Progression at age 16 of young people from underrepresented backgrounds towards careers in STEM

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Executive summary

Skills in STEM (science, technology, engineering and mathematics) fields are vital for innovation and growth. Yet there is a major shortage in the supply of STEM skills and there are systematic differences in the representation of different characteristic groups in the STEM labour market. These differences in representation are often driven by much earlier decisions around which pathways pupils take during formal education. This report focuses on a pivotal juncture in the pipeline for building careers in STEM – the progression from the end of secondary school to post-16 study. Importantly this is when STEM subjects such as science and maths are no longer compulsory.

In three distinct, but linked strands of work, we shed light on:

1. The existing evidence on why some pupil groups are underrepresented on post-16 STEM courses.
2. The role secondary schools in England play in supporting young people of underrepresented backgrounds to study STEM beyond age 16.
3. The key enablers and barriers to supporting wider post-16 STEM participation.

Each strand can be read as a standalone piece of work, but our recommendations and summary findings draw on common themes across all strands. To strengthen our understanding and conclusions, our strands combine quantitative and qualitative research methods.

In our first strand we review the existing literature on the evolution of STEM education in England and the likely drivers of STEM participation post-16. We identify three key drivers of participation – pathway, prior qualifications and preferences – constituting the 'three P's' model. These three drivers are found to produce differences in progression rates by pupil characteristics. We focus throughout this report on differences by gender, ethnicity and socio-economic disadvantage. Prior attainment is often the largest driver, particularly for low socio-economic status pupils. The gender differences are perhaps best understood, particularly by constituent subjects, with patterns of progression varying between life and 'hard' sciences. We also highlight specialist teacher shortages in schools as a potential driver of prior attainment outcomes and preferences.

In our second strand, we use administrative data to establish patterns of progression by pupil and school characteristics, as well as identifying school-level effects on pupils' likelihood of progressing to STEM related courses post-16. We again focus on differences in progression rates by gender, ethnicity and socio-economic disadvantage. We find that in aggregate secondary schools have a role to play in pupils' likelihood of progressing to post-16 STEM. In most cases though the differential effect of schools on different pupil groups is relatively small, when compared to the overall effect schools have on all their pupils.

In our third and final strand, we conducted interviews and focus groups with school leaders, teachers and pupils to develop a more detailed account of the barriers that underrepresented pupils experience to post-16 STEM progression and what schools do to overcome these barriers. We observed that the barriers to progression for underrepresented groups are often multifaceted, with prior attainment again identified as a key driver for disadvantaged pupils, as well as the availability of local opportunities and a restricted understanding of STEM careers.

Summary of key findings

- Around one in five pupils who left secondary school in the three academic years between 2016/17 and 2018/19 went on to complete a level 3 STEM qualification.
- Progression to level 3 STEM is dependent on pupils being on a certain *pathway*, with the necessary *prior qualifications*, and having a *preference* for STEM. The independent effects of these three different factors are not always easy to delineate.
- The STEM umbrella covers a wide range of subjects and future careers. We find differences in the patterns of uptake across life science and health subjects compared to the physical and mathematical sciences, particularly by gender.
- Pupils are found to often have a restricted understanding of STEM careers, focusing primarily on traditional careers such as medicine or engineering.
- We estimate the odds of progressing to level 3 STEM are 42% lower for girls, compared to boys, and 44% lower for pupils eligible for free school meals compared to their more affluent peers. Compared with White British pupils, Black Caribbean pupils have similar odds of progressing to level 3 STEM. White and Black Caribbean, and Gypsy/Roma and Traveller of Irish heritage have lower odds (25% and 75% lower compared to White British pupils). On the other hand, Chinese pupils have almost five-time greater odds and Indian pupils almost 3.5 times the odds than their White British peers.
- KS4 attainment is a key driver of differences in progression rates to level 3 STEM. Whilst girls on average have higher attainment than boys, they are around 40% less likely to progress to level 3 STEM. Differences in attainment mask the underlying differences in the likelihood of progression to studying a level 3 qualification. We estimate girls are around 60% less likely to progress when comparing girls to boys that have similar KS4 attainment.
- Disadvantaged pupils have both lower KS4 attainment and lower progression rates to level 3 STEM qualifications. The lower average attainment of disadvantaged pupils accounts for almost all the observed difference in progression rates to level 3 STEM qualifications. Pupils eligible for Free School Meals in the last six years (FSM6) have around half the odds of progressing compared to their more advantaged peers. However, the odds are 4% lower for an FSM6 pupil when comparing to a peer with similar KS4 attainment.
- In general, the difference between the likelihood of pupils from different ethnic backgrounds of progressing to level 3 STEM is narrower if they have similar KS4 attainment. However, Black Caribbean pupils are identified as particularly hindered by low attainment. Black Caribbean pupils are estimated to be 40% more likely to progress to level 3 STEM than White British pupils with the same attainment. The opposite is true for

White Irish pupils – they progress at greater rates than White British pupils, but this is due to relatively high KS4 attainment.

- In our qualitative work we find prior attainment was also linked to perceptions of subject interest, as students were more likely to express a preference for subjects that they saw themselves as being successful in. Pupils also made a link between their option choices and perceived teacher quality, or in some cases simply the availability of specialist teachers.
- We also find that in many school settings STEM routes are found to be limited to traditional A level academic routes with prior attainment entry barriers. There is often a lack of clear pathways to post-16 STEM qualifications for 'middle attainers'.
- Our case studies also highlight the role that local socio-economic deprivation has in influencing the availability of local opportunities, as well as the capacity of staff to deliver the full range of guidance and support they and students desired.
- Secondary schools play a modest role in determining pupils' likelihood of progressing. After adjusting for observable pupil characteristics, around 6.6% of the remaining variance in the likelihood of progressing to STEM level 3 is due to differences in the school attended. We find that 23% of secondary schools have a significant negative impact on the odds of pupils progressing pupils to level 3 STEM qualifications whilst 25% have a significant positive effect.
- There are systematic differences regardless of pupil characteristics, in schools' effects on progression rates. A stark example is that pupils attending a selective school have 2.5 times greater odds of progressing to level 3 STEM than those who attend non-selective schools, even after controlling for prior key stage 2 attainment. Attending a single sex girls' school significantly increases the likelihood of girls' progress to level 3 STEM by 21%, however, for boys, attending a single-sex school has no effect on the odds of progressing.
- The school a pupil attends has slightly more bearing on their likelihood of progressing to level 3 STEM: for girls than it does for boys; for disadvantaged compared to non-disadvantaged pupils; and for pupils in all major ethnicity groups compared to White pupils. So, for some underrepresented groups (girls, disadvantaged pupils) the school attended appears to matter a little more, but the same does not hold true for ethnicity. In fact, which school a pupil attends appears to matter most for those who are ethnically Chinese, an overrepresented group.
- In most cases the differential effect of schools on different pupil groups is relatively small, when compared to the overall effect schools have on all their pupils. This is consistent with our case studies, where schools tended to have broadly the same approach to interventions across all pupils, although the specific barriers to, and enablers of, post-16 STEM participation varied.

Recommendations

- **The Curriculum and Assessment Review** should consider how access to non-A level post-16 STEM qualifications can be improved, including how to fill gaps in local provision. Routes to level 3 STEM qualifications are generally quite limited to traditional A level academic routes with prior attainment entry barriers.
- **The Curriculum and Assessment Review** should also consider the role employers should play in ensuring that all post-16 qualifications, in particular vocational qualifications such as T levels, closely meet the needs of both industry and students.
- **The government** should develop a renewed strategy for closing the disadvantage gap which acts as a barrier to accessing level 3 STEM subjects. This should include the adequacy of disadvantage funding across all phases and the introduction of a student premium for those studying in post-16. Low prior attainment is a particular barrier preventing more disadvantaged pupils progressing to level 3 STEM. We know that by the end of secondary school disadvantaged pupils are 19 months of learning behind their peers in English and maths.[1]
- **The government** should ensure the sufficient supply of specialist teachers in secondary schools by increasing retention through differentiated pay. Pupils' preferences for further study in a field are influenced by their current teachers. In 2023/24 the government only met 17% of its recruitment target for physics teachers, 36% for computing and 63% for maths teachers.[2]
- **School leaders** should consider how they can implement programmes that are more tightly focused on increasing the representation of currently underrepresented pupil groups. Individual schools rarely target underrepresented pupil groups in their incentivisation of STEM progression post-16. As a result, we do not observe differential school level effects on the progression rates of underrepresented pupil groups.
- **Careers leaders** should continue to work with careers advisers and hubs to provide employer experiences that offer 'real world' examples of what it is like to work in STEM jobs in practice, particularly focusing on representation from currently underrepresented groups. Students report often do not have a good understanding of the wide range of STEM career opportunities and improving awareness of the courses and routes that are available will likely increase participation.
- **Employers** should encourage and support employees, particularly those from underrepresented groups, to become STEM ambassadors and provide high quality workplace and employer experiences in schools. They should seek to pursue longer-term partnerships with schools where possible to ensure sustainable and more meaningful opportunities.

[1] Tuckett et al. (2024) 'EPI Annual Report 2024'

[2] Department for Education (2023) 'Initial Teacher Training Census, academic year 2023/24'

Introduction

Skills in STEM (science, technology, engineering and mathematics) fields are vital for innovation and growth. Yet there is a major shortage in the supply of STEM skills in the labour market. Seven in ten STEM employers report struggling to recruit staff with the requisite skills, leading to an average of ten unfilled roles per employer.[3] This shortage is costing firms and the wider economy – to the tune of £1.5 billion a year.[4] If this shortfall is left unaddressed, other estimates suggest it could cost the UK economy up to £120 billion by 2030.[5]

One of the contributing factors to the shortage of STEM skilled labour are the systematic differences in representation amongst different characteristic groups. These differences in representation in the labour market are often driven by much earlier decisions around which qualification to study for during formal education. Uptake in some STEM subjects is disproportionately low among girls, some ethnic minorities and young people from disadvantaged backgrounds, even among equally high-achieving pupils.

A pivotal point in the pipeline for building careers in STEM is between GCSE and post-16 study, when STEM subjects such as science and maths are no longer compulsory. This report focuses on this junction of young people's lives, and seeks to understand:

1. The existing evidence on why some pupil groups are underrepresented on post-16 STEM courses
2. Whether some secondary schools in England are more successful at supporting young people of underrepresented backgrounds to study STEM beyond GCSE
3. The key enablers and barriers to supporting wider post-16 STEM participation

Schools, particularly at secondary, are well-placed to kindle an interest and aspiration in pursuing STEM education and careers. Specialist teachers, teacher retention, careers advice, quality of curricular and extra-curricular provision can all impact on pupils' positive feeling towards STEM subjects. Schools are also best placed to mediate some of the other known factors which can influence a young person's pathway and subject choices. They support pupils through pre-16 qualification choices and help them to achieve and progress in their learning, helping pupils meet selection criteria required to enrol on many post-16 STEM courses.

However, secondary schools are only part of the picture. The likelihood that a young person will obtain post-16 qualifications in STEM subjects beyond GCSE are partially determined long before the age of 16. Some of the determining factors sit beyond school, including pupil- and family-level factors such as gender, ethnicity, the family's 'science capital' and their broader socio-economic status. The availability of post-16 STEM courses in the local area is also an important factor.

[3] STEM Learning (2018) 'STEM Skills Indicator'
[4] Ibid
[5] Melville and Bivand (2019) 'Local Skills Deficits and Spare Capacity'

This report is split into three distinct strands following the three key bullets above. First, we review the existing literature on the evolution of the STEM education in England, the likely drivers of STEM participation post-16, and the difference in progression rates by pupil characteristics. Importantly, we identify three key drivers of participation – pathway, prior qualifications and preferences – which we constitute as the 'three P's' model.

Second, we link administrative data from the National Pupil Database and Individual Learner Records to track individuals from secondary school into level 3 qualifications. We then use statistical models to establish patterns of progression to level 3 STEM by pupil and school characteristics. Subsequently, we use more complex multilevel models to identify individual school level effects on pupils' likelihood of progressing to STEM related courses post-16. Further technical details of our modelling approach can be found in Appendix 3.

Third, we take a deeper dive into the activities which take place within schools. Six focus groups with pupils and eight expert interviews with school leaders were undertaken. This provides further insight into why certain pupils are underrepresented and what actions schools are taking to attempt to mitigate these differences in progression to level 3 STEM.

These three strands come together to help identify and learn from the secondary schools which are most successful in supporting underrepresented young people to continue STEM study beyond the age of 16, thereby building the pipeline of young talent towards rewarding careers in STEM.

Strand 1: existing evidence on STEM progression routes

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Introduction

In this strand, we set the scene for the quantitative and qualitative analysis in strand's 2 and 3. First, we discuss the challenges of defining a consistent definition of progressing to STEM in post-16 education. We then develop a model to describe the factors that need to coalesce for a pupil to progress to post-16 STEM.

Our 'three P's' model states that a pupil must be on a plausible *pathway* (continue study to level 3), have the necessary *prior qualifications* to be accepted on to STEM courses, and have a *preference* to study STEM subjects. Using this model we then review the literature related to the differential progression rates to level 3 STEM of different pupil groups. In particular we focus on differential rates of progress amongst pupils of different genders, ethnicities and socio-economic status.

Appendix 1 provides additional details on how the school system and curriculum, and post-16 landscape have changed over time. We summarise changes to how science is taught and assessed in both schools and post-compulsory education, and how this might affect student progression to post-16 STEM courses, including the role of specialist teachers.

Key takeaways

- **There is no universally accepted definition of STEM.** Different official bodies and academic researchers include different subjects and qualifications within their STEM definitions. STEM subjects are not clearly delineated in official sources, particularly at level 3.
- **The degree to which gender, ethnicity and disadvantage affect the uptake of post-16 STEM varies across different subjects.** In particular, there are substantial differences in patterns of uptake across life science and health subjects and the physical and mathematical sciences.
- **Progression to level 3 STEM is dependent on pupils being on the right pathway, with the right previous qualifications, and having a preference for STEM.** The independent effects of these three different factors are not always easy to delineate.
- **The importance of prior attainment can make it difficult to untangle the influence of gender, ethnicity, and disadvantage.** Because prior attainment is such an important factor for progression to level 3 STEM, but one that varies with our characteristics of interest, it is often hard to establish whether differences in STEM uptake are driven by differences in prior attainment or other factors.
- **Gender has the most well-understood impact on progression to STEM.** There are two almost equally sized groups of pupils within well-established categories making it easier to consistently identify trends. Girls are more likely to study A level Biology, equally likely to study Chemistry, and less likely to study other STEM subjects. For vocational

qualifications, girls are much more likely than boys to choose health courses. Gender gaps in Applied Sciences are small. Girls are even less likely to study engineering/construction courses than physical sciences A levels.

- **For low socio-economic status pupils, the key barrier to progressing to a post-16 STEM pathway is low prior attainment**. Most of the differences in the uptake of STEM qualifications can be explained by differences in pathways. Over two-thirds of pupils not eligible for free school meals (FSM) continue to level 3, whereas only 45 per cent of pupils that are do. High-achieving disadvantaged students are more likely to choose STEM subjects than other high-achieving students. For students taking level 3 vocational qualifications, disadvantaged students are more likely to choose Applied Science and less likely to study construction and engineering.
- **White British pupils are among the least likely to study science A levels, alongside some Black pupils.** Pupils from Black Caribbean backgrounds are particularly unlikely to choose STEM. This pattern seems to repeat across some vocational qualifications. The new T level qualifications are the exception to this rule, being disproportionately studied by White British pupils in their first year.

Defining STEM progression in post-16 education

In the entirety of this report, we consider progression in science, technology, engineering and mathematics (STEM) subjects in post-16 education and training. In England, studying science and maths is compulsory until age 16 but after this, students can choose whether or not to keep studying STEM. As such, any review of the factors affecting whether students choose to take STEM subjects after age 16 must also consider their experiences pre-16, as these are likely to strongly influence which subjects' students choose to study later on.

Whilst STEM is a commonly used term in education policy and beyond, there is no consistent definition of the courses that it covers. Unresolved issues include whether health subjects and subjects on the boundary of social and natural sciences, such as psychology and economics should be included.[6] Within the education system, biology, chemistry, computer science, mathematics, and physics are *"generally accepted as sitting under the STEM umbrella"*[7], but this leaves unresolved questions about subjects such as design and technology (which is sometimes located within the creative subjects) and whether courses that focus on the use of technology (such as many ICT qualifications) rather than pure computer science should be included.[8]

A recent review of diversity and inclusion in STEM reflected that there are distinctly different patterns in uptake of STEM subjects between *"maths-based"* courses such as physics and maths

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[6] House of Lords Select Committee on Science and Technology (2012) 'Higher Education in Science, Technology, Engineering and Mathematics (STEM) Subjects'.
[7] House of Commons Science and Technology Committee (2023) 'Diversity and Inclusion in STEM'
[8] Thomson (2023) 'What Has Progress 8 Done for the Creative Subjects?'; Robinson and Coleman (2022) 'Digital Skills Divided: Technical Provision for 16 to 19 Year Olds'.

and *"life sciences-based"* courses such as biology. It therefore may be useful to consider these two qualifications groups separately.[9]

As a starting point for this work, we consider as a STEM qualification any post-16 course that is designated by Ofqual as being in one of the following Sector Subject Areas[10]:

- Science and Mathematics
- Engineering and Manufacturing Technologies
- Construction, Planning, and the Built Environment
- Information and Communication Technology

Our search for evidence has centred on these subjects. However, as a literature review, this first strand is bounded by the definitions used by previous authors.

