standard method, but is it the easiest?

Do you need to work out the denominator to make the comparison? If not, why not?

*Common numerator*?

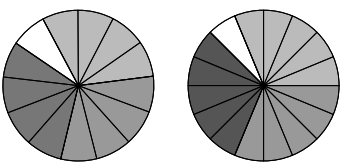
$\frac{4}{13} = \frac{4 \times 5}{13 \times 5} = \frac{20}{65}$

$\frac{5}{16} = \frac{5 \times 4}{16 \times 4} = \frac{20}{64}$

How does this help decide which is bigger?

*What about thinking of several of 'them'*?

In this case three of each is helpful because both are close to 1/3 (how do we know that?)

$3 \times \frac{4}{13}$  $3 \times \frac{5}{16}$

How close is three of each of the fractions to 1? i.e. $\frac{1}{13}$ vs $\frac{1}{16}$.

How does this help decide which is bigger?

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*What about comparing these pairs of fractions?*

$$\frac{3}{17} \text{ and } \frac{6}{35} \qquad \frac{997}{998} \text{ and } \frac{998}{999}$$

$$\frac{5}{12} \text{ and } \frac{7}{16} \qquad \frac{3}{8} \text{ and } \frac{11}{24}$$

Which method is easier, depends on the numbers.

Deep understanding of fundamental maths, developed through a 'teaching for mastery' approach, supports flexible, efficient mathematical thinking.

*Specialist teacher shortage*

'The best available evidence indicates that great teaching is the most important lever schools have to improve pupil attainment.'

This is what the Education Endowment Fund [28] has to say about the importance of teachers, and it is why addressing the shortage of secondary school maths teachers is so important.

The chronic shortage of secondary and post-16 maths teachers reduces the quality of maths education and limits progression in maths post-16. Sadly, schools with high proportions of children from disadvantaged backgrounds are more severely affected [29]. Should we incentivise maths teachers to work in such schools? I think we should.

Countries like Singapore [30] that perform highly in maths education internationally have career structures which reward maths subject teaching expertise as well as management responsibility. The development of Multi-Academy Trusts (MATs) and the Maths Hubs provide opportunities for highly expert maths teachers to lead and develop others. Maths Hub 'Local Leaders of Maths Education' (LLME) [31] develop the skills of teachers of maths in their own schools and in schools across their Maths Hub region. Their expertise should be formally recognised and rewarded.

Chartered Mathematics Teacher status [32] has existed since 2008, but uptake is low. Recognition through a salary uplift on achieving chartered status would emphasise the professional status of maths teaching, incentivise engagement with professional development and give new maths teachers a clear first step in their career progression.

I consider addressing the secondary and post-16 maths teacher shortage as the highest priority for improving maths education in England. Making maths teaching a more attractive career option is essential. Professional recognition, flexible working, clear structures for career progression and more competitive salaries can all play a role. MEI's discussion paper: 'Recruiting, developing, and retaining the mathematics teaching workforce in England' [33] considers issues relating to mathematics teacher shortage in more detail.

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*School maths and technology*

Use of graphing technology, spreadsheets and other digital tools in the maths classroom make many aspects of the subject easier to understand and learn and can also transform the teaching of statistics from meaningless number crunching with small data sets to genuine statistical analysis.

Progress in the use of digital tools to enhance the teaching and learning of maths and statistics has been frustratingly slow. The Joint Mathematics Council (JMC) reported:

> "This 2023 Report, and the JMC Working Group's activity that preceded it, was motivated by a strong sense that despite the promises of digital technology to enhance mathematics education, and the ongoing transformation of all aspects of modern society by technology, little has changed in the intervening years since the publication of the 2011 Report. Progress against its recommendations has been slow at best." [34]

The DfE specification for the current AS and A level Mathematics qualifications [35] states that technology 'must permeate the study of AS and A level mathematics' and that students must become familiar with large data sets and 'use technology such as spreadsheets or specialist statistical packages to explore the data set(s)'.

The changes in A level Mathematics teaching the specification hoped to drive didn't happen.

Good intentions were thwarted by three factors:

- Many maths teachers' reluctance to change their practice.
- The lack of access to computer hardware in schools.
- The exclusion of the use of digital technology (beyond hand-held calculators) from public examinations, which means that students can be prepared for exam success with little or no classroom use of digital technology.

Sadly, assessment is a powerful driver of classroom practice.

We must find ways to integrate the use of digital technology to enhance students' understanding and to equip them to use the power of technology to address mathematical and statistical problems.

MEI has done pioneering curriculum work in mathematical and data education:

- 'Further Pure with Technology' A level Further Maths option [36], which integrates graphing software, spreadsheets and programming into its assessment.
- Data Science courses for teachers and students [37], which will be expanded through the AMSP in academic year 2025/26 [38].

