ASPIRES 3

Young People's STEM Trajectories, Age 10-22

MATHEMATICS

Summary of Contents

1. Executive Summary

In this report, we share evidence from the ASPIRES research project, a fourteen-year, mixed methods investigation of the factors shaping young people's trajectories into, through and out of STEM education (science, technology, engineering and mathematics), with a particular focus on access to STEM degrees. The study collected survey data from over 47,000 young people and conducted over 760 qualitative interviews with a longitudinal sample, which tracked 50 young people (and their parents/carers) between the ages of 10 and 22.

The project also conducted secondary analyses of UK National Statistics and Higher Education Statistics Agency (HESA) data sets on England domiciled students, aged 18 to 24. This report focuses on analyses of survey data collected at age 21/22 and longitudinal interviews conducted from age 10 to 22, to shed light on the factors shaping STEM trajectories, particularly at degree level.

Key Findings

Who studies mathematics at advanced and degree level in England?

Analyses of HESA and National Statistics data show that:

- **Participation in mathematics GCSE and A level is high**, compared with other STEM and non-STEM subjects. For instance, 30.4% of the A level cohort in 2021/22 took a maths A level, the highest of all subjects. While **more young men than women take maths at A level** (e.g. 37.4% of those taking maths A level in 2021/22 were female), the subject is not as male-dominated as computer science (15.1% women) and physics (22.9% women);

- **The high participation in mathematics at A level does not continue into university study**. In 2020/21, mathematics students made up 1.7% of all undergraduates, or 9.4% of all those taking STEM subjects. **Take-up of maths at degree level has declined** since 2017/18, both as a proportion of all those studying for undergraduate degrees, and of those studying STEM. Indeed, maths was the second least popular STEM degree (just ahead of physics) between 2015 and 2021;

- **Participation in mathematics degrees remains gendered**. For instance, in 2020/21 in England, 32.8% of maths undergraduates were women (comparable with the average across all STEM degrees: 31.8%). Black students (4.4%) and those from the lowest IMD quintiles (13.1%) remain underrepresented on maths degrees, compared with other STEM subject areas;

- **Rates of non-completion are relatively low among mathematics degree students, compared with those in engineering and computing (but comparable with chemistry).** For instance, in 2019/20 in England, 4.3% of first-year maths undergraduates aged 18 to 24 left their degree course with no award by the end of their first year.

What shapes young people's mathematics trajectories

Analyses of the ASPIRES survey and longitudinal interview data found that:

- The **most common reason given by almost half of all mathematics degree students (45%) for their choice of course was 'being good at' the subject.** This stood out from other STEM students' reasons for choosing their degrees, with most other STEM students citing subject interest/liking/passion as the primary reason (and less than a quarter citing being good at the subject);

- Among people who had qualifications that would have enabled them to take a maths degree, **the most common reason given by those who did not pursue maths at degree level was dislike/no interest/hate of the subject (50%), followed by not feeling good at the subject (19%)**. These reasons and patterns were broadly mirrored in other STEM subject areas;

- Survey analyses show that **at age 21/22, the majority (87%) of young people do not strongly identify with mathematics** (while those who do reflect particular demographics);

- Analysis of longitudinal interview data from age 10 to 22 shows that **interactions of identity, capital and field are key** factors shaping students' subject engagement and trajectories. In particular:
  - A 'wrap-around' of mathematics-related social, cultural and economic capital over time is important for making a maths identity and trajectory possible and desirable;
  - Mathematics identities are dominated by notions of intellectual superiority and 'natural talent' (e.g. having a 'maths brain', being a 'maths person') which are gendered, classed and racialised notions that restrict many young people from developing maths identities and trajectories;
  - Young people's self-identifications with mathematics competence were neither clear-cut nor one-off.
- Generally, **maths degree students expressed broadly positive views of their undergraduate experiences**, although there remains a notable minority (just over a third of students) who expressed less positive views;
- Of those studying for a maths degree, **61% felt that A levels had adequately prepared them for their course** – a figure that is comparable with most other STEM degree students (52% overall). Likewise, **61.3% of maths students would choose the same subject again** (comparable with 63% of all STEM students). However, just **19.4% of maths degree students felt their course was good value for money** (slightly lower than the 28% of STEMM degree students overall);
- Almost two thirds (64.5%) of maths degree students said that they felt comfortable and that they 'belonged' on their course, which was slightly lower than found among other STEM and medicine students overall (70%);
- Most withdrawals happen within the first year, but ASPIRES survey data suggests that **18% of maths students in later years of study** also **express concerns about completion**, comparable with chemistry but almost half the rate found in computing and engineering;
- Across all subjects, concerns about completion most often related to academic issues and were **most frequently expressed by women, racially minoritised students, and students from low IMD backgrounds;**
- After graduation, **75% of maths degree students plan to enter the workforce (compared with 69.5% STEM students overall) and over two thirds plan to stay within their field of specialism.** The latter is comparable with computing (64%), higher than for chemistry (21%), but lower than for engineering (82%).

Key Recommendations

From the overall study findings, we identify six main recommendations for policymakers and practitioners who want to support increased and more diverse participation in mathematics specifically, and STEM more generally. Five of these (listed below) apply directly to supporting young people's mathematics trajectories (whereas the remaining recommendation derives from wider study findings, reported elsewhere, relating to GCSE science qualification routes).

1. Support and value young people's mathematics and STEM identities over time and across contexts.

2. Challenge ideas of maths competence as being based on 'natural talent'.

3. Challenge peer sexism and create more gender-equitable cultures within maths degrees and outreach programmes.

4. Support more equitable experience and retention on maths degrees, particularly among students from underrepresented communities.

5. Facilitate greater access to key forms of social and cultural capital for young people from underrepresented communities, to support social mobility in mathematics and beyond.

These are discussed in more detail at the end of report, with suggestions on how they might be operationalised.


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Mathematics

2. What are the patterns in participation in mathematics from GCSE to degree level?

Policymakers and employers have long-standing concerns about the UK's poor mathematical skills relative to the UK's economic competitors. These relate to both a lack of people who can fill the technological and scientific roles that need high-level mathematics,[1] and poor numeracy across the population, with an estimated 49% of working-age people in England having "the numeracy level that we expect of primary school children", something that has been calculated to cost the UK economy £20B per year and individuals £460 per year.[2] There are persistent inequalities in maths participation by gender, race/ethnicity and social class, with women significantly less likely than men to pursue maths trajectories.

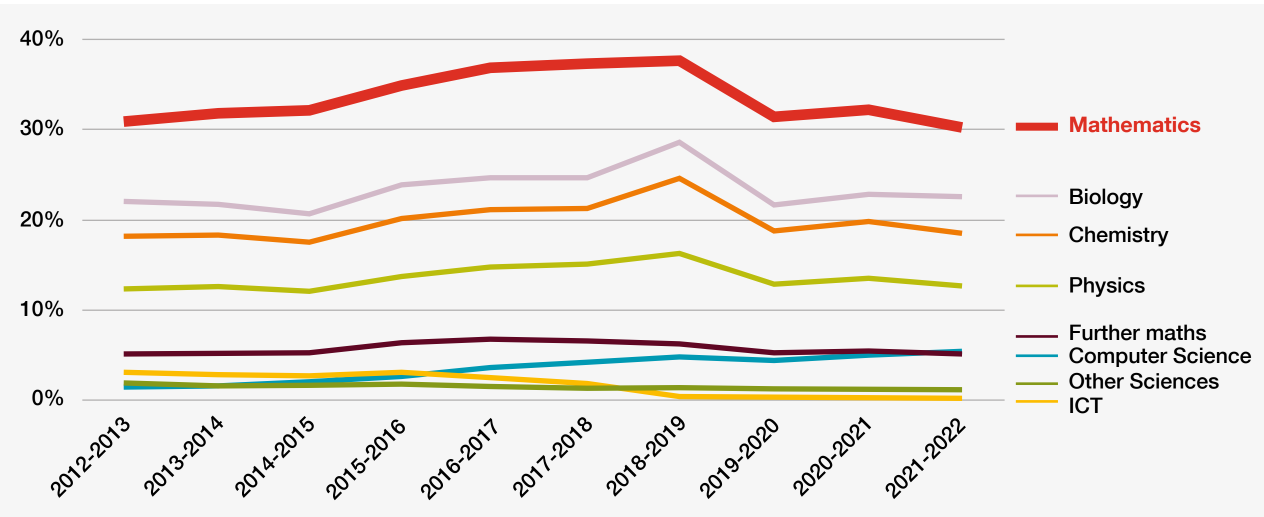
In this report, we summarise key findings from the ASPIRES study which add to the weight of evidence that these patterns in participation are structural rather than due to individual failings, such as an innate lack of confidence or ability. We propose that maths participation cannot be improved simply by making mathematics compulsory to 18, or by interventions aimed purely at supporting attainment. We will outline some of the changes that we think are needed, focusing on where changes might usefully be made to the systems, cultures and practices of mathematics education in order to support increased and diversified participation.