Whether a young person is considered to be taking a STEM pathway is also complex. Young people in post-16 education and training typically obtain more than one qualification across several different subjects. For example, individuals that follow the academic A level route typically study 3 different subjects of which only a subset may meet our definition of STEM. This is also true of young people that take vocational pathways. Qualifications may also be of a different 'size'. An A level is typically made up of 360 guided learning hours, but a young person may take an AS level alongside their A levels, which has half the 'size'. Furthermore, qualifications taken in combination may not all be of the same level. Some individuals will take level 2 or even level 1 qualifications post-16.

We overlook some of this complexity in our review of the literature and are guided by previous authors' own definitions. However, we do typically focus on evidence that loosely defines progression to post-16 STEM as studying towards at least an A level worth of level 3 qualifications.

Progression to post-16 STEM: The Three Ps model

Several factors need to coalesce for a student to progress from GCSE to a Level 3 STEM qualification. We have summarised these as Pathway, Prior Qualifications and Preferences.

> **Pathway** refers to the fact that not all students stay in formal education after the age of 16, and not all those that do take level 3 qualifications. In 2022, 6.3 per cent of 16- and 17-year-olds were not in education or training (4.5 per cent were not in education, employment or training).[11] A substantial proportion of pupils who stay in education study level 2 qualifications, equivalent to GCSE grades 9–4, rather than level 3 courses. By age 19, 60.3 per cent of young people will be qualified at level 3, although some may have started courses, they failed to complete.[12]

[9] House of Commons Science and Technology Committee (2023) 'Diversity and Inclusion in STEM'.
[10] Ofqual (2024) 'Qualification descriptions'.
[11] Department for Education (2023) 'NEET Age 16 to 24, Calendar Year 2022'.
[12] Department for Education (2023) 'Level 2 and 3 Attainment Age 16 to 25, Academic Year 2021/22'.

Prior Qualifications refers to the fact that many level 3 STEM courses have subject or course specific requirements, beyond the general qualifications needed to progress to level 3. For example, schools often require at least a grade 6 in STEM GCSE for entry to STEM A levels, whereas other courses typically only require grade 5 in the relevant subject.[13] Sorting into STEM and non-STEM streams might happen even earlier, for instance when pupils choose between (or were allocated into) triple or double science courses.[14] When comparing across similar cohorts, such as all A level students or all level 3 vocational students it is important to remember that while a student might be generally qualified to enter a broad qualification pathway, they might not have the necessary prior qualifications to permit entry to STEM subjects within it.

Preferences refers to students choosing from the range of subjects available to them. A student may be qualified to enter, for example, a T level in Engineering, but instead chose to study Business and Administration. Subject preferences are influenced by a range of individual and societal factors. A student's career aspirations will likely be in part shaped by their own values and aptitudes as well as by their friends and family, school and wider environment.[15]

The three Ps are broadly hierarchical. A student that is on the wrong pathway or lacks prior qualifications cannot choose a STEM subject, even if they have a preference to. However, they also interact. For instance, a student's preferences pre-16 might influence the effort they put in to achieving the qualifications necessary to choose a STEM qualification post-16, or a student might be eligible to enter a level 3 qualification but choose not to.

When thinking about differential progression to level 3 STEM it is often difficult to untangle the independent effects of the three Ps. Considering disadvantaged students, their observed lower rates of progression to level 3 STEM could happen at the pathway level (because they are less likely to stay in any formal education and take level 3 qualifications post-16), the prior qualifications level (because they lack the specific qualifications to choose STEM courses) or preference level (because they see STEM as a less attractive or attainable study/career choice). Untangling the effects is further complicated by the fact that entry requirements for level 3 STEM are not standardised across institutions: similarly qualified students in different schools or colleges might be permitted or forbidden from entering a level 3 STEM qualification based on local rules.

Choosing a baseline for comparison

There are two baselines typically used in previous research into the progression of pupils to level 3 STEM qualifications. Some studies compare take-up as a proportion of the whole pupil cohort at 16. This has previously been done across different pupil characteristics such as ethnicity, gender and disadvantage.[16] Other studies examine how many students take a particular subject at A

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[13] Plaister (2023) 'Are A-Level Entry Requirements Higher for Some Subjects than Others?'.
[14] House of Commons Science and Technology Committee (2023) 'Diversity and Inclusion in STEM'.
[15] Mann et al. (2020) 'Dream Jobs: Teenagers' Career Aspirations and the Future of Work'.
[16] STEM Learning (2022) 'Science Education in England: Gender, Disadvantage and Ethnicity'.

level/level 3 qualification compared to the population of students taking A level/level 3 qualifications.[17]

Both approaches are theoretically valid but must be interpreted slightly differently. The first 'cohort wide' approach takes the total number of 18-year-olds as the baseline. This means the effects of pathways, prior qualifications and preferences are jointly observed and cannot be easily disentangled. The second main approach separates out the effect of differential sorting into different post-16 pathways, but it is still difficult to disentangle the effects of subject-specific prior qualifications from student preferences. We take the first approach in our later modelling work where we look at STEM uptake post-16. We take this approach because we are interested in differential school effects in facilitating STEM uptake post-16 and so are fairly agnostic as to how the school achieves this.

Further studies use statistical techniques to account for a variety of control measures. Prior attainment is the strongest predictor of subject choice and is a common control measure, as are gender, ethnicity and socio-economic disadvantage (which correlate with attainment).[18] Controlling for the effects of prior attainment helps untangle how ethnicity, disadvantage or gender independently influence STEM uptake. This is useful for trying to isolate the effect of preference on subject choice. However, it does not account for the fact that, for example, pupils eligible for free school meals are typically different from the rest of the pupil population. If we want to know how the whole school system can support more disadvantaged pupils into STEM subjects then raw differences, which include the effects of having lower prior attainment or living in a neighbourhood with fewer educational opportunities, are equally important.

In what follows we summarise the literature on differential progression to level 3 STEM qualifications across three key pupil characteristics; gender, socio-economic disadvantage and ethnicity. Where possible, we try to delineate the different effects of pathway, prior qualification and preferences, but this is not always possible.

Post-16 STEM progression by characteristics

Ethnicity

This section reviews existing evidence for differences in STEM uptake by pupils from different ethnic backgrounds. Differences in the way that ethnicity is recorded and analysed can sometimes mask nuanced patterns. White British students are often among the least likely to choose STEM subjects, alongside Black Caribbean pupils, pupils from Mixed Black backgrounds and gypsy/Roma traveller pupils.

[17] Morgan and Scarlett (2021) 'Accelerating Change: Improving Representation of Black People in UK Motorsport'.
[18] The Royal Society (2008) 'Exploring the Relationship between Socioeconomic Status and Participation and Attainment in Science Education'.

Unpacking differential rates of progression to level 3 STEM qualifications by pupils from different ethnic groups can be difficult due to the way this data is collected and analysed.[19] In particular, patterns can change depending on the level of data aggregation. Figure 1.1 shows how average attainment at the end of key stage 4 varied by ethnic background in 2020/21. On average, Asian pupils have above average Attainment 8 scores (55.8 vs 50.9 national average). However, distinct sub-groups perform differently. Indian pupils have higher average scores (62.0) whereas the average for Pakistani pupils is below national average (50.5). What is true for the larger 'Asian' group is not true for the smaller 'Pakistani' group. Using major ethnicity categories maximises the number of pupils in each group, allowing the detection of smaller differences between major groups with more confidence. However, this can mask important differences between more disaggregated groupings.

Pathways for different ethnic groups vary as they progress to post-16 education at different rates. Pupils from ethnic minority groups are more likely than White British students to carry on in education post-16, even accounting for prior attainment and neighbourhood. In 2009/10 (before changes to the school leaving age in 2013 and 2015), ten per cent of White British students left school-based education at age 16 compared to only three per cent of Indian students, seven per cent of Black students and eight per cent of Pakistani and Bangladeshi students.[20] This is despite differential average prior GCSE attainment across different ethnic groups, seen in Figure 1.1. White British students are also less likely than all other ethnic groups to be studying at level 3 or to be on an academic pathway.[21]

White British students are among the least likely to choose science or mathematics A levels. In 2019, forty per cent of Chinese 18-year-olds obtained at least one science or maths A level compared to fewer than 10 per cent of the White British cohort.[22] Black African, Chinese, Mixed, Indian and Pakistani students all have a higher likelihood of choosing two or more science subjects than White British pupils. Black Caribbean, Black Other, and Bangladeshi pupils take these subjects at broadly same rate as White British A level students.[23] Overall, STEM subjects made up 28 per cent of the A levels taken by Other Asian[24] pupils but only 13 per cent of those taken by White British or Black pupils.[25] Due to small sample sizes there is often insufficient data to draw robust conclusions for students from a Mixed ethnic background or students from the White Gypsy and Roma ethnic group, however, there are indications of low uptake amongst these groups also.[26]

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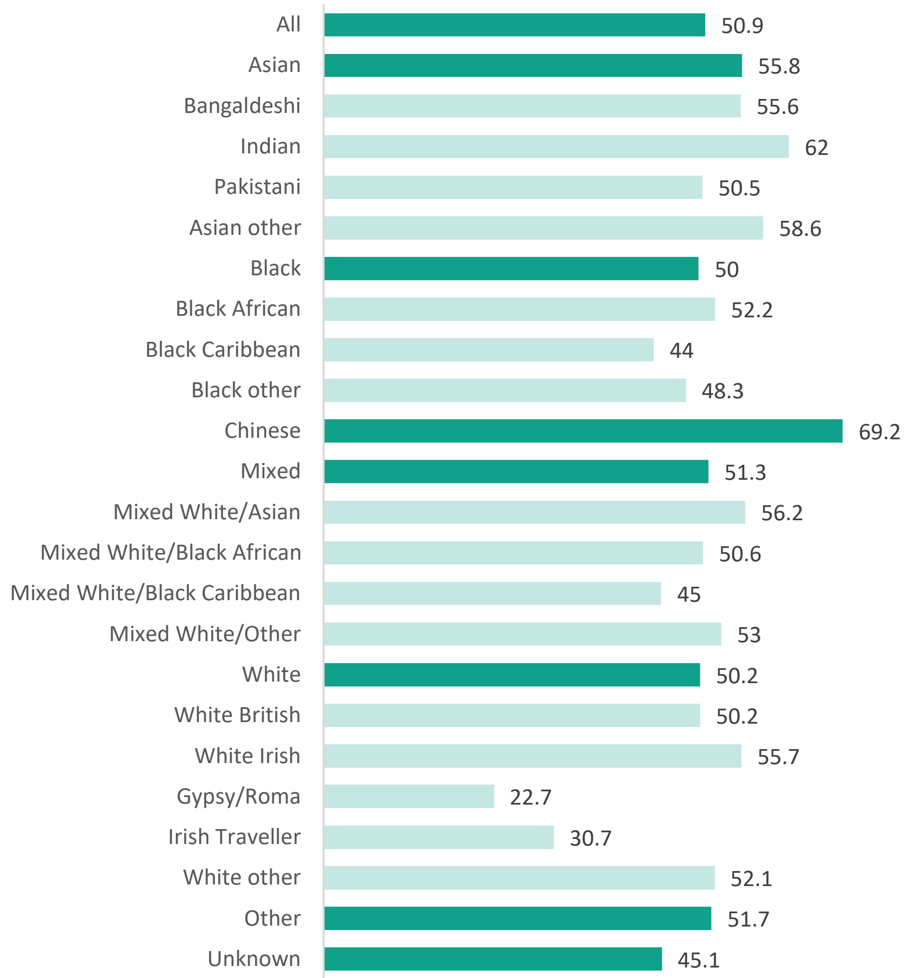
[19] DfE's National Pupil Database records pupils as belonging to 7 aggregated major ethnicity groups and 20 disaggregated minor ones.
[20] Allen, Parameshwaran and Thomson (2016) 'Social and ethnic inequalities in choice available and choices made at age 16'.
[21] Shaw et al. (2016) 'Ethnicity, Gender and Social Mobility'.
[22] STEM Learning (2022) 'Science Education in England: Gender, Disadvantage and Ethnicity'.
[23] Rodeiro, (2007) 'A Level Subject Choice in England: Patterns of Uptake and Factors Affecting Subject Preferences'.
[24] Asian pupils not of Bangladeshi or Pakistani heritage.
[25] Menzies (2017) 'Achievement and Uptake of STEM Subjects at A Level: Ethnicity, Gender and SES'.
[26] STEM Learning (2022) 'Science Education in England: Gender, Disadvantage and Ethnicity'.

Figure 1.1: Average Attainment 8 scores by ethnic background, 2020/21



Source: Department for Education[27]

Looking specifically at Maths A level and how take-up rates can vary within major ethnic groupings, 34 per cent of Black African pupils who take A levels, sit A level maths. This is more than twice the rate of White British pupils. However, only 5 per cent of Black Caribbean pupils studying A levels take Maths, about half the rate of White British students. A level pupils from Mixed White and Black Caribbean and any other Black Backgrounds were also less likely to take A level maths.[28]

Similar patterns are seen for take-up and attainment of the GCSE qualifications that are seen to provide the best preparation for A level science. Black African students have high entry rates for triple science GCSE and achieve a high proportion of top grades. However, Black Caribbean and Mixed White and Black Caribbean students have among the lowest triple science participation rates and are less likely to achieve good grades.[29] For combined science Black Caribbean boys are

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[27] Department for Education (2022) 'GCSE Results (Attainment 8), Academic Year 2020/21'.
[28] Morgan and Scarlett (2021) 'Accelerating Change: Improving Representation of Black People in UK Motorsport'.
[29] Ibid

less likely to achieve grade 4 or a grade 7 than White British boys, but the differences between White British and Black Caribbean girls are smaller.[30]

Restricting analyses to just high prior attaining students can help isolate effects. White British students are the least likely of any ethnic group to progress to A level maths, having controlled for prior attainment. In physics, Chinese students were most likely to participate, followed by Black African. White British, Black Caribbean and Pakistani pupils were least likely to choose to study A level physics. On the other hand, Pakistani students were most likely to choose Chemistry, with White British and Black Caribbean pupils again amongst the least likely.[31] This indicates that preferences as well as prior attainment do play a role in the observed variation in STEM A level uptake.

Evidence on differences in vocational choices by ethnicity is sparser. White British, Black Caribbean and Mixed White and Black African/Caribbean are found to have the lowest uptake of Level 3 IT qualifications.[32] Chinese students were marginally more likely to enter a Design and Technology A level but for all other groups entry rates were similar to the national average.[33] The new T level vocational pathway has not been initially popular with pupils from minority ethnic backgrounds: only 11 per cent of T level students in 2020 came from minority ethnic groups, compared to 24 per cent of students studying level 3 vocational and technical qualifications. However, this increased to 18 per cent in 2021 and the digital stream has been the most popular for minority ethnic students.[34]

In summary, students from many minority ethnic backgrounds are more likely to study level 3 STEM qualifications than their White British peers. After leaving school, White British pupils are less likely to be on a level 3 pathway, less likely to study academic qualifications and less likely to choose science subjects. Black Caribbean students study science qualifications at a similar or lower rate than White British students, as do pupils from mixed or other Black backgrounds and Gypsy, Roma and Irish traveller pupils.