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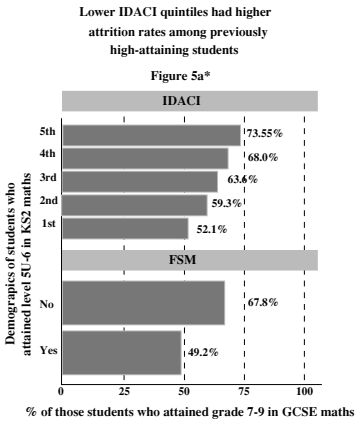
The success of this work shows that it is possible to integrate the use of digital technology into mathematical and data education. Much more curriculum development is needed, alongside integration into the initial teacher training and ongoing professional development of maths teachers.

*Socio-economic disadvantage*

A key function of education is to help society become more equitable; education should be a vehicle for transcending disadvantage.

Data show, however, that many young people from disadvantaged backgrounds do not fulfil their potential.

TIMSS and PISA indicate that England has an unusually high disadvantage gap in maths. The analysis below is from XTX Markets' 2023 Maths Excellence Pathways report [39], commissioned from the University of Nottingham. Students from disadvantaged backgrounds with high achievement at the end of Key Stage 2 were less likely to go on to achieve high grades (7 – 9) in GCSE Mathematics at the end of Key Stage 4, compared to their peers.




IDACI: 'Income Deprivation Affecting Children Index', a measure of disadvantage, with quintile 1 the being the most disadvantaged. FSM: Students who qualify for free school meals.

Only 52% of IDACI quintile 1 students (the most disadvantaged) who attained level 5U-6 in KS2 maths went on to attain grade 7-9 in GCSE Mathematics, compared to 73.5% of those in quintile 5. Free school meals data present a similar picture.

The good news, as the chart below shows, is that if disadvantaged students who perform well at KS2 do achieve a grade 7-9 in GCSE Mathematics, they are just as likely to choose to study A level Mathematics as other students.

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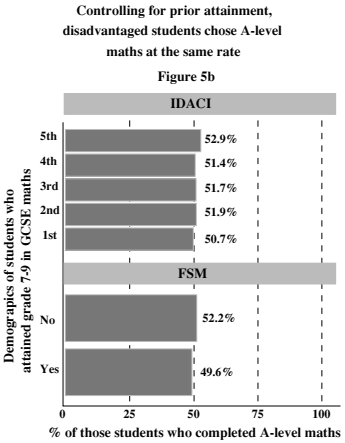


Improving the mathematical experience of students from disadvantaged backgrounds at Key Stages 3 and 4 would have a significant impact on their future success.

The AMSP is undertaking pilot work in secondary schools in academic year 2025 – 26 to investigate how to boost the higher level GCSE Mathematics achievement of disadvantaged students [40].

*Gender Gaps*

Boys are outperforming girls in maths education in England at GCSE and A level, and significantly more boys than girls choose to study maths post-16. This has been the case for many years. Worryingly, the most recent evidence from TIMSS shows a wide gender gap has opened up in students' maths performance at ages 9 and 13.

The gender gap matters because:

(1) There is no innate reason why boys achieve more highly than girls in maths [41].

(2) Higher level maths qualifications, and A level Mathematics in particular, convey a significant earnings premium [42], so this under-representation contributes to the gender pay gap.

(3) There is a shortage of people in the labour market with STEM and other maths-dependent skills.

*TIMSS data*

In 2023, the boys' year 9 score increased by 22 points compared to 2019, while the girls' score fell by 2 points. For year 5 pupils, the boys increased by 1 point, while the girls fell by 9 points.

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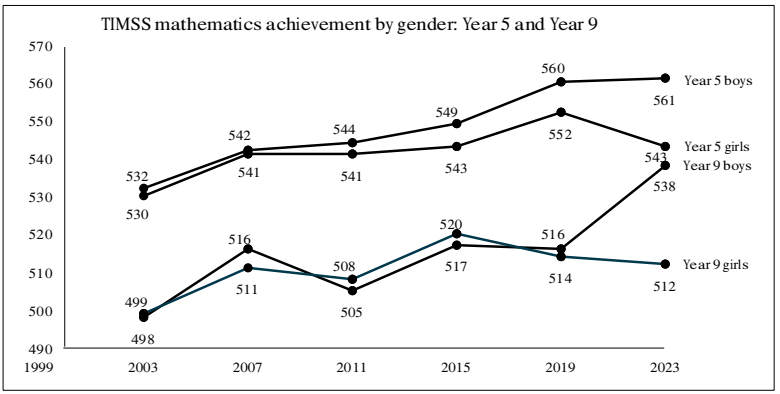


The reasons for these changes are unclear, but since the gaps opened up between 2019 and 2023 it is likely that Covid-19 was a factor. Increased gender gaps in TIMSS maths performance between 2019 and 2023 were widespread among participating countries, but England's increase was unusually large.