We begin with an overview of the patterns of participation in A level and undergraduate mathematics using new analyses conducted by ASPIRES of data from National Statistics[3] and the Higher Education Statistics Agency (HESA).[4]

In the UK, mathematics is compulsory to age 16, with 91.9% of the cohort in 2021/22 being entered for the subject at GCSE (with little change in the preceding 5 years). After this point, some decide to continue with mathematics to A level.

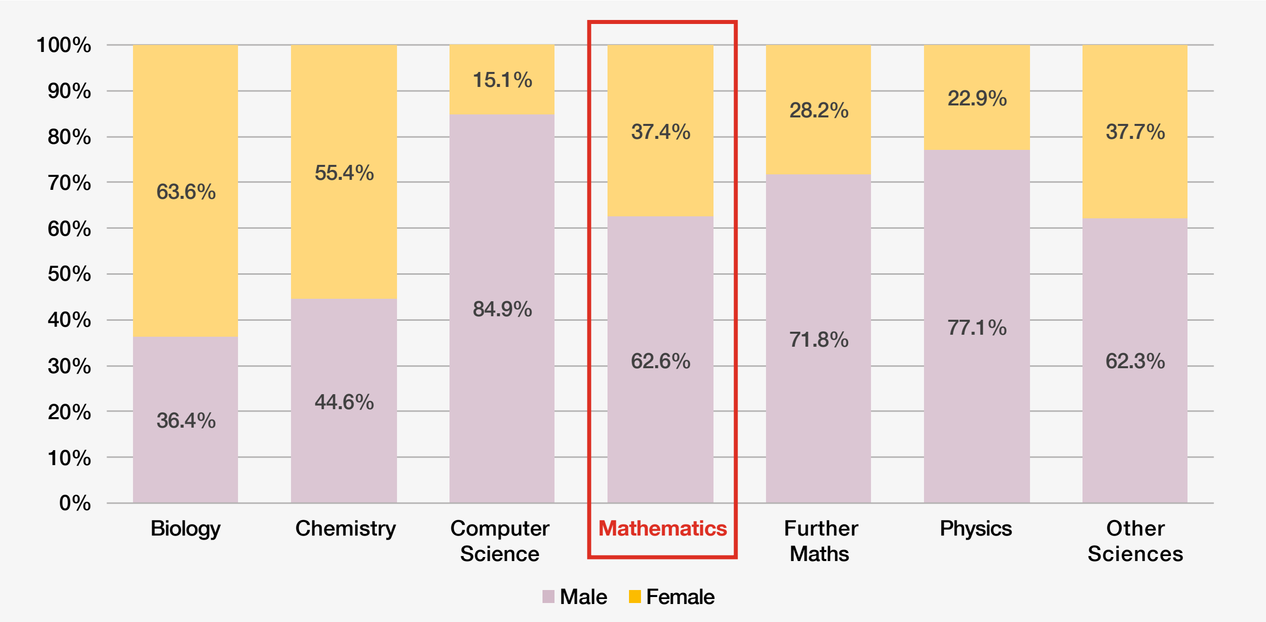
Mathematics is presently the most commonly taken A level subject. Participation in A level Mathematics is consistently higher than for all other A levels, varying between 30.4%and 37.8% across the past decade, as Figure 1 shows. Unlike for other STEM subjects, there is an option to take a second mathematics A level: Further Mathematics. Take-up of this is much lower, well below Biology, Chemistry and Physics.

Figure 1: STEM A level entries as a percentage of young people who sat at least one A level



In 2021/22, 62.6% of those taking A level Mathematics were male, as were 71.8% of those taking Further Mathematics, with only Physics and Computer Science being more male-dominated. These gender patterns are shown in Figure 2 and have changed little across the past three decades.[5]

Figure 2: Percentage of male and female students making up each STEM A level cohort in 2021/22



The high participation in Mathematics at A level does not continue into university study. In 2020/21, maths students made up 1.7% of all undergraduates, or 9.4% of all those taking STEM subjects. As Figure 3 shows, take-up of mathematics has declined since 2017/18, both as a proportion of all those studying for undergraduate degrees, and of those studying STEM. Figures 4, 5 and 6 show breakdowns of maths undergraduates by gender, race/ethnicity and IMD quintile for 2020/21, relative to other subjects, STEM and non-STEM.

Figure 3: Participation in STEM disciplines at undergraduate level from 2015/16 to 2020/21

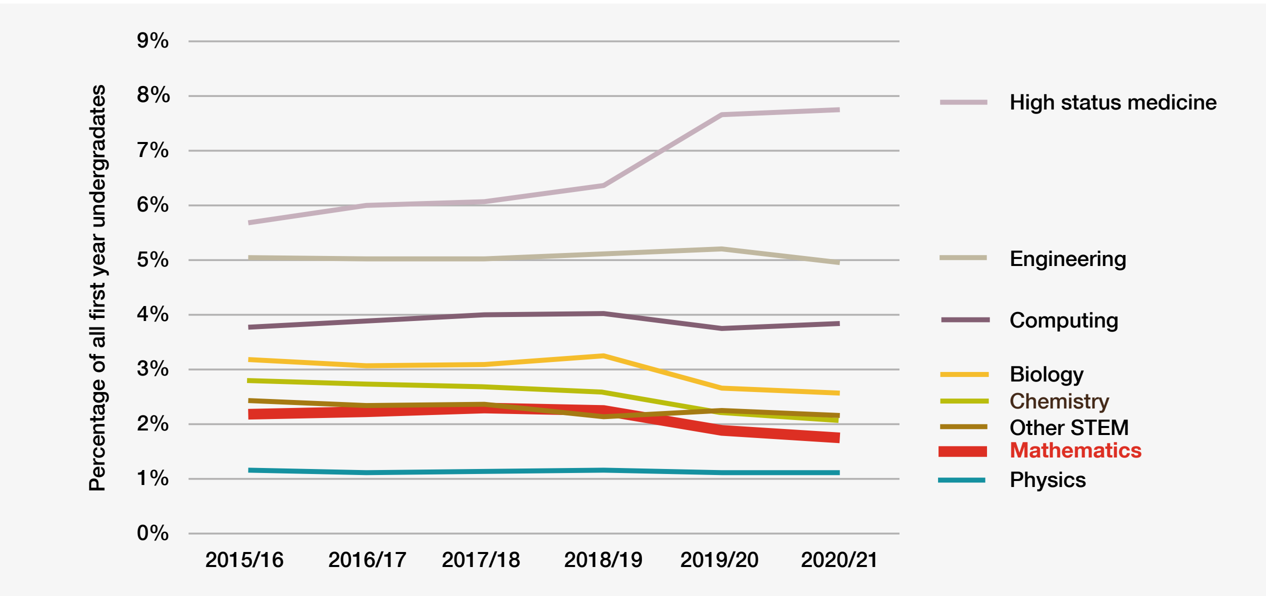


Figure 4: Breakdown by gender of first-year undergraduates in England 2020/21

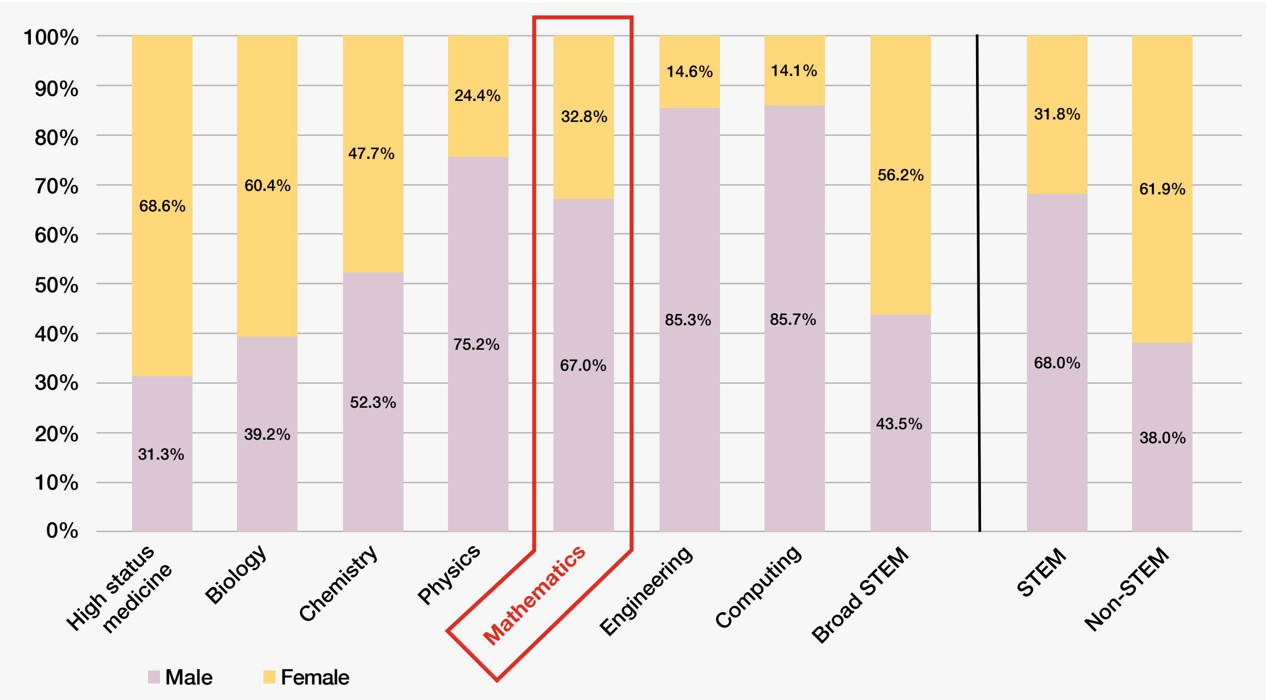


Figure 5: Breakdown by race/ethnicity of first-year undergraduates in England 2020/21