Socio-economic disadvantage

Similar to ethnicity, socio-economic disadvantage can be conceptualised in several ways. Two measures are available in the National Pupil Database: eligibility for free school meals (FSM) and the Income Deprivation Affecting Children Index (IDACI). Pupils can claim FSM if their household income is below a certain threshold or they are in receipt of certain benefits, although not all eligible households will claim.[35] In 2021/22 22.5 per cent of pupils claimed free school meals, although the proportion is lower for older pupils.[36] Within education research a commonly used measure of disadvantage is whether a pupil has claimed free school meals in any of the previous 6

[30] STEM Learning (2022) 'Science Education in England: Gender, Disadvantage and Ethnicity'.
[31] Boaler, Altendorff and Kent (2011) 'Mathematics and Science Inequalities in the United Kingdom: When Elitism, Sexism and Culture Collide'.
[32] Robinson and Coleman (2022) 'Digital Skills Divided: Technical Provision for 16 to 19 Year Olds'.
[33] Tuckett (2022) 'A spotlight on Design and Technology study in England: Trends in subject take up and the teacher workforce'.
[34] Department for Education (2023) 'T Level Action Plan 2022 to 2023'.
[35] Free school meals are available to pupils whose household income in below £7,400 or whose parents are in receipt of certain benefits.
[36] Department for Education (2023) 'Schools, Pupils and Their Characteristics, Academic Year 2021/22'.

years. IDACI is an area-based measure that counts the proportion of all children aged 0 to 15 living in income deprived families in a neighbourhood of 400-1,200 households. The IDACI scores of a pupil's home or school postcode can be ranked to indicate pupils that live or study in relatively deprived areas. The two measures of disadvantage are both valid and highly correlated but measure socio-economic status in slightly different ways.

Overall, on average, disadvantaged pupils study science A levels at lower rates than non-disadvantaged pupils. Figure 1.2 how uptake varies by disadvantage and gender. The baseline is the entire population of 18-year-olds. In physics, male pupils previously eligible for FSM are more likely to take the subject than female non-FSM pupils but in all other subjects (maths, chemistry, and biology) uptake is lower for disadvantaged pupils than their peers.

The low prior attainment of disadvantaged pupils and their low levels of participation in full-time education post-16 explains a large amount of the STEM participation gap.[37] Disadvantaged pupils have lower attainment at key stage 4 on average. In GCSE English and maths disadvantaged pupils score 1.34 grades worse than their peers, and this widens to 1.70 grades for persistently disadvantaged pupils (defined as being eligible for free school meals for at least 80 per cent of their schooling).[38] Combined science has the largest disadvantage gap of all GCSE subjects, with disadvantaged pupils scoring 1.61 grades less than their peers.[39] The grade gap is smaller in triple science GCSEs but disadvantaged pupils are less likely to take these. Disadvantaged pupils may therefore lack the prior qualifications to choose STEM courses post-16.

Over two-thirds of pupils not eligible for free school meals continue to level 3, whereas only 45 per cent of pupils who are eligible do. The gap is greater for A levels, where progression rates are only 21 per cent for FSM pupils compared to 45 per cent of their peers. Of pupils progressing to level 3, disadvantaged pupils are more than twice as likely to take vocational qualifications and half as likely to take A levels.

Among the cohort that do progress to A levels, there are differences in STEM uptake, but these are small compared to differences in the pathways that students' progress to. The largest differences are in physics and maths where more advantaged pupils are 62 and 40 per cent more likely to take the subjects. There are smaller disparities in the uptake of A levels in Biology (26 per cent), Computing (27 per cent) and Chemistry (14 per cent).[40]

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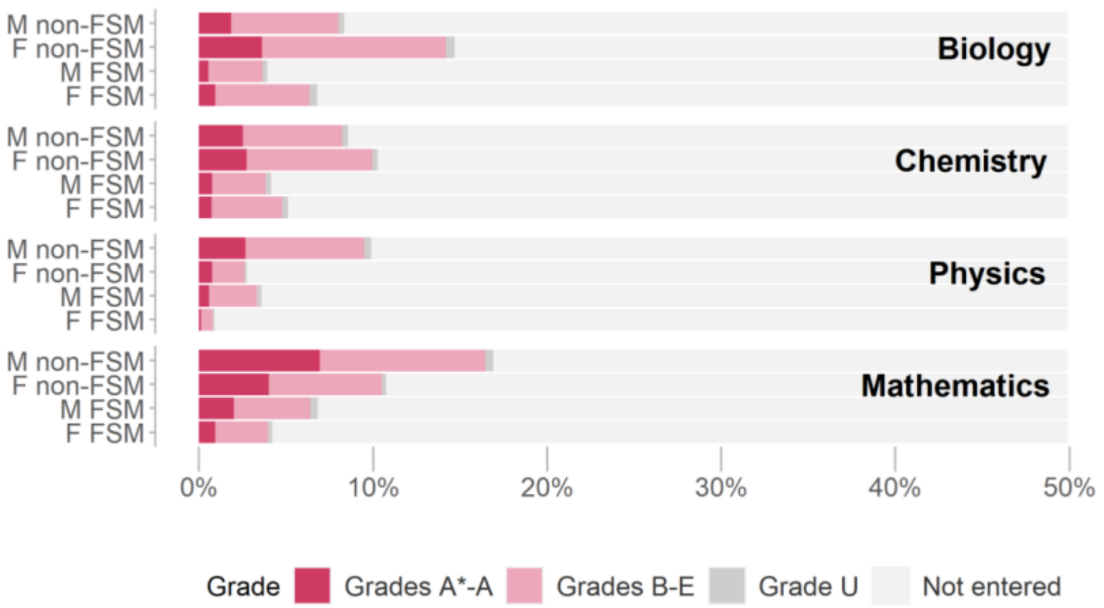
[37] Nunes et al. (2017) 'Review of SES and Science Learning in Formal Educational Settings'.
[38] Tuckett et al. (2022) 'Covid-19 and Disadvantage Gaps in England 2021'.
[39] Hunt et al. (2022) 'Covid-19 and Disadvantage Gaps in England 2020'.
[40] Nunes et al. (2017) 'Review of SES and Science Learning in Formal Educational Settings'.

Figure 1.2: A level entries by gender and socio-economic disadvantage, 2019



Source: STEM learning

STEM subjects appear to be more popular with high-attaining disadvantaged pupils. Nearly half (49 per cent) of disadvantaged A-Level students in the highest prior-attainment quintile studied chemistry, compared to 41 per cent of their peers. For biology A level, the equivalent figures are 43 and 38 per cent. In maths, further maths and computer science high-achieving disadvantaged A level pupils are also more likely to choose these subjects. Disadvantaged pupils at all prior attainment levels are less likely to choose Physics or Design and Technology (a subject which disadvantaged pupils are substantially less likely to choose).[41]

Turning to vocational qualifications, some STEM subjects are more popular with disadvantaged pupils compared to others. Figure 1.3 illustrates the percentage points difference in the proportion of disadvantaged BTEC students and their peers entering each subject. Disadvantaged pupils are nearly 4% more likely to be studying applied sciences and slightly more likely to be studying construction. However, they are less likely to study computer studies or engineering. [ibid] Further recent research confirms disadvantaged pupils are slightly less likely to study vocational engineering or computing courses.[42]

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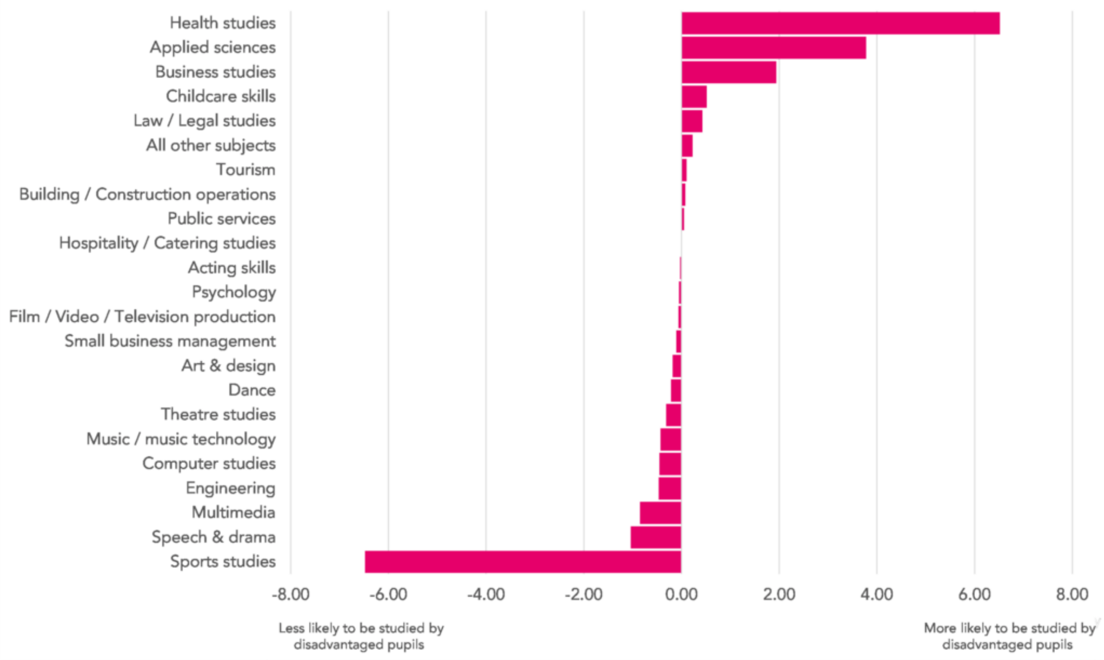
[41] Plaister (2022) 'Do Disadvantaged Students Choose Different Subjects from Their Peers at Key Stage 5?'.
[42] Robinson and Coleman (2022) 'Digital Skills Divided: Technical Provision for 16 to 19 Year Olds'; Tuckett (2022) 'A spotlight on Design and Technology study in England: Trends in subject take up and the teacher workforce'

Figure 1.3: Difference in proportion of disadvantaged students and their peers taking BTECs by subject



Source: FFT Education Datalab

Gender

The gender gap in STEM uptake is one of the most well studied. Gender gaps can generally be attributed to differences in preferences rather than pathway or prior qualifications.

Across all subjects, girls perform better than boys at GCSE, although the gap is smaller in STEM subjects. The average Attainment 8 score for girls is 53.9, compared to 48.1 for boys.[43] In GCSE Combined Science, girls are more likely to achieve a high grade than boys (5.5 per cent of girls achieve grades 9-7, compared to 4.2 per cent of boys). In separate sciences female students outperform male students in biology and chemistry and the reverse is true for physics, but differences are small.[44] In maths the gender gap is reversed but very small: 20 per cent of girls achieved a grade 7 or above compared to 21 per cent of boys. However, more boys than girls achieve the very highest grades.[45]

Reflecting their better performance at GCSE more women than men go on to level 3 qualifications.[46] As a consequence the overall A level cohort is around 55 per cent female, however, there is large variation across subjects. Across all STEM subjects the gender balance is flipped; 56.2 percent of entries are by males. Table 1.1 shows the gender balance in A level entries for the main STEM subjects. Computer science is the most disproportionately male subject of all A levels (86.8 per cent male), maths is disproportionately male (61.2 per cent of entries) while

[43] Department for Education (2022) 'GCSE Results (Attainment 8), Academic Year 2020/21'.
[44] STEM Learning (2022) 'Science Education in England: Gender, Disadvantage and Ethnicity'.
[45] Plaister (2023) 'How Does KS5 Subject Choice Vary by Gender and Prior Attainment?'
[46] Department for Education (2023) 'Level 2 and 3 Attainment Age 16 to 25, Academic Year 2021/22'.

chemistry matches the gender balance of the overall A level cohort (45.9 per cent male). Conversely, only 36.5 per cent of the biology cohort is male.[47]

Table 1.1: A level entries in STEM subjects by gender, 2021

Subject	Male entries	Female entries	Percentage male
Biology	66,841	116,275	36.5%
Chemistry	72,819	85,661	45.9%
Maths	157,600	99,795	61.2%
Further Maths	29,857	12,072	71.2%
Physics	82,599	24,269	77.3%
Computer Science	29,828	4,947	85.8%
All STEM	**439,544**	**343,019**	**56.2%**

Source: Department for Education[48]

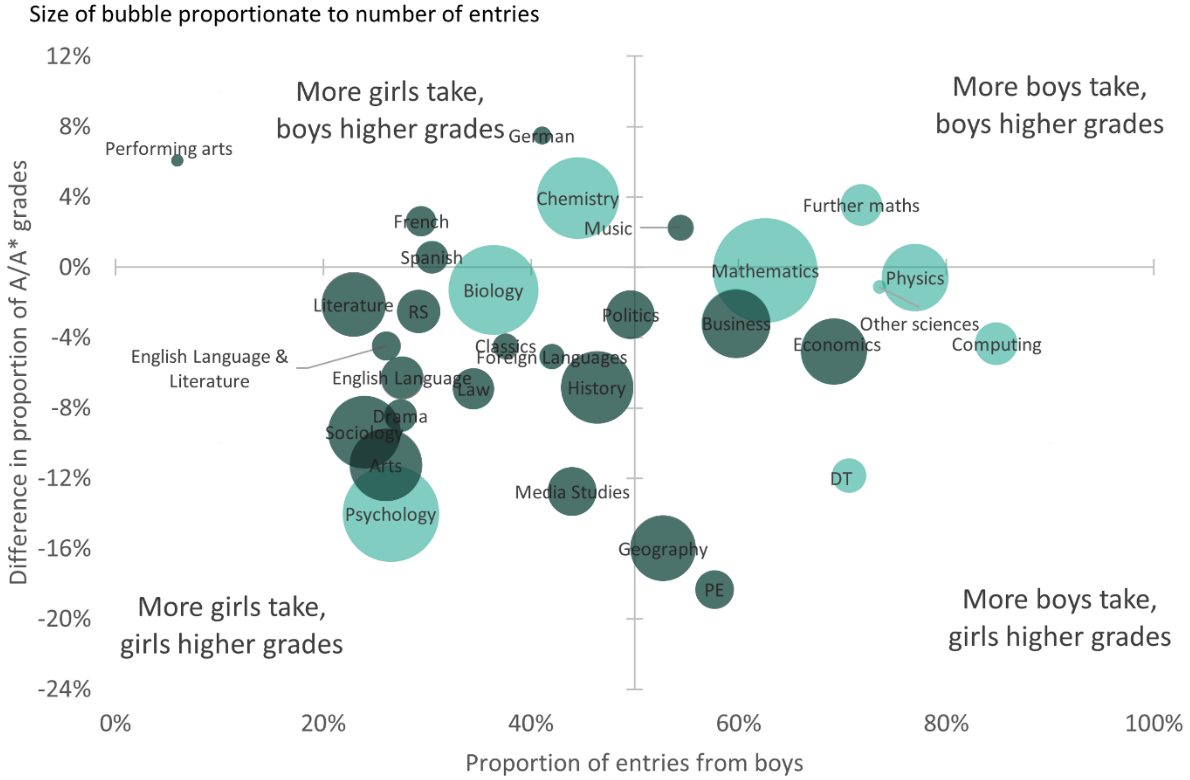
There have been no substantial changes in the gender balance of any A level subject in the last five years, but there have been some small shifts. In computer science (where entry numbers overall are rising) the proportion of female students has increased from 9 per cent in 2017 to 15 per cent in 2021. In design and technology (where the overall trend is one of falling entries) the proportion of female students has decreased from 39 to 30 per cent. Physics and further maths have seen small increases in the proportion of female students since 2017 – from 21 to 23 per cent in physics and from 27 to 29 per cent in further maths. Chemistry has become more gender balanced since 2017 with the proportion of female students increasing from 51 to 54 per cent, almost matching the cohort gender balance.

Figure 1.4 shows differences in participation and attainment for A level subjects in 2022: STEM subjects are highlighted in light green, and the size of the bubble corresponds to number of entrants. Overall, trends in the uptake of A level subject lends support to the idea that there are two clusters of STEM subjects: more 'maths-based' subjects that are more popular with boys, and the 'life-sciences' subjects that are more popular with girls.

Prior qualifications do not seem to be a barrier to girls choosing STEM A levels. Among pupils who achieved a top grade in GCSE maths 36.5 per cent of girls took maths A-level, compared to 51.1 per cent of boys. For physics 13.2 per cent of girls who achieved an A or A* at GCSE took the subject at A level, compared to 39.3 per cent of boys. There is almost no gender gap in the likelihood of taking chemistry A-level for those with high grades at GCSE and girls are more likely to take biology A-level than boys.[49] Comparing the GCSE scores of girls and boys who take who take A level physics and computer science shows girls have, on average, a substantially higher attainment 8 score, equivalent to half a grade more in each of the attainment 8 subjects.[50]

[47] Plaister (2021) 'Which A-Level Subjects Have the Best (and Worst) Gender Balance?'.
[48] Department for Education (2023) 'A Level and Other 16 to 18 Results, Academic Year 2021/22'.
[49] Cassidy et al. (2018) 'How Can We Increase Girls' Uptake of Maths and Physics A-Level?'.
[50] Plaister, N. (2023) 'How Does KS5 Subject Choice Vary by Gender and Prior Attainment?'.