More research is needed to understand this – why has England's gender gap changed so dramatically compared with other countries?

*Variation in performance in GCSE and A level Mathematics*

| Grade | Female % | Male % |
|---|---|---|
| 9 | 3.4 | 5.0 |
| 8 | 7.0 | 7.8 |
| 7 | 9.7 | 9.7 |
| 6 | 12.5 | 12.0 |
| 5 | 20.1 | 19.1 |

GCSE Mathematics grades by gender, 2023-24 [43]

Achieving grade 7 or above is a strong predictor of A level Mathematics participation. In 2024, 20.1% of female students achieved grade 7 or higher. For male students it was 22.5%, with the gap widening at the highest grades.

At A level, male students consistently achieve a higher proportion of A* grades in both Mathematics and Further Mathematics (18.0% vs 14.9% and 29.6% vs 26.3% respectively in 2024).

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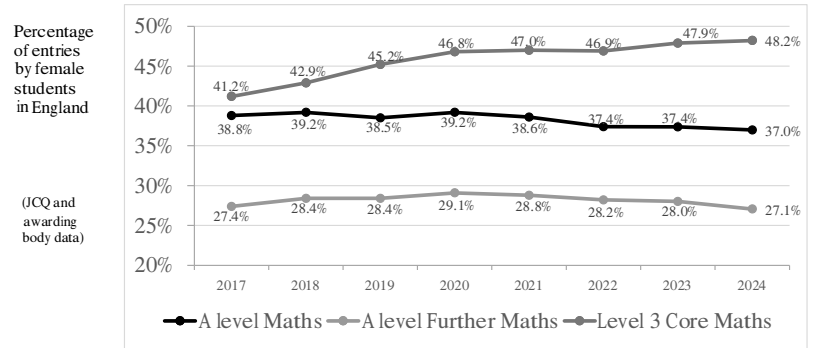
*Variation in participation in level 3 maths by gender*




The proportions of males to females taking A Level Mathematics and A Level Further Mathematics have been relatively constant at around 60:40 and 70:30 for many years. It is encouraging that the male:female ratio for Core Maths participation is approaching 50:50.

England's gender gaps in maths seem to be a cultural challenge. The 2023 TIMSS analysis showed that girls in England are significantly less confident with maths, enjoy maths less and are less likely to aspire to study maths post-16 than boys. Research suggests that there are strategies that could help to close the gaps [44].

The AMSP will be doing pilot work in secondary schools in academic year 2025 – 26 to investigate this area [45].

*Curriculum and assessment*

The key purpose of teaching maths is to equip young people with the mathematical knowledge and skills they need for future success. England's current curriculum and assessment system does not achieve this.

The government Curriculum and Assessment Review [46], which is taking place as I write, represents an important opportunity to improve maths education in England.

There is a wide consensus that England's current maths curriculum is too large.

Analysis of Japan's TIMSS results suggests that teaching a smaller curriculum deeply can result in better outcomes than more superficial teaching of a larger curriculum.

Compared to other countries, Japan's children cover less curriculum content but score more highly on TIMSS. This suggests spending more time developing strong and deep understanding of fundamental concepts equips students to use maths more effectively.

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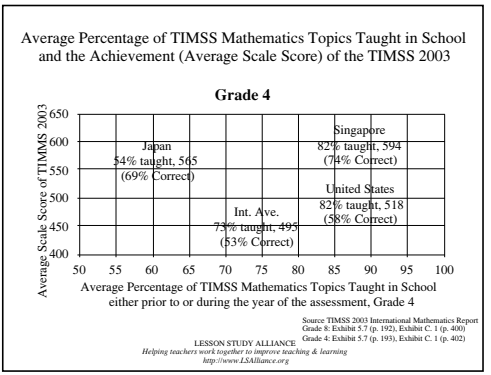


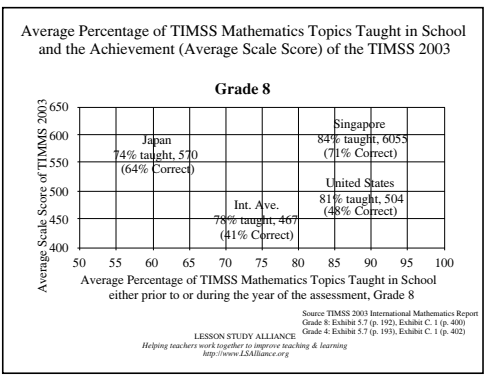


Currently more than 170,000 students in England each year fail to achieve a Level 2 pass in GCSE Mathematics by age 16 and must therefore continue with Level 2 maths post-16. Only a quarter of them go on to achieve Level 2 by age 19 [47]. Many of these students have experienced maths as an ever-growing list of rules and procedures they cannot remember, rather than as an empowering subject that helps them make sense of the world.