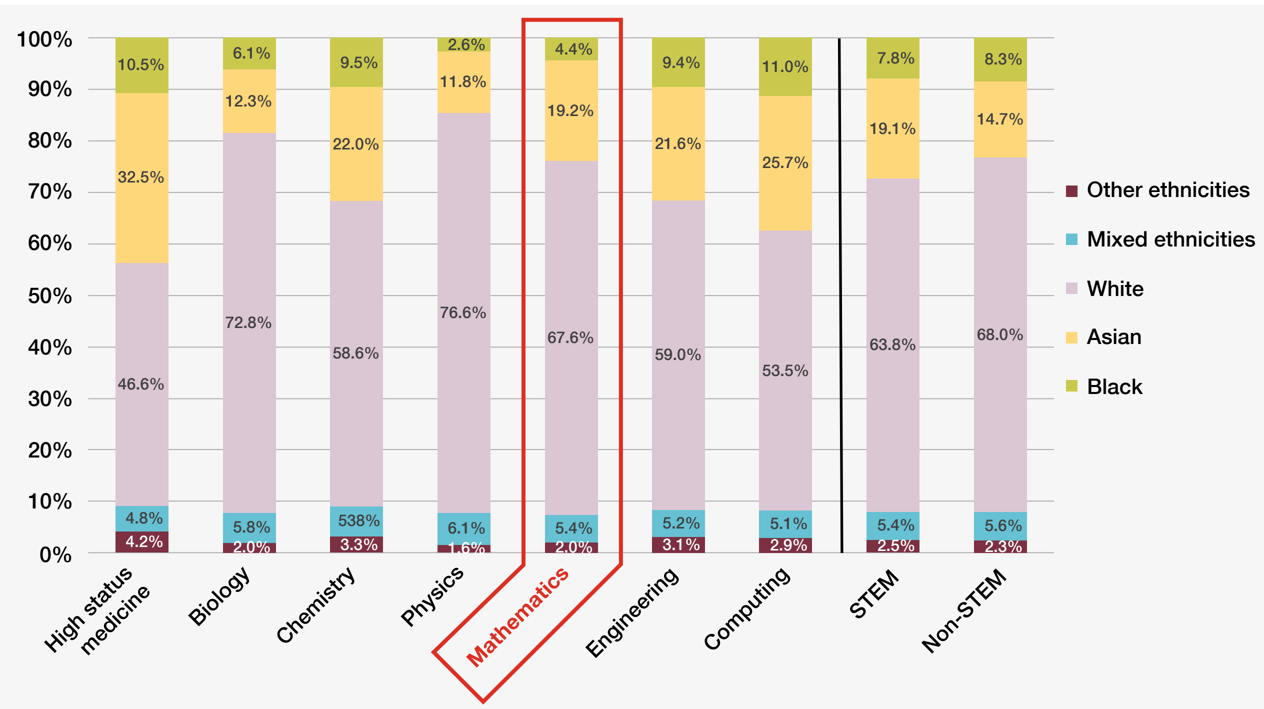
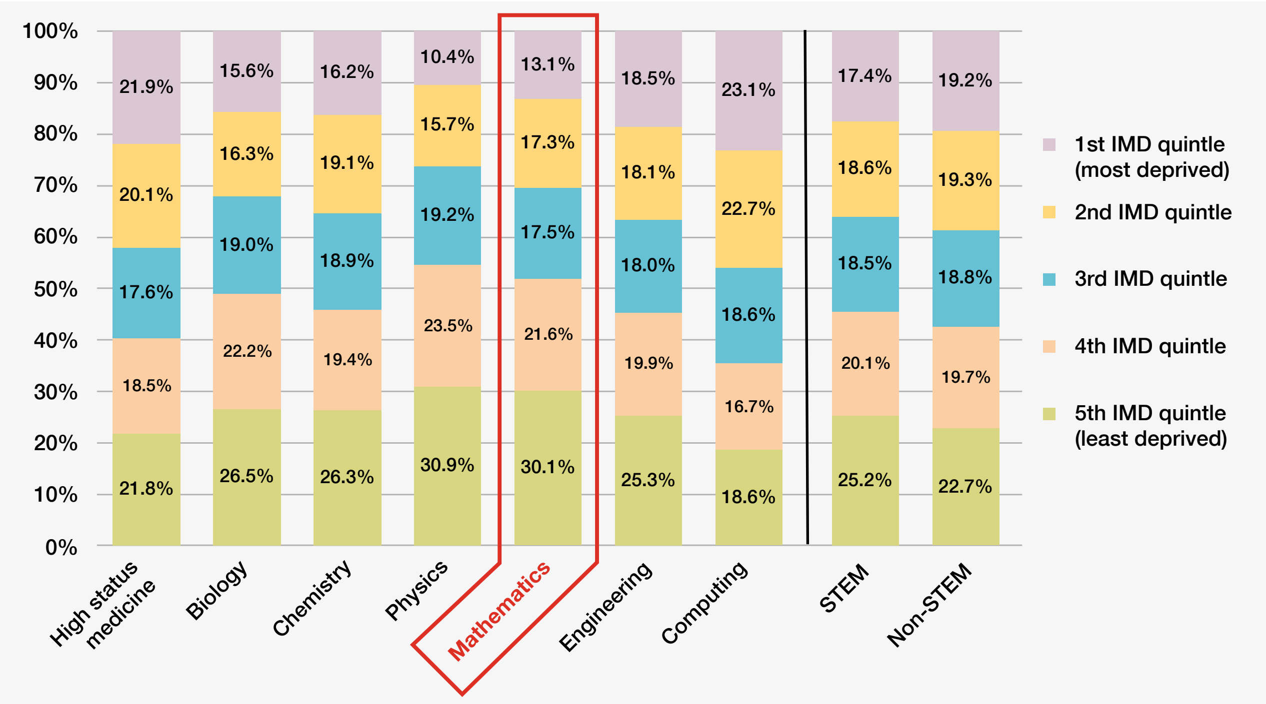


Figure 6: Breakdown by IMD of first year-undergraduates in England 2020/21



As at A level, the proportion of female students in undergraduate mathematics is approximately one in three. This is similar to that across all STEM fields at undergraduate level, though lower than chemistry, the most gender-balanced STEM subject, and much lower than across non-STEM fields.

Among maths undergraduates, there are similar percentages of students on average from Asian backgrounds (18.8%) as in STEM overall (18.1%), and more than in non-STEM degrees (13.7%) between 2015 and 2021. The proportion of Black students (4.4%) is much lower than in both STEM and non-STEM degrees in 2020/21. Maths degrees attract fewer young people from low-IMD backgrounds than STEM and non-STEM degrees overall, and **over half of maths undergraduates are drawn from the two highest IMD quintiles**.

Between 2015 and 2020, on average 4.8% of first-year mathematics undergraduates from England aged 18 to 24 left their course with no award during, or at the end of, their first year; 1.7% withdrew during, or at the end of, their second year; and 0.8% during, or at the end of, their third year. **These non-completion rates are lower than for STEM degrees overall.** In 2019/20, those from the most deprived IMD quintile left their maths degree in their first year at a higher rate than those in the most privileged quintile: 7.3% vs. 3.2%. Male maths undergraduates had a slightly higher rate of non-completion than women: 4.8% vs 3.3%.

3. Prior research base and conceptual approach

In the UK, there is a damaging and dominant idea that success and failure in mathematics are primarily due to 'natural ability'. In the 1980s, the Girls and Mathematics Unit documented how teachers frequently viewed girls' high attainment in maths as due 'hard work', judging it as of less value than boys' lower attainment, which they ascribed to 'natural ability'.[6] Since then, research has shown that these ideas about hard work and natural ability persist and are shared widely in the population.[7] Deeply embedded dominant ideas about gender, race/ethnicity and social class mean that women and girls, Black young people, and those from working-class backgrounds are less likely to be recognised by others, and to recognise themselves, as 'good at maths', than White male, middle-class students.[8] Dominant images of the mathematically able in popular discourse depict mathematics as produced by individuals not collectives, and through rapid strokes of genius, rather than through sustained, often repetitive work.[9] Such myths mean that many who do not fit this ideal doubt their abilities, even when they do well.