Figure 1.4: A level entries in STEM subjects by gender, 2021



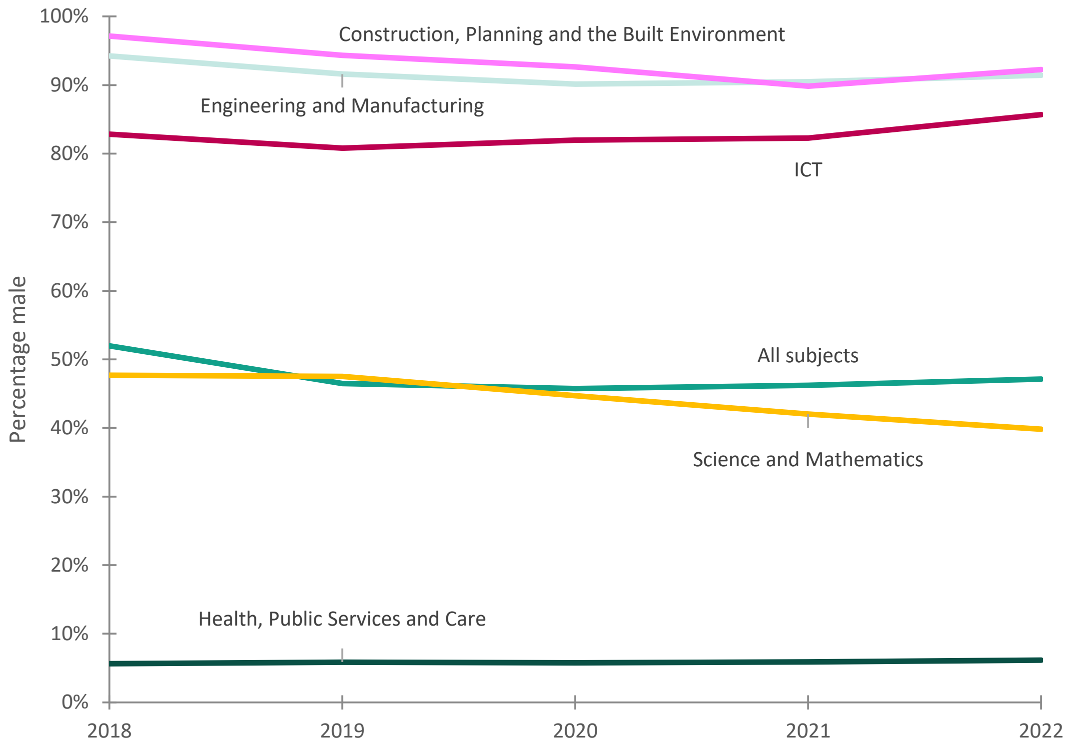
Qualitative research has shown key stage 4 girls and boys have different attitudes to science. Female pupils were less likely to rank a STEM-related subject first for enjoyment (32 per cent compared to 59 per cent) and less likely to consider themselves to be best at a STEM subject (33 per cent compared to 60 per cent). Male and female students both thought STEM subjects were likely to lead to high-paying jobs, but boys thought maths was the most useful subject whereas the most common answer for girls was English.[51] Work on science capital has shown that science is typically aligned with concepts of masculinity, and this can negatively impact girls' identification with, and aspirations in, science.[52]

Gender gaps for vocational STEM qualifications vary significantly across component subjects. Figure 1.5 shows entries to vocational qualifications that appear in the 16-18 performance tables in recent years. As for A levels, the cohort overall is slightly more female than male (47 per cent of qualifications awarded to men in 2021/22). Science and mathematics qualifications, of which BTEC Applied Science is the largest, broadly match the overall gender balance. However vocational qualifications in other STEM strands are much more popular among men: in 2021/22 86 per cent of vocational ICT qualifications, 91 per cent of engineering and manufacturing qualifications and 92 of construction qualifications were taken by men. Of the level 3 vocational

[51] Department for Education (2019) 'Attitudes towards STEM Subjects by Gender at KS4: Evidence from LSYPE2'.
[52] Archer et al. (2020) 'Aspires 2: Young People's Science and Career Aspirations, Age 10–19'.

qualifications, engineering and construction qualifications have the highest economic returns.[53] Conversely, Health, Public Services and Care qualifications are overwhelmingly female (94 per cent of entries).

Figure 1.5: Entries to level 3 vocational qualifications in the 16-19 performance tables, by gender



Source: Department for Education[54]

Intersectionality

Ethnicity, socio-economic disadvantage, and gender do not exist in isolation. Each individual's personal characteristics interact in a unique way. How socio -economic disadvantage affects a pupil's likelihood of progressing to post-16 STEM might vary for pupils of different genders and ethnicities, and vice versa. Some studies have looked at how gender, disadvantage and ethnicity interact, but this area is not as well researched as the independent effect of each of these characteristics. Studying interaction effects is complicated by the large number of possible combinations of characteristics across multiple dimensions of progression to level 3 STEM. Considering two categories of socio-economic disadvantage, two gender categories and six major ethnicities gives 24 different combinations of individual characteristics. Even considering how these vary across the three broad domains of pathway, prior qualifications and preferences results in a matrix of 72 effects to be investigated.

[53] McDool and Morris (2022) 'Gender differences in science, technology, engineering and maths uptake and attainment in post-16 education'.

[54] Department for Education (2023) 'A Level and Other 16 to 18 Results, Academic Year 2021/22'.

For example, since prior attainment is the most important predictor of progression to STEM courses, overall GCSE attainment is relevant.[55] The average Attainment 8 score for girls is 5.8 points higher than it is for boys, and girls have higher average Attainment 8 scores than boys across every ethnic group.[56] The gender attainment gap is smallest for Chinese pupils (a gap of 3.4 points) and largest for black Caribbean pupils (a gap of 7.6 points).

The disadvantage attainment gap also varies for different ethnic groups. On average pupils eligible for free school meals score 39.1 points, compared to an average of 53.6 amongst their peers, a gap of 14.5 points. FSM-eligible pupils score less than non-eligible pupils across all ethnic groups, but differences are smallest for Chinese pupils (FSM-eligible average score of 66.5, non-eligible score of 69.4, a gap of 2.9 points) and largest for White pupils, particularly White Irish pupils (FSM-eligible 37.4, non-eligible 58.9, a gap of 21.5 points). In percentage terms, the gap for Chinese students is 80 per cent smaller than average and the gap for White Irish pupils is 48 per cent bigger.

Since the gender and disadvantage gap is smallest for Chinese pupils it would be tempting to conclude that ethnicity is the most important factor in determining a pupil's previous qualifications for this group. However, take-up of triple science is also important. Non-FSM-eligible male Chinese students are more likely to enter triple science GCSEs than non-FSM-eligible girls, but this pattern reverses for FSM-eligible pupils where girls are more likely to enter triple science than boys. For students from White British backgrounds, entries to triple science are similar across genders, whereas Black Caribbean girls are more likely to enter triple science than Black Caribbean boys, regardless of disadvantage.[57] This demonstrates the complexity in unpacking intersectionality.

Looking at A levels, patterns of take up across gender and disadvantage remain relatively stable across different ethnicities.[58] Gender gaps in STEM participation are smaller for Black and Other Asian (as opposed to Pakistani and Bangladeshi pupils). The higher prior achievement of Black girls compared to Black boys means they are more likely to progress to level 3 qualifications, particularly A levels. This, combined with the small gender gap in participation, means that more Black girls take science A levels than boys. [59]

The disadvantage gap in uptake of STEM A levels is largest amongst White British pupils and much smaller amongst Black pupils. Considering gender, more disadvantaged girls are found to be less likely to study STEM A levels, even after accounting for prior achievement and other characteristics.[60] For vocational subjects, there is no disadvantage gap in the probability of taking a STEM qualification for female pupils. However, looking within the cohort of pupils taking level 3

[55] The Royal Society (2008) 'Exploring the relationship between socioeconomic status and participation and attainment in science education'.
[56] Department for Education (2022) 'GCSE Results (Attainment 8), Academic Year 2020/21'.
[57] STEM Learning (2022) 'Science Education in England: Gender, Disadvantage and Ethnicity'.
[58] Ibid
[59] Menzies, L. (2017) 'Achievement and Uptake of STEM Subjects at A Level: Ethnicity, Gender and SES'.
[60] McDool, E. and Morris, D. (2022) 'Gender differences in science, technology, engineering and maths uptake and attainment in post-16 education'.

vocational subjects, disadvantage is associated with a greater likelihood of choosing a STEM subject for male pupils.

Conclusion

The existing literature suggests that there are a range of reasons why different pupil groups have different patterns of progression to level 3 STEM qualification. Gender gaps can generally be attributed to differences in preferences. The low prior attainment of disadvantaged pupils and their low levels of participation in full-time education post-16 explains a large amount of the difference in STEM participation between disadvantaged pupils and their peers.

Differences in the way that ethnicity is recorded and analysed can sometimes mask nuanced patterns. Nevertheless, the evidence suggests that White British students are often among the least likely to choose STEM subjects post-16, alongside Black Caribbean pupils, pupils from Mixed Black backgrounds and Gypsy/Roma traveller pupils.

How the interaction between different characteristics such as gender, ethnicity and disadvantage influence the likelihood of progression is less well understood, compared to the independent effects of each. This is partly because this area is less well-researched and partly because the many different combinations of characteristics and relevant factors makes clear patterns harder to identify.

Strand 2: quantitative analysis of administrative data

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Introduction

In our review of our literature (Strand 1) we explored how the STEM education landscape has changed over time as well as the differential progression rates to level 3 STEM qualifications across three key pupil characteristics; gender, socio-economic disadvantage and ethnicity. Whilst changes to the system appear to have altered the numbers of pupils in aggregate, differences between pupil groups have remained. Exploring the key factors that need to coalesce for a student to progress from GCSE to a level 3 STEM qualification, namely pathways, prior qualifications and preferences. We also noted varying differences in patterns of uptake across life science and health subjects, compared to the physical and mathematical sciences.

In this second strand of the project, we attempt to identify schools that exceed expectations in facilitating the take-up of post-16 STEM courses by underrepresented groups. To do this, we first link data key stage 4 data from the National Pupil Database with records of post-16 qualifications to identify where pupils who complete post-16 STEM qualifications attended school pre-16.

We then estimate a series of statistical models to identify both patterns of progression to post-16 STEM qualifications. First, we complement our findings in strand 1, by exploring variation in progression by observed school and pupil characteristics. Second, we identify individual schools at which, for unobservable reasons, attending increases or decreases the likelihood of a pupil progressing to level 3 STEM. We pay particular focus to identifying schools that do not just induce an effect on all their pupils, but appear to be *relatively* better at progressing pupils from certain underrepresented groups (e.g., a school has a positive effect on the likelihood of disadvantaged pupils progressing over and above the effect it has on non-disadvantaged pupils). Formal descriptions of all statistical models can be found in Appendix 3.

Key takeaways

- **Around one in five pupils who left secondary school between 2016/17 and 2018/19 went on to complete a level 3 STEM qualification.**

- **Some pupil groups are much less likely to progress to level 3 STEM.** We estimate the odds of progressing to level 3 STEM are 42% lower for girls, compared to boys, and 44% lower for pupils eligible for free school meals compared to their more affluent peers. Compared with White British pupils, Black Caribbean pupils have similar odds of progressing to level 3 STEM. White and Black Caribbean, and Gypsy/Roma and Traveller of Irish heritage have lower odds (25% and 75% lower compared to White British pupils). On the other hand, Chinese pupils have almost five-time greater odds and Indian pupils almost 3.5 times the odds than their White British peers.

- **KS4 attainment is a key driver of differences in progression rates to level 3 STEM.** Whilst girls on average have higher attainment than boys, they are around 40% less likely to progress to level 3 STEM. Differences in attainment mask the underlying differences in the likelihood of progression to studying a level 3 qualification. We estimate girls are around 60% less likely to progress when comparing girls to boys that have similar KS4 attainment.

- Disadvantaged pupils have both lower KS4 attainment and lower progression rates to level 3 STEM qualifications. **The lower average attainment of disadvantaged pupils accounts for almost all the observed difference in progression rates to level 3 STEM qualifications.** Pupils eligible for free school meals in the last six years (FSM6) have around half the odds of progressing compared to their more advantaged peers. However, the odds are 4% lower for an FSM6 pupil when comparing to a peer with similar KS4 attainment.

- **The difference between the likelihood of pupils from different ethnic backgrounds of progressing to level 3 STEM is narrower if they have similar levels of GCSE attainment.** However, Black Caribbean pupils are identified as particularly hindered by low attainment. Black Caribbean pupils are estimated to be 40% more likely to progress to level 3 STEM than White British pupils with the same attainment. The opposite is true for White Irish pupils – they progress at greater rates than White British pupils, but this is due to relatively high KS4 attainment.

- **After adjusting for observable pupil characteristics, around 6.6% of the remaining variance in the likelihood of progressing to STEM level 3 is due to differences in the school attended.** We find that 23% of secondary schools have a significant negative impact on the odds of pupils progressing pupils to level 3 STEM qualifications whilst 25% have a significant positive effect.

- **There are systematic differences regardless of pupil characteristics, in schools' effects on progression rates.** For instance, attending a selective school systematically increases the odds of progressing to level 3 STEM. Attending a single sex girls' school significantly increases the likelihood of girls' progress to level 3 STEM by 21%, however, for boys, attending a single-sex school has no effect on the odds of progressing.

- **The school a pupil attends has more bearing on their likelihood of progressing to level 3 STEM for girls than it does for boys, for disadvantaged compared to non-disadvantaged pupils, and for all major ethnicity groups compared to White pupils.** So, for some underrepresented groups (girls, disadvantaged pupils) school matters more, but the same does not hold true for ethnicity. In fact, which school a pupil attends appears to matter most for those who are ethnically Chinese, an overrepresented group.

- **In most cases the differential effect of schools on different pupil groups is relatively small, when compared to the overall effect schools have on all their pupils.**

Data

We link individual level data from the National Pupil Database (NPD) and Individual Learner Records (ILR). The spine for our sample consists of 1,568,920 individuals who are identified in the NPD has attending state-funded secondary schools at the end of key stage 4 in the academic years 2016/17, 2017/18, and 2018/19. The NPD allows us to observe which school pupils attended, certain pupil characteristics (such as gender, ethnicity, and whether they were eligible for free school meals (FSM)), and their attainment both at KS4 and previously at KS2. We attempt to link these detailed records with records in the ILR 2 and 3 years in the future, using a unique anonymised pupil identifier. For example, we search for a match in the 2018/19 and 2019/20 ILR for pupils who completed key stage 4 in 2016/17. A full breakdown of the sample can be found in table A2.1 (see Appendix 2).

We then pool data from each school across the three academic years. Schools that converted to become an academy or were re-brokered during the three-year period are treated as multiple separate schools, as we believe this change in organisational structure may have important implications for the outcome of interest, progressing to level 3 STEM.

As discussed in strand 1, whilst STEM is a commonly used term in education policy and beyond, there is no universal, consistent, definition of the courses that it covers. Different official bodies and academic researchers include different subjects and qualifications within their STEM definitions. As a starting point for this work, we consider as a STEM qualification any post-16 course that is designated by Ofqual as being in one of the following Sector Subject Areas (SSA)[61]:

- Science and Mathematics (2)
- Engineering and Manufacturing Technologies (4)
- Construction, Planning, and the Built Environment (5)
- Information and Communication Technology (6)

To complicate things further, at level 3 pupils often study qualifications in multiple subjects alongside each other. We therefore define 'progressing to level 3 STEM' as completing the equivalent of 2 A-levels in STEM subjects, where STEM subjects are those that fall within the 4 (of 15) SSAs listed above. This provides the initial definition.

There are further unresolved issues, which we identified in strand 1, including whether health subjects and subjects on the boundary of social and natural sciences, such as psychology and economics should be included. In particular, there are distinctly different patterns in uptake of STEM subjects between 'maths-based' courses such as physics and maths and 'life sciences-based' courses such as biology.

As a result, our preferred definition places an additional restriction – to have 'progressed to level 3 STEM' a pupil must study the equivalent of at least one A-level in a subject within the above SSAs,

[61] Numbers in brackets refer to the corresponding SSA code.

but not in biology, psychology or other life-science related subject. This ensures that pupils have taken at least one A-levels worth of 'maths-based' courses.