The maths curriculum necessary for a Level 2 pass should focus on students developing mastery of the fundamental mathematical knowledge and skills that everyone needs.

The current GCSE Mathematics assessment structure means many young people are awarded grades based on earning a very small proportion of the available marks. For example, in 2023, 40,000 young people achieved a grade 4, a Level 2 pass, in higher tier GCSE Mathematics by scoring between one fifth and one third of the marks [48]. This means that the grade gives little indication of their mathematical knowledge and skills. GCSE Mathematics should be reformed to ensure young people who achieve a Level 2 pass have demonstrated mastery of fundamental maths. Several useful proposals have been made that can help inform improvements to GCSE Mathematics assessment [49, 50].

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*Maths to age* 18

The opening paragraph of Sir Martin Taylor's introduction to the Royal Society's 'Mathematical Futures' [51] report, published last year states:

'Mathematical and data sciences are everywhere and their influence is growing rapidly... …The massive increase in the use and availability of data through digital technologies means that this influence can only grow. For all our sakes, our education system must adapt to this rapid change.'

A key way our education system must adapt is by increasing post-16 participation in mathematical and data education amongst students who achieve a Level 2 pass in GCSE Mathematics at age 16. Core Maths has a key role to play.

'It's a tragedy that 80% of those students in England with a grade 4 or better in their GCSE maths don't continue studying any maths after 16. Our economy increasingly requires everyone to handle numbers and data, and Core Maths could be revolutionary in filling this data skills deficit that we face.'

Hetan Shah, Chief Executive of the British Academy, 2022 [52]

Less than 15% of the overall cohort achieve a Level 3 maths qualification post-16 (13.5% in 2024) [53]. Most of our economic competitors have far higher rates of post-16 maths study beyond the level of GCSE Mathematics [54].

Increasing Core Maths participation is crucial. We should aim for all young people to participate in some form of mathematical and data education to age 18 within the next ten years. Increasing participation in Core Maths should make a key contribution. The key limiting factor, as discussed earlier, is teacher shortage.

*Curriculum coherence*

'Curriculum coherence' is a strong feature of the maths curriculum in the highest performing jurisdictions, such as Singapore. In a coherent curriculum:

> 'all elements of the system (content, assessment, pedagogy, teacher training, teaching materials, incentives and drivers etc.) should all line up and act in a concerted way to deliver public goods' [55].

So, how coherent is England's current maths curriculum?

- Content and assessment

  As discussed above, much needs to be done. The Curriculum and Assessment Review is due to report in autumn 2025. The Royal Society's Mathematical Futures report and the Maths Horizons report will help inform its recommendations.

- Pedagogy

  The NCETM's 'Teaching for Mastery' pedagogy underpins teacher professional development through the NCETM/Maths Hubs/AMSP.

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- Teacher training

  Our current system of initial teacher training is complex, inconsistent and fragmented. We have a relatively good provision of professional development for teachers of maths through NCETM/Maths Hubs and the AMSP.

- Teaching materials

  There is a commercial market in maths teaching materials, but quality is variable. Oak National Academy [56] and LUMEN [57] maths curriculum materials are research-informed, high-quality and available free of charge.

- Incentives and drivers

  There is much work to do: how to address gender gaps, disadvantage gaps and progression post-16 and post-18 are all areas we need to understand better.

To achieve curriculum coherence will require long-term planning. MEI has proposed that an independent maths education expert body is needed to lead curriculum development in maths:

> 'The work of this body should take place on a regular cycle, over a number of years and oversee development and implementation with the aim of ensuring coherence across curricula, teaching, professional development and assessment.'[58]

## *Why is securing the future of maths education so important?*

Bertrand Russell is one of my heroes. I think he nailed the importance of education to democratic society over 90 years ago:

> 'One of the impediments to successful democracy in our age is the complexity of the modern world, which makes it difficult for ordinary men and women to form an intelligent opinion on political questions, or even to decide whose expert judgement deserves the most respect. The cure for this trouble is to improve education.'
>
> Bertrand Russell, 1932 [59]

High quality education is crucial across the curriculum. To meet the challenges of today's world, mathematical and data education is more important than ever.

We must future proof maths education to help future proof our society, both economically, and to ensure our citizens are equipped to play a full part in a healthy and effective democracy.

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