The ASPIRES project is informed by sociological and educational research that shows how **interactions of identity and capital (social and cultural resources) shape young people's pathways through schooling and into further and higher education and employment.**[10] Young people can accrue capital from home, family, school and other educational contexts.[11]

In the ASPIRES research, we explore how **mathematics-related capital is translated into resources and practices that help produce and sustain young people's high interest, attainment and aspirations in maths.** We show that **interactions of identity and capital are key to producing and sustaining maths trajectories, and that where there is close alignment between maths-related identity, resources and the field of mathematics education, they are more likely to feel competent and interested in maths, and so are more likely to choose to continue with the subject**.

Importantly, we also argue that **prevalent ideas about mathematics competence being based on 'natural talent' restricts participation in maths (particularly at degree level),** and limits the opportunities for the majority of young people (and particularly women) to feel that a maths degree trajectory is possible and desirable 'for people like me'.

4. What data did the ASPIRES research collect?

ASPIRES is a mixed methods study that focuses on young people from a single cohort, born between September 1998 and August 1999. It comprises survey data from over 47,000 young people from this cohort, and qualitative interview data from a longitudinal tracking of 50 participants from the same cohort (with their parents/carers) between the ages of 10 and 22, totalling over 800 interviews. Table 1 summarises the quantitative and qualitative data collected at each stage of the research.

Table 1: Summary of ASPIRES project data collection

	ASPIRES			ASPIRES2			ASPIRES3
Data point	1	2	3	4	5	Interim catch up	6
Year	2009/10	2011/12	2012/13	2014/15	2016/17	2017/18	2020/21
Age	10/11	12/13	13/14	15/16	17/18	18/19	21/22
School Year Educational stage	Year 6 End of Key Stage 2 – Final year of primary school	Year 8 Key Stage 3 – Second year of secondary school	Year 9 End of Key Stage 3 – Third year of secondary school	Year 11 End of Key Stage 4 / GCSEs – Final year of secondary school	Year 13 End of Key Stage 5 / College	1st year university, work, gap year, other	First year after completing university / continuation of university studies or work
Number of survey participants / schools	9,319 279 primary schools	5,634 69 secondary schools	4,600 147 secondary schools	13,421 340 secondary schools	7,013 265 schools / colleges	N/A	7,635 N/A
Number of interviews with young people	92	85	83	70	61	60	50
Number of interviews with parents	84 parents of 79 children	Parents not interviewed	73 parents of 66 young people	67 parents of 63 young people	65 parents of 61 young people	Parents not interviewed	35 parents

The ASPIRES3 survey comprised a large-scale postal survey of young people in England and was conducted by obtaining a sample of young people born between 1st September 1998 and 31st August 1999 who were registered on the Open Electoral Roll. Following data cleaning, the overall achieved sample of 7,635 young people was roughly proportional to (though not fully representative of) official government population estimates in England for 21- and 22-year-olds based on sex, ethnicity, region, Index of Multiple Deprivation, Urban/Rural classification and long-lasting health conditions.[12]

Within the ASPIRES3 survey sample of 7,635 young people, 4092 took A levels (53.6%), of whom 1164 (28%) took A level Mathematics and replied to the relevant questions.[13] 70 of these pursued a degree in mathematics, starting in 2018.[14] The breakdown of the maths undergraduates was: 35% Women, 61% Men; 68% White, 22% Asian, 4% Black, 6% Other ethnicities and prefer not to say; 39% IMD1 and IMD2 quintiles, 18% IMD3 quintile, 43% IMD4 and IMD5 quintiles.

5. Why do suitably qualified students take – or not take – a mathematics degree?

Figures 7 and 8 summarise the open-ended responses from the final ASPIRES survey of:

- The reasons STEM degree students gave for their subject degree choice, classified into: subject interest/passion; feeling 'good at maths'; positive views of mathematics jobs; family encouragement; and other;
- The reasons young people who had taken A level subjects that would have enabled them to apply for STEM degrees gave for their decision not to pursue these subjects, classified into: subject dislike/hatred; feeling 'bad at maths'; negative views of mathematics jobs; family discouragement; do not want to go to university; and other.

Figure 7: The reasons STEM degree students gave for their subject degree choice

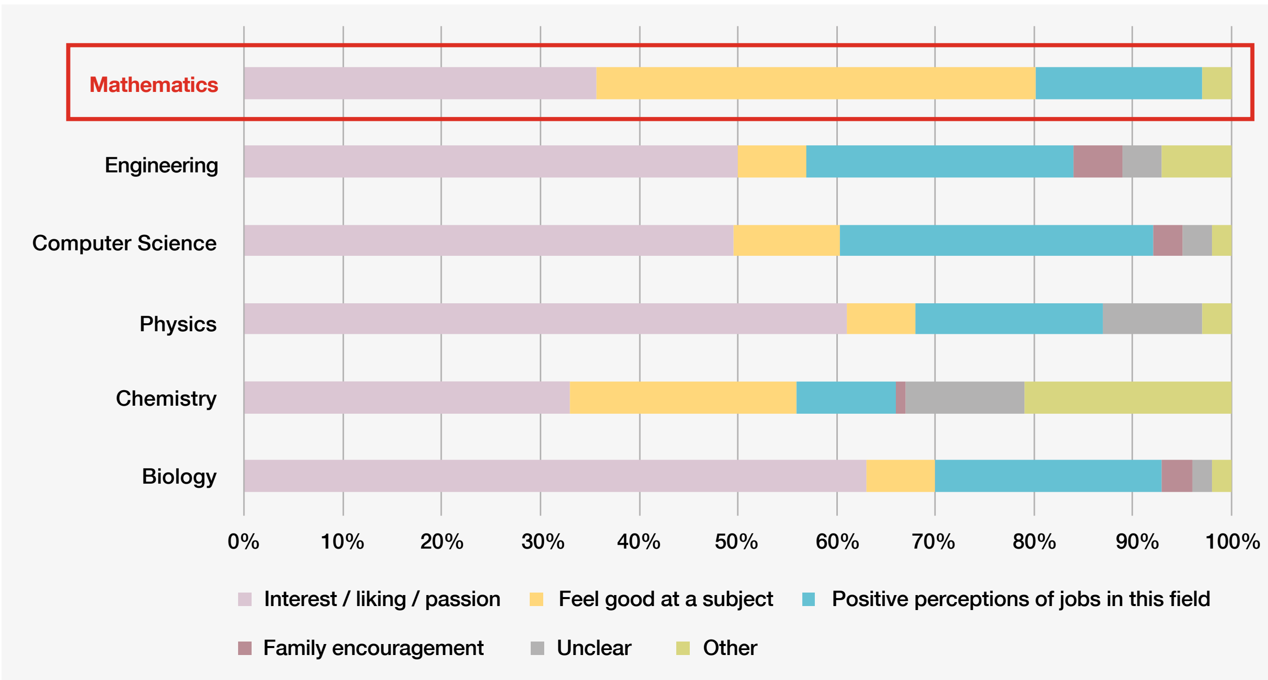
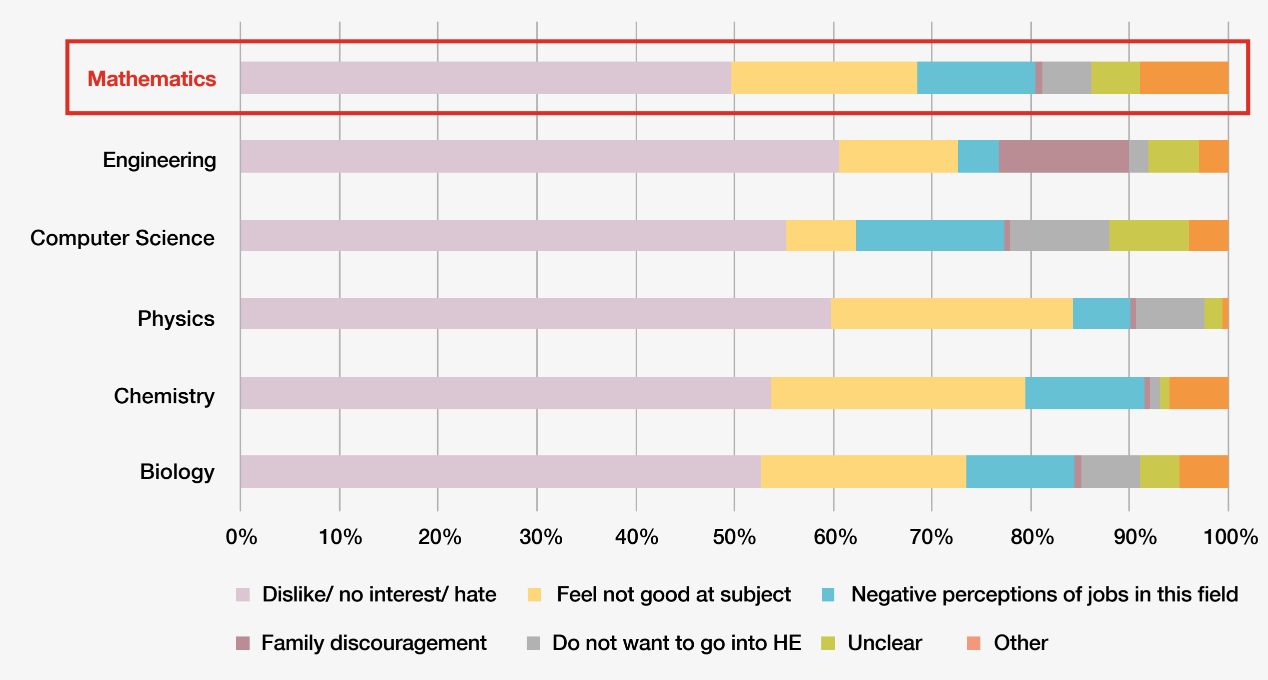