Descriptive picture

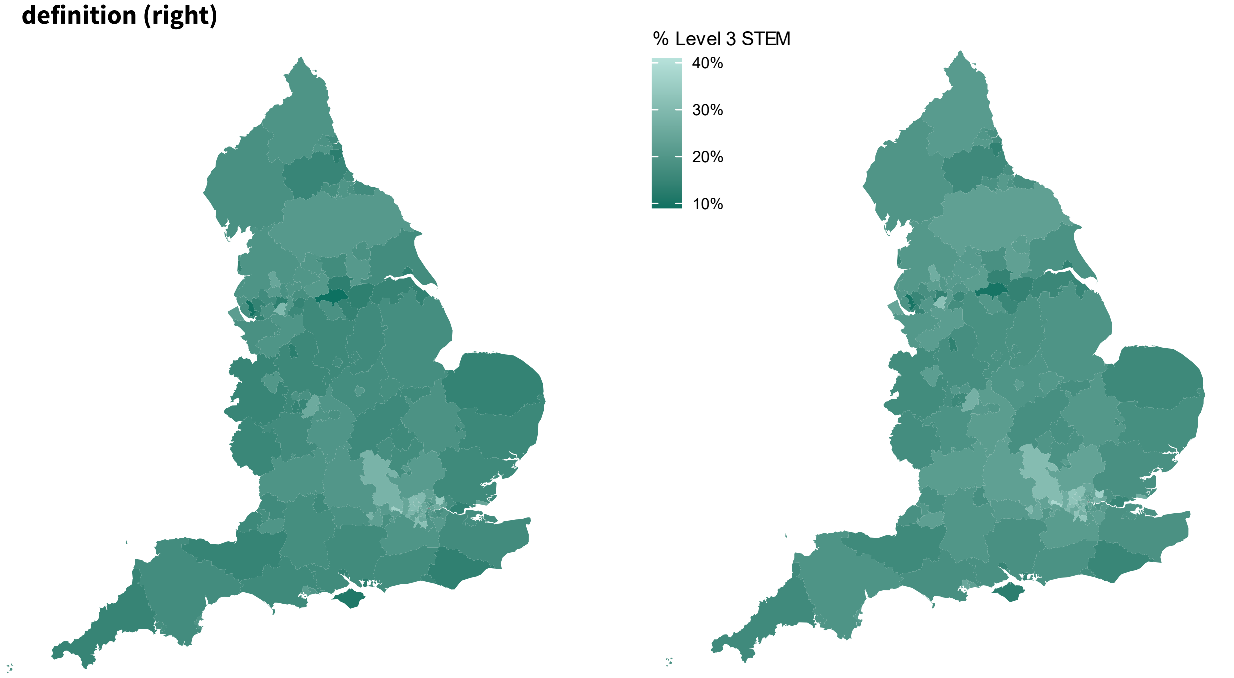
Pupil and school characteristics

Using our definition of level 3 STEM outlined above, around one in five pupils who left secondary school between 2016/17 and 2018/19 went on to complete a level 3 STEM qualification. There are distinct patterns of uptake of these courses by pupil characteristics, many of which have been discussed in our review of the prior literature. Table A2.2 shows boys (23%) are more likely than girls (15%) to complete a level 3 STEM qualification, with the gap narrowing slightly under our alternative definition. There is an even larger gap in uptake between those that are eligible for free school meals and their peers and white pupils are least likely of all the major ethnicity groupings.

More revealing are the differences in uptake by secondary school characteristics, shown in table A2.3. Pupils attending academy convertors and free schools are most likely to go on to complete level 3 STEM qualifications (21–25%) and those attending sponsor-led academies the least likely (14%). Similarly, schools with higher Ofsted grades see more of their pupils' progress to level 3 STEM (28% in Outstanding schools compared to 15% in RI schools). Single sex schools and those with selective admissions also see more of their pupil's progress. Almost half of pupils in selective secondary schools complete a level 3 STEM qualification. Finally, pupils attending a secondary school with a sixth form are more likely to go on to complete level 3 STEM qualifications.

Geographic variation

Figure 2.1 Progression rates to level 3 STEM by local authority, preferred (left) and alternative definition (right)



Source: EPI analysis of the National Pupil Database

Rates of progression to level 3 STEM also vary across the country and are noticeably higher in London and surrounding areas to the west of the capital. Rates are highest in the local authority areas of Slough and Redbridge, where more than one in three pupils go on to complete level 3 STEM qualifications after leaving secondary school. Notable hotspots outside of the South East, include Birmingham (26%) in the West Midlands, and Trafford (30%) and Blackburn and Darwen (25%) in the North West. Conversely, in the local authority areas of Barnsley and Knowsley less than one in ten pupils go on to complete level 3 STEM qualifications. These geographically differences often reflect local challenges, for example Knowsley is less than 30 miles from Trafford but suffers from a lack of A-level courses being offered in the authority.[62]

Prior GCSE attainment

As discussed in our review of the literature, one key determinant of the likelihood of completed level 3 STEM studies is prior qualifications, as many qualifications specify grade or qualification requirements in order to enrol. Unsurprisingly, therefore we find only 4.2% of pupils with GCSE maths at grade 4 or below progress to level 3 STEM compared to 34% of those achieving a grade 5 or above. Similarly, 44% of pupils studying triple science progress to level 3 STEM compared to only 10% of those pupils that do not.

Table 2.1 Progression rates to level 3 STEM by GCSE outcomes

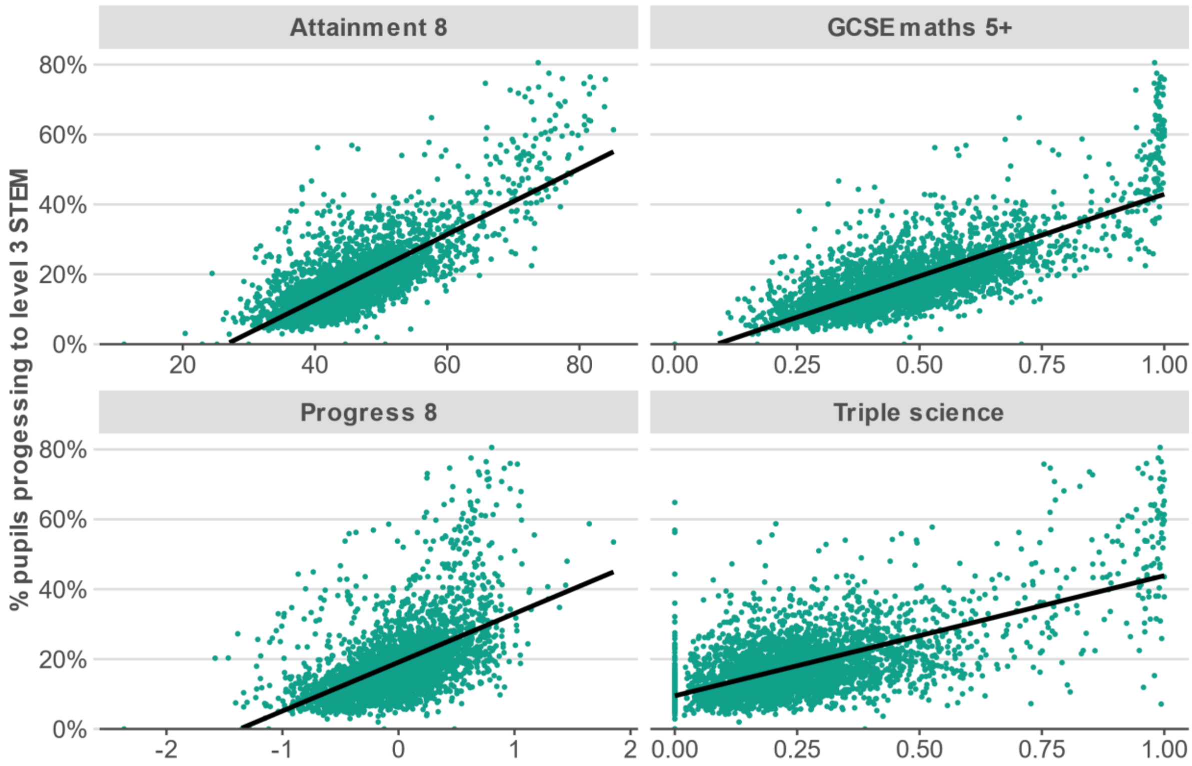
		% Level 3 STEM		**Number of pupils**
		Preferred definition	*Alternative definition*	
Overall		**19.0%**	**20.8%**	**1,568,920**
GCSE maths	≤4	4.2%	4.5%	787,434
	5+	34.0%	37.2%	781,486
Triple science	No	9.9%	10.9%	1,148,129
	Yes	44.0%	47.7%	420,791

Source: EPI analysis of the National Pupil Database

At the school level there is also a clear positive correlation with overall measures of attainment and progress. A crude linear model, shown graphically in Figure 2.2, suggests that for every 1-point increase in school level average attainment 8 score increases the fraction of pupils from the school progressing to level 3 STEM by 1 percentage point.

[62] BBC News (2022) 'Knowsley must do better than lack of A-levels on offer, council chief says'.

Figure 2.2 Progression rates to level 3 STEM by GCSE outcomes, school level



Source: EPI analysis of the National Pupil Database

Notes: Solid black lines denote fitted linear models. Each point represents a school. The four attainment measures are average Attainment 8 score, average Progress 8 score, percentage of pupils achieving a 'strong pass' of 5+ in GCSE maths, and percentage of pupils achieving GCSE triple science (as opposed to combined science)

Logistic regression model

Above we report the percentage of pupils that progressed to Level 3 STEM nationally after completing key stage 4 in the academic years 2016/17 to 2018/19. However, to jointly model the effect having a set of pupil and school characteristics has on the probability of progressing to level 3 STEM a statistical model is required. We first estimate a logistic regression model. A logistic regression models the log-odds of an event (such as progressing to Level 3 STEM) as a linear combination of one or more independent variables. (see Appendix 3 for a formal description of the logistic model)

We fit the logistic regression model to our dataset of three consecutive KS4 cohorts. Table 2.2 shows the resulting coefficients under five different specifications, where in each specification we alter the set of independent variables included and our definition of Level 3 STEM.

Model 1 uses our preferred definition of progressing to Level 3 STEM [63] and includes a range of pupil characteristics as independent variables, including FSM eligibility, gender, major ethnicity

[63] Level 3 qualifications equivalent to 2 or more A-levels in STEM subjects, where at least one A-level (or equivalent) is not in biology, psychology or other life science.

group, EAL, SEND, and birth quarter. We also control for prior attainment (KS2 maths and reading scores) and the academic year the pupil completed KS4, as our sample is pooled across three cohorts.

Certain groups of pupils have, on average, different likelihoods of progressing to level 3 STEM.

The exponential of the estimated coefficients can be interpreted as the marginal effect on the odds of progressing to level 3 STEM. For example, in model 1 the female coefficient is -0.483, which implies that the odds of females progressing to Level 3 STEM are approximately 38% lower than they are for males.[64] Model 1 also estimates that pupils eligible for Free School Meals have around half the odds of progressing compared to their more advantaged peers.[65] Compared to White pupils, pupils are from all major ethnicity groups are found to have higher odds of progressing to Level 3 STEM. Chinese pupils are the most likely, with over 4-times greater odds of progressing than their White peers.

Model 2 is our 'core' model and uses more granular 'minor' ethnicity categories. This provides a more nuanced picture of the differences in progression to level 3 STEM amongst pupils from different ethnic backgrounds. In model 1 we estimated that Black pupils had odds of progressing about double that of their White peers. However, using a more granular categorisation reveals clear heterogeneities. Black African pupils have odds of progression that are almost three times greater than White British pupils, whereas Black Caribbean pupils are estimated to have the same odds as White British pupils.[66] Within the broader Asian group there are also clear differences, the odds of Indian pupils progressing are much greater than that of Bangladeshi or Pakistani pupils.

In model M1 all the ethnicity coefficients are positive and significantly different from zero, implying the odds of all non-White pupils progressing are greater than that of White pupils. Model 2 though identifies a set of ethnicities that have the same, or lower odds of progression to Level 3 STEM than White British pupils:

- Black Caribbean – approx. the same odds,
- White and Black Caribbean – approx. 25% lower odds,
- Gypsy/Roma – approx. 75% lower odds
- Traveller of Irish heritage – approx. 75% lower odds.

[64] exp(-0.483) -1 = -0.383
[65] exp(-0.738) -1 = -0.522
[66] The coefficient on Black Caribbean is -0.016 (0.22) is unsignificant even at the 90% level.

Table 2.2 Logistic regression coefficients

		Model M1	**Model M2 (‘core’)**	Model M3	Model M4	Model M5
Female		-0.483*** (0.004)	**-0.486*** (0.004)**	-0.326*** (0.004)	-0.534*** (0.005)	-0.949*** (0.005)
FSM6		-0.738*** (0.006)	**-0.712*** (0.006)**	-0.734*** (0.006)	-0.630*** (0.006)	-0.038*** (0.007)
Major Ethnicity (ref: White)	Any other ethnic group	0.963*** (0.016)	**- -**	- -	- -	- -
	Asian	1.009*** (0.008)	**- -**	- -	- -	- -
	Black	0.717*** (0.009)	**- -**	- -	- -	- -
	Chinese	1.661*** (0.029)	**- -**	- -	- -	- -
	Mixed	0.374*** (0.010)	**- -**	- -	- -	- -
	Unclassified	0.308*** (0.020)	**- -**	- -	- -	- -
Minor Ethnicity (ref: White British)	Bangladeshi	- -	**0.995*** (0.015)**	0.970*** (0.015)	0.957*** (0.016)	0.768*** (0.018)
	Indian	- -	**1.395*** (0.012)**	1.351*** (0.012)	1.248*** (0.012)	0.949*** (0.014)
	Any other Asian background	- -	**1.349*** (0.013)**	1.306*** (0.013)	1.231*** (0.014)	1.084*** (0.015)
	Pakistani	- -	**0.993*** (0.011)**	0.947*** (0.011)	0.963*** (0.012)	1.152*** (0.013)
	Black - African	- -	**1.079*** (0.013)**	1.061*** (0.012)	0.988*** (0.013)	0.865*** (0.014)
	Black Caribbean	- -	**-0.016 (0.022)**	0.0 (0.021)	-0.020 (0.023)	0.336*** (0.025)
	Any other black background	- -	**0.932*** (0.018)**	0.911*** (0.017)	0.889*** (0.018)	0.854*** (0.020)
	Chinese	- -	**1.836*** (0.030)**	1.782*** (0.030)	1.661*** (0.030)	0.818*** (0.033)
	Any other mixed background	- -	**0.653*** (0.015)**	0.624*** (0.015)	0.583*** (0.015)	0.335*** (0.018)
	White and Asian	- -	**0.683*** (0.019)**	0.657*** (0.019)	0.613*** (0.020)	0.239*** (0.023)
	White and Black African	- -	**0.453*** (0.029)**	0.429*** (0.028)	0.409*** (0.029)	0.265*** (0.033)
	White and Black Caribbean	- -	**-0.276*** (0.023)**	-0.243*** (0.022)	-0.270*** (0.024)	-0.106*** (0.026)
	Any other ethnic group	- -	**1.152*** (0.016)**	1.112*** (0.016)	1.077*** (0.016)	0.789*** (0.019)
	Unclassified	- -	**0.376*** (0.020)**	0.353*** (0.019)	0.342*** (0.021)	0.363*** (0.023)
	White - Irish	- -	**0.338*** (0.037)**	0.346*** (0.036)	0.247*** (0.038)	-0.134*** (0.042)
	Traveller of Irish heritage	- -	**-1.412*** (0.361)**	-1.401*** (0.341)	-1.346*** (0.361)	-0.875** (0.383)
	Any other white background	- -	**0.492*** (0.011)**	0.470*** (0.011)	0.448*** (0.011)	0.139*** (0.013)
	Gypsy/Roma	- -	**-1.356*** (0.133)**	-1.347*** (0.127)	-1.339*** (0.134)	-0.379*** (0.140)
Pupil characteristics		✓	✓	✓	✓	✓
Prior KS2 attainment		✓	✓	✓	✓	✓
School characteristics		×	×	×	✓	×
GCSE outcomes		×	×	×	×	✓

McFadden's pseudo R^2	0.101	**0.105**	0.101	0.118	0.315
Log-Likelihood	-684,795	**-681,420**	-718,392	-657,670	-521,968

Notes: Pupil characteristics include EA status, SEND status, GCSE cohort, and month of birth. Prior KS2 attainment includes KS2 test results in maths and reading. School characteristics include school type, admissions policies and sixth form. Coefficients can be found in table A4.1. GCSE outcomes include Attainment 8 score, indicator for a strong pass in maths, and indicator for triple science.

Unsurprisingly coefficients on the set of other covariates remain relatively stable. However, the coefficient for English as an Additional Language (EAL) is half that in model 1, although remains significant. This implies model 1 may be suffering from a form of omitted variable bias as a more fine-grained ethnicity categorisation is able to explain the variation in STEM progression more accurately, whereas in model 1 EAL status is being left to (inaccurately) explain the residual differences.

Girls are less likely to be studying 'hard' sciences at level 3 than boys.

The remaining three models act as various extensions to the 'core' model. Model M3 follows model M2 but uses our alternative definition of STEM - relaxing the definition so biology, psychology or other life science related courses can form the entirety of the STEM bucket. This has the most significant impact[67] on the gender coefficient, reducing the difference in the odds of progressing to Level 3 STEM between boys and girls – girls are estimated to have 27.8% lower odds in model 3 compared to 38.5% in model 2. This is due to more girls taking life science related subjects but shows how important our definition is understanding the dynamics at play.

There are systematic differences in the likelihood of a pupil progressing to level 3 STEM depending on the characteristics of the school they attend.

Model 4 adds school level characteristics; school type, admissions policies (selective, single sex), and whether the school has a sixth form.[68] This model is useful in providing an assessment of which school characteristics may relate to individual pupil progression to level 3 STEM. It reveals the effect for girls of attending a single-sex school rather than a mixed school increases the odds of progressing to level 3 STEM by 21%, but the effect is very small and in fact negative for boys. Attending a secondary school with a sixth form increases the odds by 14%, and more broadly the type of school attended appears to make a difference. Pupils attending a selective school have 2.5 times greater odds of progressing to level 3 STEM than those who attend non-selective schools. This is striking as we also control for prior attainment at KS2 (and other pupil characteristics), so this effect is not entirely due to differences in intake. We further consider the role individual schools play in the outcomes of their pupils, in the next section.

KS4 attainment is a key driver of differences in progression rates.

Model M5 includes additional controls for GCSE outcomes. We know that these intermediate outcomes are an important determinant of whether a pupil progresses to level 3 STEM.[69] In models

[67] z-score = -26
[68] See table A4.1 for model coefficients.
[69] See Strand 1.

1–4 we have estimated the 'total effect' of characteristic, such as gender, on the likelihood of completing level 3 STEM. This 'total effect' is most relevant to our ultimate goal of understanding the role of individual schools in progressing pupils to level 3 STEM. However, including controls for GCSE outcomes is useful here as it allows us to understand the relative importance of GCSE outcomes in determining progress to level 3 STEM.

The inclusion of GCSE outcomes leads to the female coefficient becoming more negative. This illustrates how the relatively higher KS4 attainment of girls compared to boys reduces the observed differences in the likelihood of progressing to Level 3 STEM. The model suggests that girls are 60% less likely to progress compared to boys that have similar KS4 attainment (considerably lower than the 38% estimated in the 'core' model). The FSM6 coefficient becomes much less negative. This implies most of the reason disadvantaged pupils progress to level 3 STEM at a lower rate than their peers are due to differences in KS4 attainment. The odds of progressing to level 3 STEM are only 3.7% lower for an FSM6 pupil that has similar attainment as a non-FSM eligible peer.

In general, the absolute value of the ethnicity coefficients in model 5 are smaller, implying that GCSE outcomes are a partial leveller. The difference in the likelihood of pupils from different ethnic backgrounds of progressing to level 3 STEM is smaller if they have similar attainment. There are a couple of exceptions, for Black Caribbean pupils, the coefficient moves from being insignificantly different from zero to significantly positive (40% greater odds than White British pupils). Whilst for White Irish pupils the opposite is observed, going from significantly positive to significantly negative. This implies that Black Caribbean pupils are particularly hindered by low GCSE attainment, whilst White Irish pupils the opposite is true GCSE attainment appears to hide other unobserved factors that lead to lower rates of progression to level 3 STEM qualifications. The residual, non-attainment driven, reasons for differences are though not disentangled by these models.

School level effects

Our series of logistic regression models above have established clear patterns between pupil characteristics and the probability of progression to level 3 STEM. In this section we turn our attention to our primary question of interest; the effect of attending a given individual school on the probability of a pupil progressing to level 3 STEM. This is also of interest because we know there are many school level characteristics that affect a pupil, but we cannot measure directly, e.g. teacher quality.

We extend our modelling approach to by estimating a series of multilevel models. This approach allows us to estimate both global averages and group-level effects, through allowing each school to have its own intercept. (further model details can be found in Appendix 3)

We estimate four specifications mirroring those in the models M1-M4. The coefficients for the fixed part of the model are reported in Table 2.3, showing similar patterns to the coefficients from the single level models reported in Table 2.2.

Table 2.3 Multilevel random intercept model fixed effect regression coefficients

		MLM 1	**MLM2 ('core')**	MLM 3	MLM 4
Female		-0.537*** (0.005)	**-0.539*** (0.005)**	-0.368*** (0.005)	-0.543*** (0.005)
FSM6		-0.599*** (0.006)	**-0.588*** (0.006)**	-0.604*** (0.006)	-0.585*** (0.006)
Major Ethnicity (ref: White)	Any other ethnic group	0.820*** (0.016)	-	-	-
	Asian	0.930*** (0.009)	-	-	-
	Black	0.655*** (0.011)	-	-	-
	Chinese	1.421*** (0.030)	-	-	-
	Mixed	0.301*** (0.010)	-	-	-
	Unclassified	0.257*** (0.022)	-	-	-
Minor Ethnicity (ref: White British)	Bangladeshi	-	**0.979*** (0.018)**	0.959*** (0.017)	0.981*** (0.018)
	Indian	-	**1.242*** (0.013)**	1.197*** (0.013)	1.234*** (0.013)
	Any other Asian background	-	**1.211*** (0.014)**	1.169*** (0.014)	1.207*** (0.014)
	Pakistani	-	**0.943*** (0.013)**	0.899*** (0.013)	0.946*** (0.013)
	Black - African	-	**1.009*** (0.014)**	0.990*** (0.013)	1.001*** (0.014)
	Black Caribbean	-	**-0.019 (0.023)**	-0.010 (0.022)	-0.020 (0.024)
	Any other black background	-	**0.876*** (0.019)**	0.849*** (0.018)	0.871*** (0.019)
	Chinese	-	**1.60*** (0.030)**	1.550*** (0.030)	1.599*** (0.031)
	Any other mixed background	-	**0.558*** (0.016)**	0.526*** (0.015)	0.553*** (0.016)
	White and Asian	-	**0.562*** (0.020)**	0.534*** (0.020)	0.561*** (0.020)
	White and Black African	-	**0.404*** (0.029)**	0.377*** (0.028)	0.401*** (0.029)
	White and Black Caribbean	-	**-0.251*** (0.024)**	-0.223*** (0.023)	-0.250*** (0.024)
	Any other ethnic group	-	**1.017*** (0.017)**	0.978*** (0.017)	1.015*** (0.017)
	Unclassified	-	**0.331*** (0.022)**	0.298*** (0.021)	0.340*** (0.022)
	White - Irish	-	**0.227*** (0.038)**	0.233*** (0.037)	0.217*** (0.038)
	Traveller of Irish heritage	-	**-1.382*** (0.306)**	-1.380*** (0.318)	-1.322*** (0.345)
	Any other white background	-	**0.452*** (0.012)**	0.427*** (0.011)	0.449*** (0.012)
	Gypsy/Roma	-	**-1.259*** (0.138)**	-1.240*** (0.125)	-1.247*** (0.132)
Pupil characteristics		✓	✓	✓	✓
Prior KS2 attainment		✓	✓	✓	✓
School characteristics		✗	✗	✗	✓
GCSE outcomes		✗	✗	✗	✗
Log-Likelihood		-666,457	**-664,115**	-699,364	-649,259

Notes: Pupil characteristics include EA status, SEND status, GCSE cohort, and month of birth. Prior KS2 attainment includes KS2 test results in maths and reading. School characteristics include school type, admissions policies and sixth form. Coefficients can be found in table A4.1.

The differences in likelihood of progression across pupil groups are still present once individual school effects are controlled for.

In the 'core' multilevel model, MLM2, the odds of progressing to level 3 STEM are estimated to be 42% lower for girls, compared to boys, and 44% lower for disadvantaged pupils compared to their more well-off peers. The magnitudes and patterns relating to ethnicity are again similar to in single level models. Again, Black Caribbean (same odds), White and Black Caribbean (25% lower odds), Gypsy/Roma and Traveller of Irish heritage (75% lower odds) have the same or lower odds of progressing to level 3 STEM than White British pupils. Meanwhile, Chinese pupils have almost five-time greater odds and Indian pupils almost 3.5 times the odds.

Comparing MLM4 with MLM2, we see the addition of school level characteristics in does not alter the pupil characteristic coefficients significantly. This implies that the differences observed by school characteristics are systematic and not by a small number of specific schools.

We do not include a multi-level equivalent to model M5 controlling for GCSE outcomes. This is because the purpose of these MLM's is to understand what the effect of attending a given school is on the likelihood of progression to level 3 STEM. In this context GCSE outcomes can be thought of as 'bad controls' (Angrist and Pischke, 2009). Above we discussed the role of GCSE outcomes as a mediator, this is of interest in its own right hence the inclusion but in this context, we are interested in the total effect a school has regardless of the channel of effect. Note we do include prior attainment at KS2, which allows us to make fairer comparisons across schools, as this is measured before the notional experiment, school attended.

Adjusting for observable characteristics, 6.6% of the variance in the likelihood of progressing to level 3 STEM qualifications is due to the school attended.

Before taking a closer look at the school level effects, we first want to understand whether there is indeed any variation by school and if so, how much of the variation in the likelihood of progression to level 3 STEM can be explained by the school attended. To do this we carry out a likelihood ratio test in to test the null hypothesis that there is no between school variation.[70]

The test statistics for each model is reported in the first column of Table 2.4. We compare the test statistics to the 5% point of a chi-squared distribution with 1 degree of freedom, 3.84. In all cases we can reject the null hypothesis meaning we do identify significant non-zero variation in the rates of progression to level 3 STEM between schools.

For each model we also calculate the between school variance and variance partition coefficient (VPC) which measures the proportion of the total residual variance that is due to the between-group variation. These are reported in the last two columns of Table 2.4. For ML2, the VPC is

[70] The likelihood ratio test statistic is calculated as twice the difference in the log likelihood values between the model with and without the random intercept: $\lambda_{\text{LR}} = -2\big(\ell(\theta_{1\text{ level}}) - \ell(\theta_{2\text{ level}})\big)$

calculated as 0.0662, in other words after adjusting for observable pupil characteristics around 6.6% of the remaining variance in the likelihood of progressing to level 3 STEM is due to between-school variation.[71] This is similar across MLM1-MLM3, but smaller for MLM4. The school-level variance decreases from 0.233 to 0.127, demonstrating there are systematic differences in school effects on student outcomes across the considered school characteristics.

Table 2.4 Likelihood ratio test statistics and VPCs

	Likelihood ratio test statistic, λ_{LR}	Between School Variance	Variance Partition Coefficient (VPC)
MLM1	36,676	0.242	6.86%
MLM2 ('core')	34,609	0.233	6.62%
MLM3	38,054	0.241	6.83%
MLM4	16,821	0.127	3.71%

Many secondary schools do have significantly impact on the likelihood of their pupils progressing to level 3 STEM qualifications.

One major advantage of estimating the multilevel models is that we can also explore the random intercepts themselves, these are the estimated difference from the global intercept. If this is significantly less than or greater than zero, this implies a school has a significant impact on its pupil's probability of progressing to level 3 STEM, given the set of characteristics controlled for in the model.

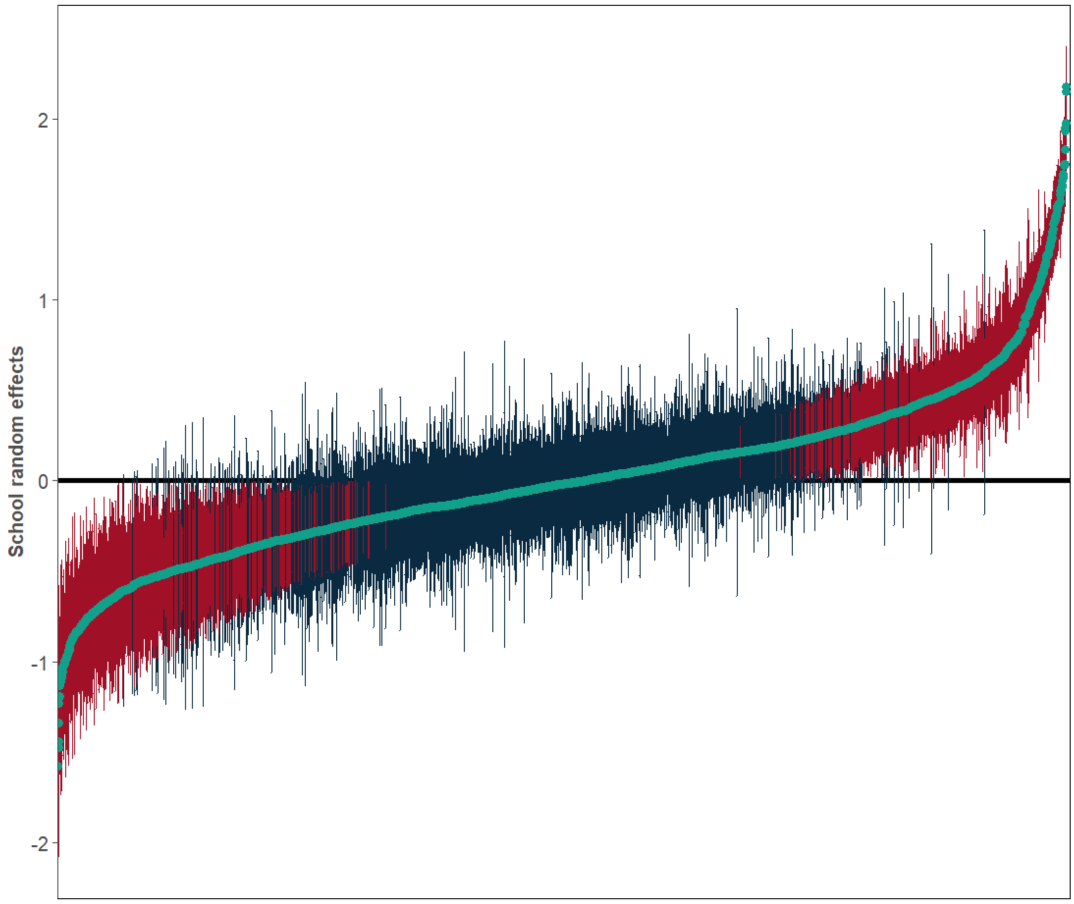
Figure 2.2 depicts the random intercepts for all schools in ascending order. Those with estimated intercepts that are significantly different to zero at the 95% significance level are highlighted in red. In total, around 23% of schools are significantly below average and 25% above are significantly above.

Table 2.5 Schools with statistically significant (95% level) random intercepts

	Number of schools	**Percentage of schools**
Sig. < 0	808	23.0%
Sig. > 0	891	25.3%

[71] $$VPC = \frac{level\ 2\ residual\ variance}{level\ 2\ residual\ variance + level\ 1\ residual\ variance} = \frac{0.233}{0.233+\frac{\pi^2}{3}} = 0.0662$$

Figure 2.2 School level random intercepts



Characteristics at the school level

In the previous two sections, we established first that certain pupil characteristics play a key role in determining the likelihood of progressing to level 3 STEM. Then subsequently that the school a pupil attends also plays a role in determining the likelihood of progression to level 3 STEM.

In this section we attempt to understand whether the effect key pupil characteristics (gender, disadvantage and ethnicity) have on the odds of progressing to level 3 STEM vary by school. In other words, is it true that the marginal effect of being eligible for free school meals is the same regardless of the school attended – in certain schools, do pupils with particular characteristics have greater odds of progression *relative* to their peers. We model this using a multilevel model as in the previous section, but with the addition of a varying-slope parameter. (further model details can be found in Appendix 3)

Socio-economic disadvantage (Free School Meals)

We first estimate a model where the school level variance is assumed to vary by FSM6 status. The slope parameter associated with FSM6 is therefore allowed to vary across schools, and in turn the relative difference in odds between disadvantaged and non-disadvantaged pupils can vary by school. The difference in odds of progression between ethnicities (and other characteristics) is though still assumed to be the same in each school.

In this section we are less interested in the fixed components of the model and instead focus on whether there is variation across schools, and whether we can identify schools that are significantly different from the average in the population. First, we carry out a likelihood ratio test to test the null hypothesis that there is no between school variation in the difference between FSM and non-FSM pupils. The likelihood test statistic[72] is 201 and the 5% point of a chi-squared distribution with 2 degrees of freedom is 5.99. We therefore conclude that the difference in odds between FSM6 and non-FSM6 pupils does vary across schools (201 > 5.99).

Now that we have allowed the effect of free school meal eligibility on the probability of progressing to level 3 STEM to vary by school, the between school variation depends on free school meal eligibility. Table 2.5 shows the amount of between school variation for both FSM6 and non-FSM6 pupils. The greater amount of between school variation for FSM6 pupils (0.265 vs. 0.233) indicates that the school attended has a stronger effect on the probability of progressing to level 3 STEM for FSM6 pupils than their peers.