Figure 8: The reasons young people who had taken A level subjects that would have enabled them to apply for STEM degrees gave for their decision not to pursue these subjects



Analysis showed that **among those who went on to study for a degree** in a STEM discipline:

- **Feeling 'good at maths' was the top reason – given by 45% of young people – for choosing the subject**, which we interpret as reflecting the power of dominant discourses of natural ability (discussed further below). **This stood out notably from other STEM subjects**, where subject competence accounted for between just 7% to 23% of reasons for taking a subject at degree level. For all other STEM disciplines, interest/ passion was the top reason;
- When we look in more detail at the demographic profile of maths degree students who cited being **'good at maths'** as the primary reason for their degree choice, we see that it primarily reflected responses from socially privileged maths undergraduates, namely **White male students, and from the most affluent social quintiles (IMD4 and IMD5).** In comparison, other maths degree students tended to give reasons that more closely reflected those of their peers taking other STEM degrees;
- Positive views of maths-related jobs was a relatively **less important factor** in the degree choices of maths students (17%) than was found for students in other STEM fields, such as engineering (27%), computing (32%) and biology (23%), although it was comparable with those in physics (19%), and higher than found among chemistry students (10%).

Looking at the reasons given by suitably qualified young people for *not* pursuing degrees in particular STEM subjects, analysis showed that:

- As found in relation to other students' reasons for not pursuing a given STEM degree, **dislike/ hatred of maths was the most commonly given primary reason for not pursuing a maths degree**, cited by 50% of those who had taken A level Mathematics but who had not pursued a maths degree;

- Perceived competence, and feeling 'bad at' the subject, was the second most common reason given by students for not taking a maths degree, similarly to the reasons given by other STEM degree students for not pursuing a given discipline;
- Negative views of subject-related jobs were most commonly cited in relation to computing (15%), biology, chemistry and maths (12%), and least often in relation to engineering (4%) and physics (6%).

These data suggest that **students' reasons for taking a maths degree stand out from the reasons given by other STEM students** for why they pursued their particular degree area. However, the reasons given by those *not* taking a maths degree do not stand out notably from the reasons given by students for not pursuing other STEM fields.

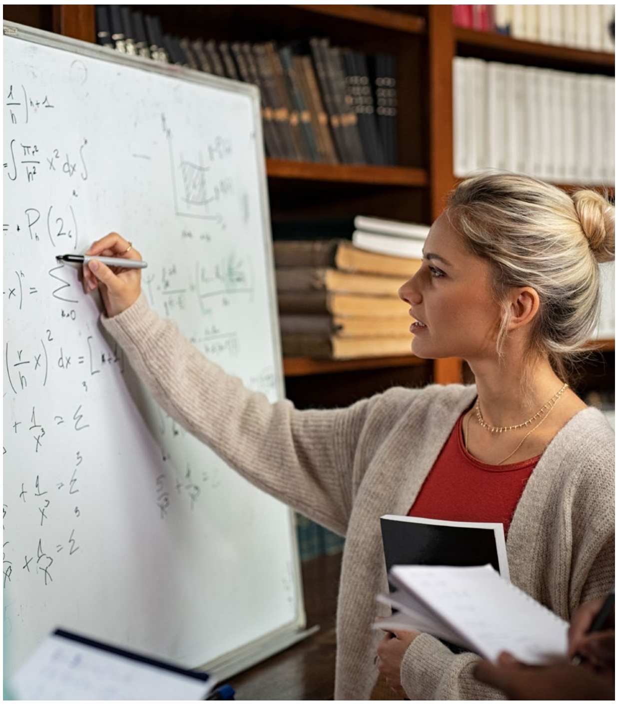
As discussed next, the qualitative interview data help us to understand how interactions between young people's identity and capital with the field of mathematics education shaped their trajectories into and away from maths degrees in socially patterned ways.

6. What factors shape mathematical trajectories?

As discussed next, analyses of the longitudinal qualitative data show how **students' choices are influenced by the extent of the fit between their identity, capital and the field of mathematics, which shapes the extent to which maths pathways are felt to be 'for people like me', or not**. Yet the ASPIRES survey data suggests that the majority of young people at age 21-22 do not identify strongly with maths.

The qualitative data shows how a range of factors come together to shape pathways into, and out of, mathematics, including how **maths-related capital and experiences during school years are important for developing and sustaining an interest and aspiration towards mathematics** and the **particular importance of popular notions of mathematical competence being ascribed to intellectual superiority, 'natural ability' and having a 'maths brain'**.

These issues are exemplified by two case studies of Joanne and Tom, both of whom attain highly in mathematics, but pursue different degree trajectories. These case studies challenge dominant ideas that mathematical ability is 'natural' by showing the role of capital in shaping mathematical trajectories.



Factor 1: At age 21/22, the majority (87%) of young people do not strongly identify with mathematics (while those who do reflect particular demographics)

Existing evidence underlines how strong maths identities are important precursors for maths participation. Yet the ASPIRES survey data show that at age 21/22, the vast majority (87%) of young people do not strongly identify with maths, despite the importance accorded to it throughout compulsory schooling, and the popularity of Mathematics A level.

Men are almost twice as likely to identify as having a strong mathematics identity as women, but even this represents just one in three men. This finding illustrates an ongoing issue with gendered identifications with mathematics. East and South Asian young people are significantly more likely than Black and White young people to identify as having a strong maths identity, but even among these groups, over 60% do not identify strongly with maths.

Finally, there is little variation by IMD quintile, but those in education or training are more likely to identify as having strong maths identities than those in employment or NEET (Not in Education, Employment or Training). These data help explain the low levels of take-up of undergraduate maths and the persistent differences in maths participation by gender and social class.

Case Study 1: Joanne is a White British young woman. Her parents are both from working-class backgrounds and neither went to university, but they have since become socially mobile. When we first met Joanne at age 10, she saw herself, and was recognised by others, as a good "all-rounder", attaining highly in all subjects, although she was doing exceptionally well in maths. As Joanne said, "I think maths is my best subject", due to being "the first person in school to get through the finals of the Primary Maths Challenge". As her father explained, "they say collectively at the school she's the brightest pupil they've ever had", adding, "I can see her quite quickly outstripping us both in terms of our maths knowledge and science."

At age 12/13, Joanne was still an "all-rounder" who enjoyed maths, which she attributed to her teacher. The following year, she again represented her school in a national mathematics competition. This time, she was less successful, which she felt was due to her school team being unprepared compared with some private school competitors who had been "training for three months". Her mother felt that Joanne was "driven a lot by what she's good at" and could see her daughter becoming more science-orientated, benefiting in particular from having science teachers who "go out of their way to motivate her".

By the time of the national GCSE exams at age 16, Joanne had started to lose interest in maths, finding it more difficult and questioning whether to continue with it. Despite this, she decided to study Mathematics, Further Mathematics, Biology and Chemistry at A level. She described people who take Mathematics as "very smart" and her friendship group as "the maths-y group", adding, "I think you've got to have a mind that's right for it". However, she ended up dropping Further Mathematics because it was "too much maths" and she wanted more time to focus on other subjects. She felt vindicated in this choice when she later saw her friends "swearing at the maths text books now, because Further Maths is so hard". She engaged in a range of science-related extracurricular activities and developed a deep personal connection with biological sciences through both family health experiences and the support she received from teachers and outreach experiences. She attained the top A* grades in all her mathematics and science A levels.

Joanne went on to take a natural sciences degree at an elite university. At age 21, she reflected back on the role that her teachers had in supporting her science trajectory: encouraging her to learn beyond the curriculum and take part in out-of-school opportunities in which she gained recognition and deeper engagement. She contrasted it to her feeling that "I think maths teachers realised kids don't want to do maths for longer than they have to".

Case Study 2: Tom identifies as middle-class and of South Asian (Pakistani Muslim) heritage. He described his father and brother as interested in and "good at maths", and his uncle as "phenomenal" at the subject. Over the years, Tom returned to a pivotal experience in primary school, aged 6 or 7, when his class had a mathematics competition with the year above, which Tom won in the final round, beating the "cleverest boy in the year above". After this, he started to both strongly identify – and be recognised by others – as 'strong at maths'. He described finding maths "easy" and something which "I can kind of excel at" and "love doing". His teachers identified him as 'Gifted and Talented' at mathematics, opening up further opportunities including "two maths workshops – one about matrices and one about problem solving, working out ratio, everything!" Tom enjoyed asking his dad to set him "really hard maths sums" when younger, and loved watching Countdown[15] together on television – the latter continuing until he left home.