Table 2.6 Between school variance and VPC, FSM6

	Between School Variance	Variance Partition Coefficient (VPC)
FSM6	0.265	7.46%
Non-FSM6	0.233	6.62%

We also explore the random slopes. Figure 2.3 plots these slopes in ascending order, highlighting those that are significantly different from the global effect. At the 95% significance level 19 schools have a significantly different slope, 0 lower and 19 higher. So, despite the difference in the odds of progression being identified as varying by school, no schools are significantly worse for FSM6 pupils than average, and very few are identified as significantly better.

[72] The likelihood ratio test statistic is calculated as twice the difference in the log likelihood values between the model with and without the random slope for FSM.

Figure 2.3 School level random slopes, FSM6

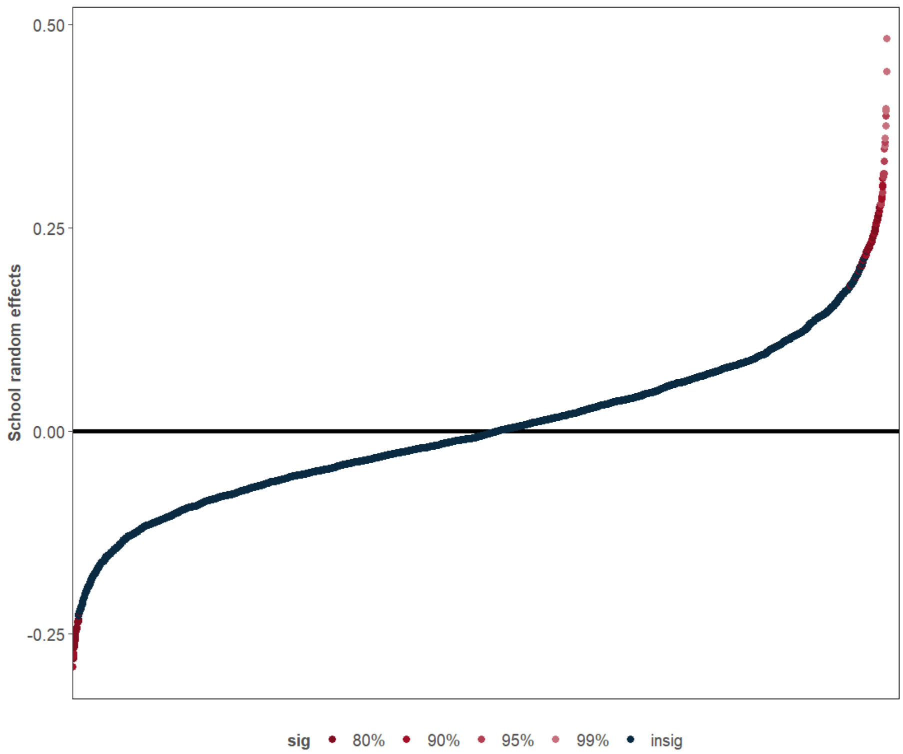


Table 2.7 Schools with statistically significant random slopes, FSM6

	Number of schools				Percentage of schools			
Sig. level	*99%*	*95%*	*90%*	*80%*	*99%*	*95%*	*90%*	*80%*
$\varepsilon_j^{\beta} < 0$	0	0	4	29	0.0%	0.0%	0.1%	0.8%
$\varepsilon_j^{\beta} > 0$	7	19	45	106	0.2%	0.5%	1.3%	3.0%

Gender

Next, we estimate a similar random slopes model, but instead of including random slopes for FSM, we instead allow the effect of gender to vary between schools. Two versions of this model are estimated using both our standard and alternate definitions of what constitutes a level 3 STEM qualification.[73] Using a likelihood ration test, for both models we reject the null hypothesis that there is no between school variation in the difference between gender.[74] Implying that the difference between boys and girls does indeed vary across schools.

As before the between school variation estimated by the model now varies by gender. Table 2.8 shows the difference in the amount of school variation between boys and girls. The greater amount of between school variation for girls in both models, indicates that the school attended has a stronger effect on the probability of progressing to Level 3 STEM for girls than for boys.

[73] The alternate definition includes life science and health subjects.

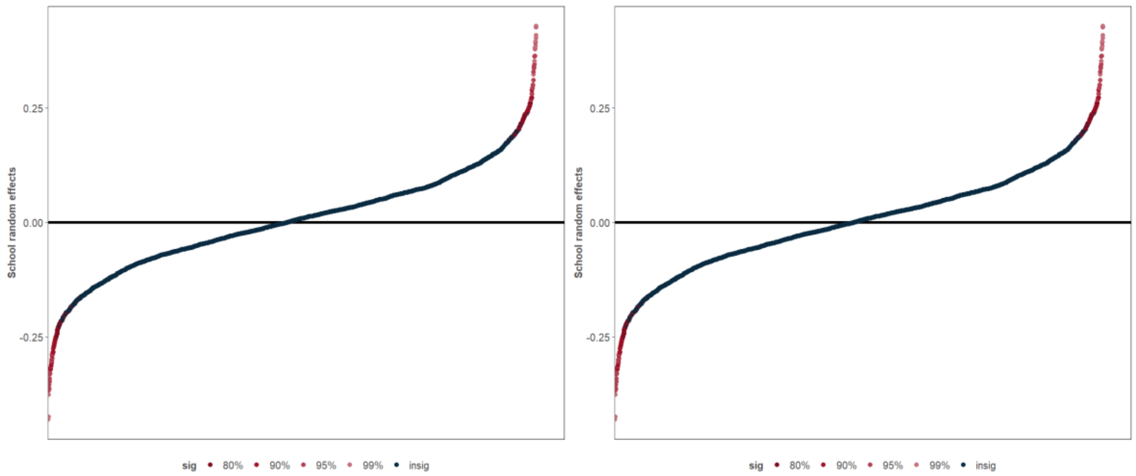
[74] The likelihood test statistics are 382 and 464 respectively

Table 2.8 Between school variance and VPC, gender

		Between School Variance	Variance Partition Coefficient (VPC)
Standard definition	**Girls**	0.246	6.96%
	Boys	0.233	6.63%
Alternate definition	**Girls**	0.261	7.35%
	Boys	0.237	6.72%

Figure 5.2 plots the random slope values for each school. in ascending order, highlighting those that are significantly different from the global effect. At the 95% significance level, 59 schools have a significantly different slope parameter, 26 smaller and 33 larger. No schools are significantly worse for FSM pupils than and very few are significantly better.

Figure 2.4 School level random slopes, gender



Note: Using our standard definition of level 3 STEM (left) and the alternate definition (right).

Table 2.9 Schools with statistically significant random slopes, gender

	Number of schools				**Percentage of schools**			
Sig. level	*99%*	*95%*	*90%*	*80%*	*99%*	*95%*	*90%*	*80%*
$\varepsilon_j^\beta < 0$	3	26	49	112	0.1%	0.7%	1.4%	3.2%
$\varepsilon_j^\beta > 0$	9	33	64	143	0.3%	0.9%	1.8%	4.1%

Ethnicity

We repeat the same analysis by ethnicity. The estimation of a varying-slope model for minor ethnicity categories though fails to converge due to the large number of parameters this requires the model to estimate. We therefore estimate two different varying-slope models, one where the slopes vary by major ethnicity categories and another that places the minor ethnicities into 3 groups based on the likelihood of progression to level 3 STEM qualifications in the populations. The groups are White British (70% of the pupil population); ethnicities that on average have similar or lower rates of progression (Black Caribbean, White and Black Caribbean, Gypsy/Roma, and Traveller of Irish heritage); and ethnicities that on average have higher rates of progression (all other minor ethnicity groups).

We again calculate likelihood ratio statistics to determine if the ethnicity effect varies by school, concluding that it does (likelihood ratio statistics 1,736 and 1,181 respectively). Table 2.10 then illustrates that between school variation is smallest for White/White British pupils, and greatest for those typically under-represented. Although as shown by the major grouping breakdowns, which school a pupil attends appears to matter most in terms of their likelihood of progressing to level 3 STEM, to those who are ethnically Chinese. This is true despite Chinese pupils have some of the highest odds of progressing on average.

Table 2.11 shows the number of schools that are identified as having significantly different slope parameters in the two models. We identify relatively more schools that have systematic differences in the relative rate of progression for Black and Asian pupils compared to the other major ethnicity groups.

Table 2.10 Between school variance and VPC, ethnicity

	Between School Variance	Variance Partition Coefficient (VPC)
Any other ethnic group	0.300	8.35%
Asian	0.364	9.96%
Black	0.287	8.03%
Chinese	0.432	11.60%
Mixed	0.279	7.81%
Unclassified	0.451	12.05%
White	0.254	7.16%
Over-represented	0.290	8.11%
Under-represented	0.318	8.82%
White British	0.260	7.32%

Table 2.11 Number of schools with statistically significant random slopes, ethnicity

		Significance level			
		99%	*95%*	*90%*	*80%*
Any other ethnic group	$\varepsilon_j^{\beta} < 0$	6	15	27	85
	$\varepsilon_j^{\beta} > 0$	0	11	22	64
Asian	$\varepsilon_j^{\beta} < 0$	26	83	137	216
	$\varepsilon_j^{\beta} > 0$	21	65	104	181
Black	$\varepsilon_j^{\beta} < 0$	20	63	114	196
	$\varepsilon_j^{\beta} > 0$	11	37	75	143
Chinese	$\varepsilon_j^{\beta} < 0$	0	0	4	17
	$\varepsilon_j^{\beta} > 0$	0	< 3	3	6
Mixed	$\varepsilon_j^{\beta} < 0$	3	8	23	90
	$\varepsilon_j^{\beta} > 0$	< 3	16	33	97
Under-represented	$\varepsilon_j^{\beta} < 0$	0	< 3	8	26
	$\varepsilon_j^{\beta} > 0$	0	6	11	40

Combined

The final model we estimate is a joint model where we allow the slope parameters to vary by all three of the pupil characteristics we have explored. The first column of Table 2.12 shows the number of schools with slope parameters that are significantly different from zero at the 95% level. These schools, as we have discussed above, therefore have differences in the rates of progression to level 3 STEM amongst these pupil groups than would be expected. The second column then combines these slope parameters with the random intercepts to estimate the number of schools where pupils in that group are more likely to complete level 3 STEM compared to pupil with same characteristic at an average school.

This total in the second column is often an order of magnitude bigger suggests that in the majority of these schools higher or lower observed rates, even after accounting for intake, are driven by the effect the school has on all pupils rather than any specific pupil demographic. For example, there are 744 schools where attending the school increases the odds of an FSM pupil progressing to level 3 STEM compared to attending the 'average' school. However, in all but 28 cases this is driven primarily by the fact all pupils at the school are more likely, so the relative rates of disadvantaged pupils progressing compared to their peers is the same as is typically seen throughout the country.

Table 2.12 Schools with statistically significant random slopes and overall group differences (95% significance level)

		Random Slope	*Total*
FSM6	**< 0**	0	598
	> 0	28	744
Girls	**< 0**	26	546
	> 0	32	734
Asian	**< 0**	87	591
	> 0	63	721
Black	**< 0**	64	373
	> 0	39	549
Chinese	**< 0**	0	441
	> 0	< 3	634
Mixed	**< 0**	10	516
	> 0	16	693

Conclusion

In this strand we have attempted to better understand the relative impact pupil and school characteristics have on the likelihood of pupils progressing to level 3 STEM. We have also attempted to identify the effects individual schools have on pupils from underrepresented groups in terms of their likelihood of progressing to study post-16 STEM courses. We have achieved this through the estimation of a series of single- and multi-level statistical models.

We find that some pupil groups are much less likely to progress to level 3 STEM. We estimate the odds of progressing to level 3 STEM are 42% lower for girls, compared to boys, and 44% lower for disadvantaged pupils compared to their more well-off peers. Black Caribbean pupils (same odds), White and Black Caribbean (25% lower odds), Gypsy/Roma and Traveller of Irish heritage (75% lower odds) have the same or lower odds of progressing to level 3 STEM than White British pupils. We highlight that KS4 attainment is a key driver of these differences. Whilst we also identify preferences as another key factor in our three P's model, we are unable to observe these in the data and so cannot comment on their relative importance. We do however further explore the role of preference in the qualitative work undertaken in Strand 3.

We also find systematic differences regardless of pupil characteristics, in schools' effects on progression rates. For instance, attending a selective school systematically increases the odds of progressing to level 3 STEM. However, after adjusting for observable pupil characteristics, we estimate that a modest 6.6% of the remaining variance in the likelihood of progressing to STEM level 3 is due to differences in the individual school attended.

We uncover that the school a pupil attends has a differential effect on the likelihood of them progressing to level 3 STEM given their pupil characteristics. The school attended has more influence on the likelihood of progressing to level 3 STEM for girls than it does for boys, for disadvantaged compared to non-disadvantaged pupils, and for all major ethnicity groups compared to White pupils.

In most cases though the differential effect of schools on different pupil groups is relatively small, when compared to the overall effect schools have on all their pupils. So, the marginal effect of, for instance, being eligible for free school meals on the likelihood of progression, is broadly similar regardless of the school attended.

Strand 3: views from inside schools

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Introduction

In Strand 3 we use qualitative interviews and focus groups to explore further how schools encourage and support post-16 STEM participation, progression and attainment, particularly for students from underrepresented backgrounds. We visited four schools, held focus groups involving a total of 45 students (31 in year 10 and 14 in year 12), and interviewed 15 school leaders with responsibility for overseeing either STEM subjects or careers.

The data collected provided insight into the strategies school leaders were using to widen STEM participation by students from groups of students identified in Strand 1 of this report as underrepresented in STEM careers, and key enablers and barriers they face in doing so. In this section we set out our methodology for collecting and analysing this qualitative data before setting out key themes in our findings, concluding with recommendations drawn from those findings to suggest ways to improve participation, progression and attainment in STEM for underrepresented pupils.

Key takeaways

- **The schools we studied tended to have broadly the same approach to interventions, although the specific barriers to, and enablers of, post-16 STEM participation varied.**
- **Socio-economic background appears to be an especially significant factor in post-16 choices.** It influences the availability of local opportunities, as well as the capacity of staff to deliver the full range of guidance and support they and students desired.
- **School-based STEM routes are generally quite limited to traditional A level academic routes with prior attainment entry barriers.** There seems to be a lack of clear pathways to post-16 STEM qualifications for middle attainers at key stage 4 (KS4) (achieving grades 4 or 5 in particular).
- **Prior attainment is a key driver of pathways, determining what options were available to students at both KS4 and key stage 5 (KS5).** Prior attainment was also linked to perceptions of subject interest, as students were more likely to express a preference for subjects that they saw themselves as being successful in.
- **STEM careers are viewed as high status and financially rewarding, but pupils are also motivated by subject interest.** However, the students we spoke to in our research also mostly had a quite restricted understanding of STEM careers, focusing primarily on traditional careers such as medicine or engineering.

Methodology

Based on the quantitative research in Strand 2, we adopted a structured approach to sampling and recruitment, aiming to interview schools and school leaders from settings that performed both above and below national averages for STEM participation, progression and attainment. Participating schools were offered an incentive of £250 for their time, along with a summary of findings from the research with examples of practice that they could explore for their schools as appropriate.

We used the same working definition of STEM as Strand 2 but also maintained some openness to which subjects research participants, especially school leaders, understood STEM to include. This generally meant Science, Maths, Engineering, Technology and Computing, but some leaders also included more vocational or technical subjects such as Health and Social Care, or Construction and the Built Environment.

From this approach we were able to visit three schools located in London and one in Essex on the border of Greater London, holding focus groups with students and interviews with two school leaders within each school. These school leaders were selected by the school and were generally STEM subject leaders or held responsibility for careers. Structured interviews were carried out with school leaders to explore barriers and enablers around STEM participation, with particular reference to underrepresented groups and the specific context of their school. The interviews also explored qualifications and pathways available for students, careers advice and guidance where relevant, and what interventions were in place at a school-, or potentially trust-level.

In all four schools we held a focus group with around 5-7 year 10 participating students, and in two of the schools we held an additional focus group with around 5-7 year 12 participating students. Each of the focus groups began with a general discussion around their proposed career choices and what they understood by the idea of ‘a STEM career’, as well as what made STEM more or less attractive to them. We also held discussions around the careers guidance and support that they had experienced and explored what experiences they had around studying STEM subjects at different points in their education, with a specific focus on interventions intended to support attainment or progression.

After the initial recruitment, several schools experienced constraints on their capacity to participate in this research (such as Ofsted inspections) that led to them dropping out of the research. As a consequence, we recruited an additional eight school or trust leaders of STEM subjects, or careers, from outside our sampling frame. These leaders were recruited via open invitations to participate via social media and bulletins from a variety of organisations working across education. They represented a diverse sample of mainstream secondary schools in different regions of the country, both urban and rural. The interviews were structured in a similar manner to those carried out in the schools, exploring barriers and enablers around STEM participation, pathways and careers guidance, and interventions in place to promote attainment, progression and participation.