Aged 12/13, Tom developed an interest in a mathematics career, particularly after his mother told him that the government predicted high future demand for mathematicians. At 14, he aspired more to medicine, but noted his dad's advice to maintain his interest in maths. Tom was selected to attend a two-day mathematics workshop at an elite university, where he met peers who "love maths as much as I do", motivating him to want to do a maths degree to meet more like-minded people. The following year, he started tutoring younger students in maths.

Tom attained highly in his national GCSE examinations. In his final year at school, he was made deputy head boy, responsible for championing STEM. He did work experience at his father's hospital, where he was able to apply mathematics. He described his maths teachers as "fantastic", going "beyond the test" and encouraging him to pursue the subject independently. After achieving top grades in Mathematics and Further Mathematics at A level, he took a gap year, during which he worked as a tutor and volunteer learning assistant, providing mathematics and physics support in school.

At age 21, Tom was studying an applied mathematics degree at an elite university. He had a strong and secure maths identity, describing how he felt he had "a knack" for it, was "becoming a mathematician", and was looking forward to seeing "where maths will take me". He enjoyed watching science and maths YouTube content and reading humorous science and maths books (for the "fun side" of these subjects) along with "mid-level" text books. He reflected how his home and school experiences, but particularly his primary teachers, had been key to building his maths identity by helping him "to see that I am good at maths".

Factor 2: A 'wrap-around' of mathematics-related social, cultural and economic capital over time is important for making a maths identity and trajectory possible and desirable

Longitudinal analyses[16] of the trajectories of maths degree students from the ASPIRES project show that developing and sustaining an identity as 'good at maths' relied on learners accessing maths-related capital – economic, cultural and social resources – through their families, schooling, and wider networks, as exemplified by Tom's account and the multiple forms of support that he was able to access over time. Analyses of data from other maths students in the sample also reveal how classed differences in the distribution of capital were implicated in the strategic decision-making practices and differential outcomes between maths degree students. For example, Gerrard (a White, working-class young man from an Eastern European background) felt that while he loved mathematics, a maths degree would be too risky and 'selfish' an option to pursue, as he was not aware it could lead to secure, well-paying careers that would enable him to provide financially for his family.

Maths-related social and cultural capital was generated through:

- Knowing, and being encouraged over time to continue with maths by, family/friends/social contacts with maths qualifications, knowledge, interest and/or jobs;
- Undertaking informal maths activities in one's free time, e.g. through hobbies, media consumption, clubs, competitions;
- Participation in more formal maths-related programmes, masterclasses, activities and outreach through educational, and other, organisations.

Young people's maths participation was also supported by economic capital in the form of sufficient family finances, bursaries or grants to make the pursuit of a mathematics qualification feel possible and desirable.

Factor 3: Mathematics identities are dominated by notions of intellectual superiority and 'natural talent' (e.g. having a 'maths brain', being a 'maths person'), which restrict many young people from developing maths identities and trajectories

As demonstrated by both the survey data and the longitudinal interviews, 'being good at maths' was pervasively associated with notions of natural talent and intellectual superiority, as encapsulated by notions of the 'maths brain'. These ideas are evident in both Joanne's and Tom's case studies – for instance, Tom's trajectory from primary school Gifted and Talented to having "a knack" for the subject at university, and Joanne feeling you need "a mind that's right for it", while increasingly doubting that she does.

The pervasive popular association of maths competence with 'natural talent' means that many young people whose maths attainment is produced in other ways, such as 'hard work', are not able to see themselves (or be recognised by others) as 'good at maths'. Previous feminist research has analysed how dominant conceptions of mathematical success as determined by natural ability are organised through a binary construction of attributes, in which mathematical ability is aligned with traits perceived as masculine, such as reason, hardness, rapid brilliance, independence and competition. These traits are more highly valued than their feminine-linked opposites of emotion, softness, diligence, dependence and cooperation. These oppositions are also classed and racialised, with the more highly valued side aligning with White, middle-class, masculine ideals of muscular intellect over physical prowess.

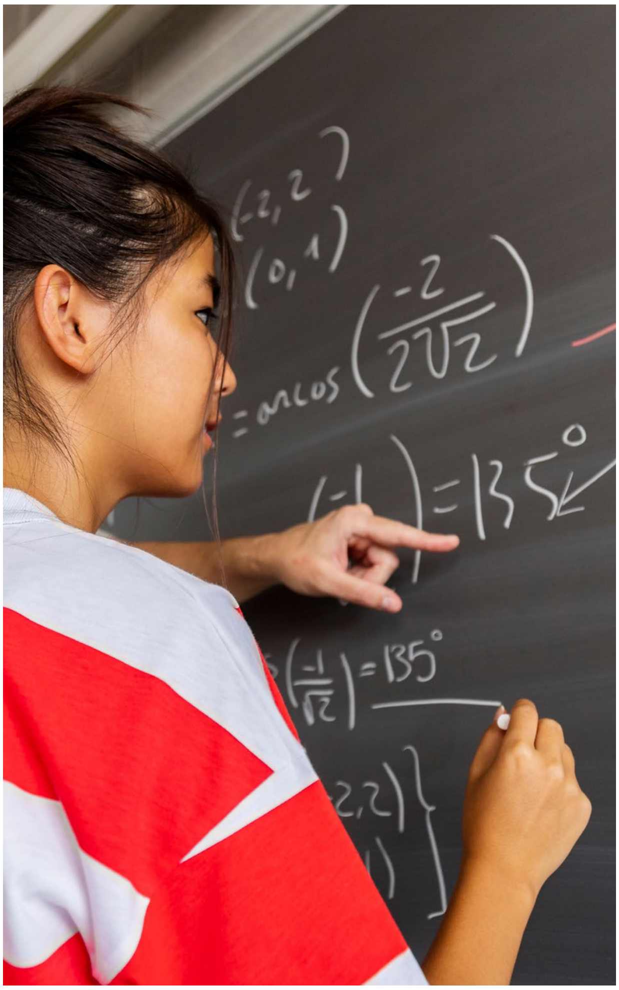
These historic cultural associations for maths and mathematical competence make it difficult for women, but also working-class and some racially minoritised young people, to identify with maths, or to recognise themselves as 'good at maths', irrespective of their attainment in the subject.[17]

ASPIRES evidence[18] supports and extends these prior findings, identifying additional, new, discursive distinctions that make up this binary construction of attributes, including intrinsic and extrinsic relationships with maths (e.g. valuing maths for its intrinsic pleasure/interest, versus seeing it as a tool for facilitating other pathways), and being a subject specialist (mathematician) versus being a generalist (e.g. "all-rounder"). As a result of these narrow, pervasive binary constructions of maths, our analyses suggest that many young people may find it hard to identify themselves as being 'good at maths', irrespective of their attainment in the subject.

Over time, we noted that those young people who went on to take maths degrees were more likely to continue to identify with dominant ideas about being naturally gifted at maths, whereas among those who took A level Mathematics but went on to pursue other post-18 routes, alternative narratives become more prevalent over time. While it may be encouraging to see that, on balance, more young people appear to adopt broader, less stereotypical views of maths competence over time, arguably these broader views of what it means to be good at maths may not have the impact they would, had these young people gone on to become the next generation of mathematicians and maths teachers.

Factor 4: Young people's self-identifications with mathematics competence were neither clear-cut nor one-off

Our longitudinal analyses reveal how there was no single moment at which young people came to define themselves as naturally talented, as opposed to competent (or "OK") at mathematics. Their identifications evolved over time and could be contradictory. A young person's alignment with being naturally mathematically talented could be precarious and easily disrupted, as in the case study of Joanne, when her sense of herself as being 'good at maths' was disrupted by 'losing' an inter-school mathematics competition. Our longitudinal data show that experiences of recognition as 'good at maths', when repeated over time, help sustain identification with maths, which, in turn, helps to realise a mathematics trajectory. For some, such as Tom, these initiate a 'virtuous circle', amplifying access to maths-related capital, support and opportunities, further reinforcing one's identity as 'naturally able'.



7. What do mathematics undergraduates say about their degree experiences?

Generally, mathematics degree students expressed broadly positive views of their undergraduate experiences, although there remains a notable minority (just over a third of students) who expressed less positive views.

Levels of satisfaction

Of those who were currently studying for a maths degree,[19] **61% felt that A levels had prepared them well.** This is slightly higher than found generally among STEM and high-status medicine degree students (53%). However, 39% of mathematics degree students did not feel adequately prepared by A levels, suggesting scope for further support and intervention.

61% of maths degree students said that if they could do it again, they would choose the same subject. This is slightly lower than the average for all STEM and high-status medicine degree students (67%).

Just **19.4% of maths degree students felt their course was good value for money –** a figure that was slightly lower than found among STEM and medicine students overall (28%).

Almost two thirds (64.5%) of maths degree students said that they felt comfortable and 'belonged' on their course, which was slightly lower than found among other STEM and medicine students overall (70%).

Concerns about completion

The proportion of students who expressed worries about completing their degrees was lower in mathematics (18%) than the average across all other STEM degrees (27%). Across all subjects, students expressed similar reasons for these concerns, with academic issues paramount, alongside financial worries, health issues, the impact of COVID and, for a small number, caring responsibilities and/or social integration issues. As a general pattern across all STEM areas, those from underrepresented groups – women, racially minoritised students, and students from low IMD quintiles – were the most likely to express concerns.

Experiences of sexism on STEM degrees

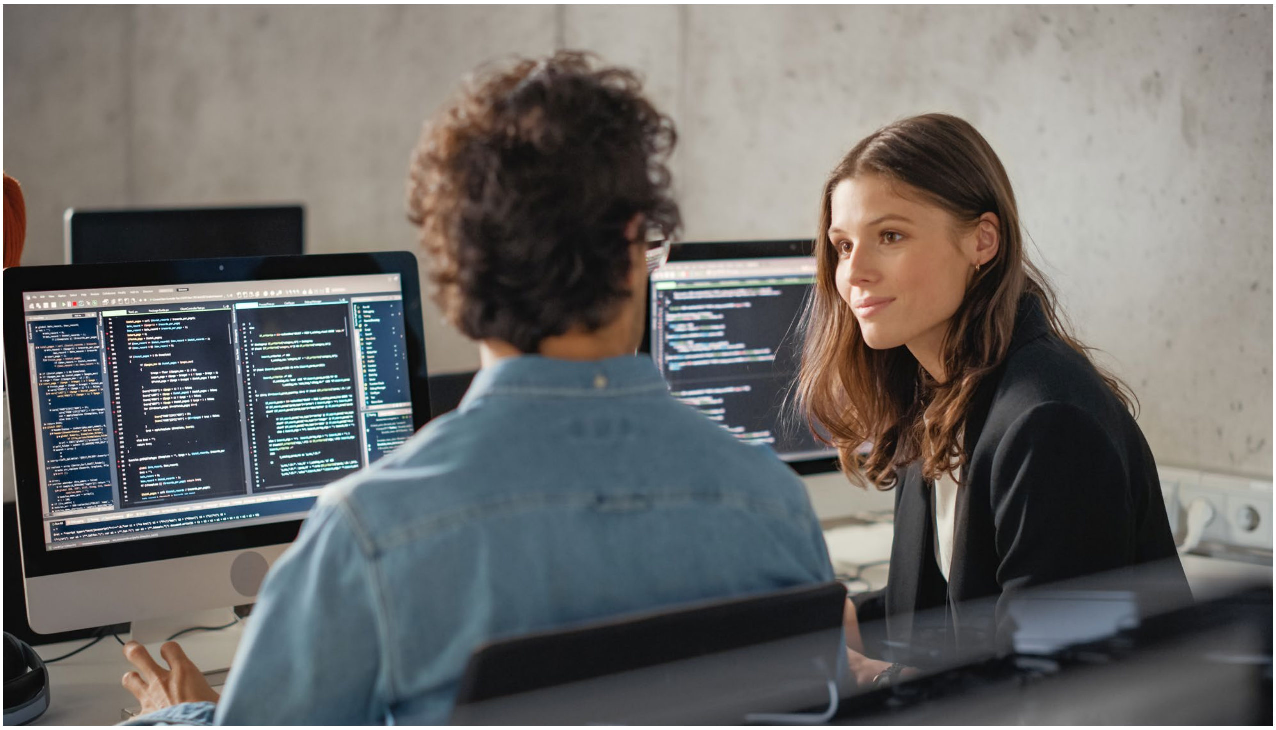
15% of women in STEM and high-status medicine had experienced sexism within their educational setting within the past year – this figure was **significantly higher than for those in non-STEM fields.**[20]

Within STEM and high-status medicine fields, **women studying maths were the least likely to report sexism (3%),** and women in physics and engineering the most likely (50% and 30%, respectively**). Sexism was most frequently attributed to male peers.**[21] The interviews revealed that peer sexism usually involved everyday gendered microaggressions and acts of disdain and disrespect, such as questioning women's academic legitimacy, and ignoring and patronising them.

Plans for after graduation

In line with other STEM fields, **most maths degree students/graduates**[22] **were planning to go into, or continue in, full-time work (75%)** or postgraduate study (15%).

Maths degree students/graduates were less likely than those in other STEM fields to plan on staying within mathematics after graduation – 7.6% of maths students planned to stay within mathematics, compared with 18% of those across all STEM and high-status medicine fields who planned to stay within the same field as their degree. Among maths degree students/ graduates, 21% planned to go into technology and computing, and 33% into other fields allied to mathematics. A further 23% of maths students/graduates were working /planned to work outside of STEM.



8. How can policy and practice support participation in mathematics?

In England, Mathematics A level is the most commonly taken advanced level qualification, yet it is taken by comparatively few students at degree level. Students express generally positive views of maths degrees, although women remain underrepresented. ASPIRES identifies the role of (i) maths capital, and (ii) the prevalent, popular association of maths with 'natural talent' as key factors that impact and restrict maths degree participation.

ASPIRES provides robust support for previous research showing that strong mathematics identities and degree trajectories are difficult for young people to achieve. This is especially the case for those who do not fit the image of the 'natural' mathematician – notably, young women and working-class young people.

Maths skills impact active citizenship and individual and collective mobility, and maths qualifications have high status and considerable exchange value. Identification and engagement with maths can be increased when policy and practice actively support recognition and maths-related capital among a broader range of young people, enabling everyone to feel capable at maths and to find pleasure in it.

Our findings suggest that there are limits to what can be achieved by changing the views of individual students without addressing systemic practices in mathematics education at all levels, from school to higher education and beyond. Our recommendations fall into five categories.

Support, value and grow young people's maths identities and capital over time and across contexts

To enable more young people to experience a 'wrap-around' of maths-related social, cultural and economic capital over time that can support their maths interest and identity development, funders and policymakers might usefully:

- Review the balance of support offered for short vs. longer-term interventions and consider shifting towards longer-term interventions with key communities;
- Explore the potential to create a better connected, more comprehensive and coherent maths engagement 'ecosystem', in order to offer all young people clearer 'pathways' over time and across spaces that can enable and support maths trajectories. This could include mapping provision geographically and demographically to ensure equitable distribution and provision, and to support the establishment of both local and national engagement pathways (to enable young people to better access and navigate provision);
- Consider how to mitigate the inequities associated with self-referral models and strategically consider how to reach those who could most benefit. Partnership working with other community organisations may be helpful in this respect;

- Support practitioners, teachers and educators to use pedagogical approaches and resources such as the Equity Compass and the (Primary) Science Capital Teaching Approach to increase understanding of the issues and scaffold critical professional reflection towards action. In particular, such approaches might be used to identify and implement ways to actively support and augment young people's maths identities and capital, helping them to find meaningful connection with maths and see the relevance of maths learning to their current and future lives.[23]

Challenge ideas of mathematical competence being based on 'natural talent'

To help more young people to feel that they are 'clever enough' to continue with maths, funders and policymakers may find it useful to:

- Review the extent to which the idea that maths is more difficult than other subjects and only for those with natural ability is reinforced and perpetuated by a range of common educational practices (such as pedagogy, attainment-based grouping practices, Gifted and Talented programmes, tiered examination entry) and develop action plans to address this at both strategic and operational levels (e.g. providing professional development to enable educators to be aware of, and challenge, everyday practices that reinforce such ideas);
- Support providers of initial and continuing professional learning to draw on existing resources and approaches to (i) increase their understanding how such ideas sustain unequal patterns of maths participation and damage many young people's relationships with the subject; (ii) help them identify changes to their practice that can enable more young people to feel 'good at maths' by centring ideas of equity[24], broadening ideas about who/what counts and gets recognised as being good at maths, using assets-based approaches (e.g. P/SCTA), and connecting mathematics to everyday activities such as work and citizenship[25] ; and (iii) clearly communicate to others how ideas of 'natural brilliance/ability'[26] and the 'maths brain' are myths that hinder increased and more inclusive maths participation.

Challenge peer sexism on maths degrees

To enable more young people – but specifically women – to experience a better 'fit' between their identities and mathematics, challenge sexist behaviours and cultures and improve women's progression and retention, policymakers, funders and practitioners might usefully:

- Consider how they can support and encourage practitioners to understand, recognise and address sexist language and behaviours among students, particularly in male-heavy subject areas. It may be helpful to integrate this work with Athena SWAN departmental task groups;
- Support anti-sexism practice and initiatives by sharing and promoting resources such as the ASPIRES 'Step Up' anti-sexism ally poster and/or by engaging with wider anti-sexism initiatives aimed at tackling the sources of sexism. Practitioners can reflect and adapt their practice to be more inclusive using tools such as the Equity Compass.[27]

Support more equitable retention and belonging and transition on maths degrees

To support and enhance the experiences of those maths students who are less positive about their degree experiences and to encourage increased retention in maths (particularly among young women), higher education policymakers, senior managers, professional societies and organisations concerned with equity in maths might usefully:

- Consider giving this issue greater policy consideration and prominence, especially in male-heavy disciplines such as mathematics – both generally and specifically regarding the retention and progression of maths students from low-income backgrounds. It may be helpful to engage and coordinate with charities and initiatives that focus on supporting underrepresented and first-generation students;
- Review how support might be directed strategically to ensure it reaches those who could most benefit – not only in terms of supporting students directly, but also ensuring that staff are equipped to recognise the issue and address it through their own practice;
- Support critical professional reflection and professional development among practitioners, with the goal of enhancing their understanding and action to improve retention and belonging among maths students. This will be useful and relevant across STEM areas, but is particularly valuable in disciplines such as computing, maths and engineering, which record higher levels of attrition.

Facilitate greater access to key forms of social and cultural capital for young people from under-represented communities, to support social mobility in mathematics and beyond

To create a more effective 'wrap-around' of support to build young people's maths-related capital over time, funders, policymakers, practitioners and those concerned with supporting more inclusive engineering participation might usefully:

- Consider how they can best support young people from underrepresented communities to access key forms of social and cultural capital to support their maths trajectories. Funding longer-term interventions that foreground the generation of mutual trust and supportive relationships between young people and key adults may be particularly helpful, along with targeted measures to reduce the costs and risks of higher-level maths routes for young people from underrepresented communities;
- Support educators and practitioners to gain insights from tools and approaches such as the SCTA to help reflect on how they might best build supportive and equitable relationships with young people that also help redistribute valuable forms of capital (e.g. knowledge, experiences, social contacts, qualification routes). Explications and the principles of 'caring' pedagogy[28] may also provide useful insights.

References

1 Smith, A. (2017). Report of Professor Sir Adrian Smith's review of post-16 mathematics, London: DfE available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/630488/AS_review_report.pdf

2 National Numeracy. (2017). A new approach to making the UK numerate, available at: https://www.nationalnumeracy.org.uk/sites/default/files/documents/nn124_essentials_numeracyreport_for_web.pdf

3 The A level data are collected by National Statistics from Awarding organisations that deliver examination entries and results for all qualifications. The A level data is given in the 'A level and other 16 to 18 results' release series. Most subject names have been consistent over time but course content might have changed. These reports are available at: https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results/2021-22; See also Annual Reports, 2022, available at: https://www.jcq.org.uk/examination-results/; There is more information about their methodology here: https://explore-education-statistics.service.gov.uk/methodology/a-level-and-other-16-to-18-results-methodology; For 2023 data that continues these trends, see: 'A-Level and other level 3 results 2023: The main trends in grades and entries', available at: https://ffteducationdatalab.org.uk/2023/08/a-level-and-other-level-3-results-2023-the-main-trends-in-grades-and-entries/

4 The undergraduate data in this section are provided by the Higher Education Statistics Agency (HESA), available at: https://www.hesa.ac.uk/data-and-analysis/students. The HESA gender statistics allow only the responses: Male, Female, Other, and Unknown. In contrast, the ASPIRES data, discussed next, uses the options: Man, Woman, Non-binary, Other, and Prefer not to say. Only England domiciled students, aged 18 to 24 at the time of data collection were included in the analysis. People with unknown ethnicities, genders, IMD and school type were included in totals and percentage calculations. Undergraduate counts are a sum of Full-Time Equivalent (FTE) counts for those in first year of study only on a first degree or other undergraduate degree. Attrition data shows FTE sums for individuals who left their course without an award before the end of first, second or third year of study. HESA data have been treated according to the HESA rounding and suppression methodology (https://www.hesa.ac.uk/about/regulation/data-protection/rounding-and-suppression-anonymise-statistics).

5 For data from the 1990s see: Mendick, H. (2006). *Masculinities in Mathematics*. Open University Press, Buckingham.

6 Walkerdine, V. and The Girls and Mathematics Unit (1989). *Counting girls out*. London: Virago Press.

7 Mendick, H. (2006). *Masculinities in Mathematics*. Open University Press, Buckingham. Similar patterns are evident in other countries in the global North, for example, Darragh, L. (2015). Recognising "good at mathematics": Using a performative lens for identity. *Mathematics Education Research Journal*, 27(1), 83-102; Foyn, T., Solomon, Y., and Braathe, H. J. (2018). Clever girls' stories: The girl they call a nerd. *Educational Studies in Mathematics*, 98(1), 77-93.

8 Jorgensen, R., Gates P., and Roper, V. (2014). Structural exclusion through school mathematics: using Bourdieu to understand mathematics as a social practice. *Educational Studies in Mathematics*, 87(2), 221-239; Black, B., Choudry, S., Howker, E., Phillips, R., Swanson, D., and Williams, J. (2021). Realigning funds of identity with struggle against capital: The contradictory unity of use and exchange value in cultural fields. *Mind, Culture, and Activity*, 28(2), 97-110.

9 Compare Burton, L. (2004). *Mathematicians as enquirers: Learning about learning Mathematics*. Dordrecht: Kluwer Academic Publishers, on how mathematicians work with this article on representations of mathematicians: Duchin, M. (2004). "The Sexual Politics of Genius." Archived by the wayback machine at https://web.archive.org/web/20170506222345/http://mduchin.math.tufts.edu/genius.pdf

10 Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge: Cambridge University Press.

11 e.g. Reay, D., David, M. E., and Ball, S., J. (2005). *Degrees of choice: Social class, race and gender in higher education*. Stoke-on-Trent: Trentham Books; Walkerdine, V., Lucey, H., and Melody, J. (2001). *Growing up girl: Psychosocial explorations of gender and class*. Basingstoke: Palgrave.

12 Data was weighted to be representative, and analyses were performed using both weighted and unweighted data. Because weighting made no difference to the findings, the analyses referenced in this report use unweighted data. Additionally, in this report, 'significant' refers to statistically significant findings from a variety of analyses. Please refer to our referenced publications within this report, or contact us for more details.

13 The wider sample was recruited on the basis that they lived in England, were born between 1st September 1998 and 31st August 1999, and were registered on the Open Electoral Roll. The total survey sample was not representative with regard to official government population estimates in England for 21-22-year-olds based on gender, ethnicity and Index of Multiple Deprivation (IMD) as it over-sampled populations of interest who tend to be underrepresented in STEM (namely women, minoritised communities and young people from lower IMD quintiles).

14 This includes those taking combined degrees in which the major subject is mathematics and degrees in which mathematics is a substantial core component such as Operational Research, but not degrees in which mathematics is an important element but not clearly core.

15 *Countdown* is a letters and numbers game show that airs on weekdays on Channel 4 in the UK. It was the first programme broadcast when the channel launched in 1982.

16 Archer, L. and Mendick, H. Becoming exceptional: The role of capital in the development and mediation of mathematics identity and degree trajectories. Under review. Copy available on request.

17 Mendick, H. (2006). *Masculinities in mathematics*. Open University Press, Buckingham; Walkerdine, V. and The Girls and Mathematics Unit (1989). *Counting girls out*. London: Virago Press.

18 Archer, L. and Francis, B. A longitudinal analysis of discursive constructions of 'being good at mathematics' among high attaining students who chose not to pursue a mathematics degree. Under review. Copy available on request.

19 The final-year ASPIRES survey sample included 79 people who were studying for, or had recently completed, a mathematics degree.

20 Survey data from 798 STEM and high-status medicine degree students and 1,959 students doing other degrees.

21 From longitudinal interviews with ten women STEM students, we identified that such peer sexism usually involved everyday acts of disdain and disrespect, such as questioning women's academic legitimacy, and ignoring and patronising them, reflecting the gendered discourses and differences in recognition discussed earlier.

22 Data based on 79 young people in the ASPIRES sample who were studying for, or had recently completed, a mathematics degree.

23 For example: PiCaM Project in Citizenship and Mathematics: http://www.citizenship-and-mathematics.eu/; cre8ate maths | STEM Maths: https://www.stem.org.uk/resources/collection/2781/cre8ate-maths; Maths in context – Maths Careers: https://www.mathscareers.org.uk/maths-context/

24 Nasir, N. S., Givens, J. R., and Chatmon, C. P. (eds). (2018). *"We dare say love": Supporting achievement in the educational life of Black boys*. Columbia: Teachers College Press; Tate, W. (1995). Returning to the root: A culturally relevant approach to mathematics pedagogy. *Theory into Practice*, 34(3): 166-173.

25 For example: PiCaM Project in Citizenship and Mathematics: http://www.citizenship-and-mathematics.eu/; cre8ate maths | STEM Maths: https://www.stem.org.uk/resources/collection/2781/cre8ate-maths; Maths in context – Maths Careers: https://www.mathscareers.org.uk/maths-context/

26 Jackson, C., Povey, H., with 'Pete' (2019). Learning mathematics without limits and all-attainment grouping in secondary schools: Pete's story. *FORUM*, 61(1), 11-26; Boylan, M. and Povey, H. (2020). 'Ability thinking', in Gwen Ineson and Hilary Povey (eds). *Debates in mathematics education (second edition)*. London: Routledge.

27 Equity-Compass-Teacher-Edition.pdf (yestem.org)

28 hooks, b. (1994) "Love as the practice of freedom" in *Outlaw culture: Resisting representations*. New York, Routledge, pp.289-98.

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