Interviews and focus groups were recorded and transcribed before being thematically analysed to form the findings in this report. All participants gave informed consent to participate in this research with names and schools remaining anonymous to preserve confidentiality.

Limitations of this research

We recognise that this research draws on a relatively small sample and therefore we do not generalise from our findings to all secondary schools, or students from underrepresented backgrounds. However, some consistent themes emerged from the evidence gathered which we believe can inform better planning, practice and policymaking to support STEM participation, progression and attainment for young people, especially those from historically underrepresented backgrounds. Further research that particularly engages with young people more widely across the country would be recommended in order to test our recommendations further.

Findings

We have organised our findings using the three Ps model we used to structure the literature review in Strand 1:

- **Pathways**
  This refers to the routes that young people take through education and training towards employment, and the qualifications they study at level 2 or 3.
- **Prior Qualifications**
  Access to many STEM qualifications may be governed by criteria related to prior attainment, for example requiring a certain grade at GCSE to gain a place to study A Level. Attainment may also affect option choices when progressing from Key Stage 3 (KS3) to Key Stage 4 (KS4), either formally or informally through guidance offered.
- **Preferences**
  Students make choices from the range of subjects and qualifications available to them which may not reflect their prior qualifications. Instead, subject preferences are influenced by a wide range of individual and wider societal factors.

Pathway

Students had quite narrow views of STEM pathways

In our initial activity with the student focus groups, we shared photo stimuli of a wide variety of STEM jobs, such as agricultural engineering and music technology. Very few of these were initially recognised by students as STEM jobs, particularly those in year 10. Instead, both year 10 and 12 students typically thought of careers in medicine, engineering or computing when discussing STEM. However, they were curious to find out more about pathways to pursue these careers.

The year 10 students we spoke to talked predominantly about traditional pathways and perceived A Levels as the only or main STEM qualifications available post-16. There was some awareness of possible apprenticeships post A Level, often characterised as more 'practical' and hands on, but nevertheless seen as an inferior choice to university. There was little talk of BTEC options, and no students mentioned T Levels.

Year 12 students in our sample were predominantly studying A Levels and intending to pursue university qualifications in STEM, with only a few mentioning considering apprenticeships.

"further maths, I picked it because I have to do it to get into a good uni"

- *Year 12 student, Essex*

Most school leaders reported that parental support when students were choosing options at GCSE and post-16 was positive overall, however they often confirmed the perception that any pathway other than A levels followed by university was seen as a 'lower status' route. A few students and leaders mentioned that some families from particular ethnic backgrounds were more likely to put pressure on their children to enter traditional fields such as engineering or medicine, but most students felt that their families were supportive of whatever choices they made. In some areas, leaders reported that pathways were narrowed by a strong preference among students and families to remain in the home area rather than leave to attend university or seek opportunities elsewhere.

Leaders were aware of pathways but faced limitations in terms of offering alternative options

Leaders, in contrast to students, had greater awareness of alternative qualifications and most worked in schools that offered some STEM related qualifications outside of A levels, including BTECs such as a Health and Social Care or Construction and The Built Environment. However, most also stated that they were unable to offer a wide range of STEM BTECs in their setting and saw other sixth forms or Further Education (FE) colleges as more likely to offer a wide range of technical qualifications. Teacher availability was a clear constraint, with some schools struggling to recruit and retain staff across STEM subjects for their existing offer. As a result, they were unable to consider offering additional qualifications, such as BTECs, in related subjects where they already offered A levels.

Leaders working outside of London particularly highlighted a lack of available alternative pathways in STEM, either via FE or other sixth form providers. As a result, students may have lacked access to wider options to consider. Careers support at KS4 helped students to consider the pathways available to them, but there was little scope to offer any preparation for alternative courses with other providers if they didn't reach the attainment standard set for access to A levels.

There is a 'gap' in the STEM offer for middle attaining students

Many leaders had a keen awareness of a lack of STEM options for 'middle attaining' students (generally those achieving grades 4-6) in STEM subjects at GCSE and unable to access A Level courses in STEM. Leaders reported a lack of alternative options for these pupils to study that would keep them on the pathway to further STEM study or work. One school we studied was able to provide a foundation year studying Level 3 ICT, computing and business for about 10-20 students keen to continue studies in sixth form, but who hadn't quite met the threshold for A Levels. Only two leaders specifically mentioned T Levels as a viable local option. None thought it was feasible for their school to offer, due primarily to the challenge of arranging the industry placement element.

"I don't think we do enough. We don't really do a lot for people who are passionate about science, but aren't grade seven."

- *Head of Careers, Essex*

One additional theme that emerged from a few leaders was that a lot of trips and activities catered more for the higher achievers, or triple science students. They called for a broader range of clubs and activities more accessible for middle attainers to generate enthusiasm.

"I've got to look at both sides of the equation. If I'm an employer, do I want [a school] sending the worst children? No. But as a teacher, some of the "worst" children, actually they might be bad because they don't engage with what we offer here in school, but actually those opportunities in STEM might be fantastic for them."

- *Careers lead, London*

Careers advice is often extensive but not always meeting the needs of students

Careers leaders we spoke to were working hard to deliver careers advice and support. In some trusts this was centrally supported and efficient, in others it remained primarily the responsibility of an individual holding other leadership roles that put constraints on their capacity. Careers and subject leaders spoke of working to incorporate careers related information into the curriculum as well as carefully curating speaker visits. They were aware of inequalities and made efforts to ensure diverse and representative speakers, particularly women in STEM careers. Many spoke of the challenges, but immense benefit, of finding engaging and inspiring speakers and providing real-world engagement. Careers leaders located outside of major cities often expressed that it was difficult to engage with local employers.

Students reported fairly similar experiences of careers advice, with specific focus on guidance in year 9 when choosing GCSE options, and again in year 11 for deciding on post-16 choices. Often this was in the form of interviews held by careers or senior leaders. Whilst a few school leaders had secured outside independent specialist guidance, in most cases it remained the responsibility of tutors or senior leaders. Students spoke positively of having teachers that they trusted to go to for advice around options choices, usually relating this to subjects they had a specific interest. They also mentioned taster sessions, particularly in subjects that weren't available at a previous key stage, e.g. Business or Economics.

"it's pretty much down to us, but I think if you go to a careers advisor, he might point you down some websites."

- *Year 12 student, Essex*

Students value work experience but schools struggle to access quality experiences

The majority of schools sought to enable work experience in both year 10 and sixth form, but some found it extremely difficult to overcome barriers caused by lack of local opportunities and logistical challenges. In most cases students were expected to secure opportunities themselves. School leaders in schools outside London frequently suggested that they faced greater barriers to providing meaningful workplace encounters and experiences; one school was providing minibus transport to enable students to take up work experience where public transport was a barrier.

Students we spoke to were vocal in their call for the ability to have 'real life' experiences of jobs, to understand what it would actually be like to perform a job on a day-to-day basis. They saw this an essential element of helping to decide their pathway for the future. In the majority of cases students were expected to source work experience opportunities themselves and they reported finding it challenging to find interesting opportunities when they lacked family contacts and networks in the sectors in which they were interested.

"when we do theory lessons with year tens, I do talk a lot about real world examples and I think they can really relate to that because the theory can be possibly boring, but relating it to real world examples does seem to give them a bit of an, oh yeah, that I can possibly do that or I can see that."

- *Design and Technology teacher, London*

Prior Qualifications

Primary experiences shape interest but remain very variable

Several students mentioned a lack of "proper science" in primary school, one going so far as to say, "I don't think we had science in primary". Some students expressed excitement about the opportunity to do more science practical experiments when they moved to secondary school, only to be disappointed by their experience of education during COVID lockdowns. A Head of KS3 described seeing real passion and hard work in science lessons when visiting primary schools, only to find a significant decline in interest once students started year 7. Several leaders mentioned the huge variation in starting points for pupils in year 7, owing to the variation of science teaching quality and curriculum focus at primary. As such, leaders felt that transition from primary to secondary was a particularly important time to capitalise on and maintain enthusiasm around science learning. Several leaders had attempted to engage with feeder primary schools to support this transition but found it very hard to maintain relationships. One leader that had seen success in inviting primary children into their secondary school to carry out science experiences had been forced to stop due to closures of their school site due to building damage.

Access to triple or combined GCSE science varies and is strongly linked to future A Level choices

Most leaders we spoke to said their school offered both triple and combined science GCSE options, although some offered only one pathway. Typically, access to triple science (where Physics, Chemistry and Biology are studied as three separate GCSEs) was based upon progress made in KS3 and students were either allocated or encouraged to take triple science only if they were performing well in science at KS3. It was more common for high achievers to be allowed by their school to opt for combined science (where Physics, Chemistry and Biology are combined into a course that leads to two science GCSEs) as a preference than it was for lower or middle attainers to be allowed to take the triple science pathway. In one school students reported having to pass a test to be allowed to take triple science. Students were typically unaware of the role that prior attainment played in their steering towards triple or combined GCSE Science, mostly believing that it was their choice. Teachers and leaders, though, spoke of careful consideration of students' aspirations and hopes, but also the importance of realistic expectations. They were keen to ensure that students achieved qualifications that gave them as many options for the future as possible, within the context of the limitations of school provision. Most students taking A level science subjects had studied triple science at GCSEs.

Outside the core offer of maths and science, access to a broader range of STEM subjects at GCSE was variable and a source of contention with a number of students. Several complained about the inability to study particular subjects at GCSE, or about receiving a narrow range of topics within a subject, such as Design and Technology. In some groups they made a clear link between their option choices and perceived teacher quality, or in some cases simply the availability of specialist teachers.

Interventions are primarily based on academic performance

Whilst quantitative analysis has shown differences in performance at GCSE across different demographic groups, and across schools, there is little evidence from the qualitative research we carried out to suggest that schools tackled interventions in ways that reflected this demographic inequality. Whilst leaders were aware of potential disparities in outcomes for different groups of students, with a particular focus on gender, all spoke of interventions being directed at those needing additional academic support, or at higher achievers considered most likely to progress to A Level, regardless of demographic characteristics. In a few cases leaders mentioned specific attention being given to students eligible for the pupil premium. In one school this included a pastoral team that identified "borderline" students for mentoring on a regular basis by members of the senior leadership.

Interventions were primarily reported as taking place in year 11, with only a few suggesting some students being targeted in year 10 with staffing and timetabling most frequently being reported as the main barriers. One trust leader, and students from a school in the trust, spoke of a high achievers' programme that targeted students in KS3 identified as having specific potential in STEM, though the students we spoke with did not view this programme very positively. Some leaders reported good attendance at interventions, but others highlighted barriers facing many students, such as transport reliability or caring responsibilities.

Many leaders perceived that interventions and activities were having a positive impact, but none said that they carried out any effective evaluation in terms of long-term outcomes. One school leader, referencing a 'push' for STEM over 12 months, had seen the numbers of pupils choosing triple science for GCSE increase nearly threefold. Students on the whole seemed relatively ambivalent about the value of interventions, tending to focus more on the inconvenience of having to attend outside of lesson time, or even at the weekend or in school holidays. None of the year 12s we spoke to discussed GCSE intervention sessions in a positive way, and often perceived these as mandatory even if they were officially optional.

Preferences

Leaders believed that students had clear preferences around subject choice from an early stage, but this was not always clear from students themselves.

In general, the year 12 students who participated in our focus groups had a clearer sense of motivation in their specific choices of subject and future career intentions, than those in year 10. They spoke of choosing subjects they enjoyed and were good at, as well as offering them routes into specific careers of interest. STEM subject and careers leads told us that students who did not achieve the grade criteria for A Level were more likely to have moved to FE or a sixth form college to access alternative qualifications. Equally, some students opted for alternative subjects in order to remain at their school sixth form.

A small number of students referenced challenges with staff as motivating their choices, usually related to teachers of particular subjects leaving, or being perceived as ineffective. One specifically mentioned dropping Maths due to a lack of understanding they blamed on the teacher.

Students in year 10 were often less determined in their preferences, and intended career paths. Only a small number indicated a chosen profession for the future, with many others having only vague awareness of how interest in certain subjects might translate to career opportunities in the future. Choices at KS4 in many schools seemed to be fairly limited and quite directed by teachers and prior attainment.

"And it's not even your fault. It depends on how they teach it. If they speak some kind of gibberish to you and you can't understand them, unless you had that for maths. I did drop maths because I did not want to have to listen to a teacher that I couldn't understand or communicate well with me, so that's why I dropped maths and took computer science instead."

- *Year 12 student, London*

Students choosing STEM are motivated by subject interest and future opportunities

In all the focus groups overall, status and monetary reward were high motivators for career aspirations, and STEM jobs were perceived as offering these.

"Like engineering is quite high status, I'd say. A lot of money in that as well."

- *Year 12 student, Essex*

Year 12 students studying A levels in STEM subjects were perhaps unsurprisingly keen on attending university, although a few talked about the possibility of apprenticeships in areas such as finance or computing. Many spoke of being potentially the first in their family to attend university, or had only one parent or a relative who had attended. Those in year 10 were more mixed in their view of university or higher education, often expressing concern over the potential financial costs, or the prospect of hard work that they felt might not be "worth it". A few students spoke directly about the importance of having a good work/life balance and flexibility in their future careers, feeling they might not get this from a STEM career.

"I feel STEM jobs are really impressive. […] They take long time and require master's and degrees and the pay's good and also, it takes a lot of dedication to get into"

- *Year 10 student, London*

Several leaders stated that they were specifically seeking to improve representation of women in STEM through the science curriculum and their approach to careers guidance and support. Sixth form subject leaders all highlighted gender imbalances that reflected national patterns, though students felt that choice of subjects was about personal motivation. Whilst they acknowledged a wider picture of underrepresentation, they rarely identified this as applying directly to them.

"I feel like it's a different path for women, because for men, because of the pay wise and the pay gap, the gender pay gap is easier for men to go do those types of jobs. But for women, you don't see many of them into STEM jobs and stuff. But for me, it feels like that motivates me into choosing STEM as one of my career paths because there's not many women."

- *Year 10 student, London*

Several leaders in schools which had female teachers in specific subjects, particularly Design and Technology or Computing, believed that this had a direct impact on uptake of subjects among girls.

Leaders were clear that families had a major influence in student choice; students mostly felt that families supported their choices.

Most students denied that parents or families were influential in their choices when asked, however several had referenced relatives as role models earlier in the discussion. Leaders were clear that they believed parental support, or lack of support for learning more generally, were significant influencers. This is something that seemed particularly significant outside of urban areas like London.

"Because my baba. He wanted to become a radiographer. He told me about it. I was like, I might as well do it."

- *Year 12 student, London*

Ethnicity was not explicitly referenced in relation to subject choices, or potential future experiences at university or in careers. In two groups of year 10s concerns were raised that it might be harder for members of some ethnic groups to attend university or achieve success in STEM careers, but argued that actually this might make them want to do it more. They often dissociated themselves from comments, referring to "some people" or families of certain heritage or culture. They did, however, speak of the benefits of seeing other people in roles, giving them "courage to do it for yourself".

"I feel like some people, a lot of people, especially me personally, I feel like you have a bit of that expectation to make my parents proud and to be able to give back and provide for parents. Especially because some people that come from ethnic minorities need to... Their parents have made sacrifices for them to have a good education and good living condition."

- *Year 10 student, London*

There were a range of wider factors influencing student preferences for STEM subjects and careers, from extra-curricular activities to geographical location

Students enjoy extra-curricular activities but organising trips and experiences was challenging for many school leaders. Budgets were tight and finding opportunities that were relevant could be difficult in some areas, or schools were only able to take advantage of free activities where available. There was also the challenge of a packed curriculum making it difficult to make time for extra-curricular activities. Many stated that staff capacity was insufficient to run additional extra-curricular clubs, or that resourcing them was too time consuming.

"nothing really beats a hands-on experience… So the whole last week of school is just trips. And it's absolute carnage. It's fantastic the carnage, and it's all trips and kids having experiences."

- *Head of Careers, Essex*

The students we spoke to in focus groups were all at schools based in or on the border of Greater London. Some were acutely aware of the opportunities this afforded them, whilst also conscious of the privilege for others such as those in private schools, who they saw as having greater connections. For leaders working in other areas of the country, particularly those outside of the main urban conurbations, or in more remote rural or coastal areas, the lack of opportunities felt stark. A couple of careers leader spoke of the challenges of arranging work experience in areas with limited public transport. Another spoke not only of transport barriers, but also a lack of desire among students to access the opportunities that did exist, particularly when that required travelling outside of students' areas of familiarity.

Conclusions

Our third strand of research used interviews and focus groups to show that there are a complex range of barriers to young people's participation and progression in STEM. These include the accessibility of STEM work experience opportunities outside of major metropolitan areas and lack of qualifications and routes for middle attainers at KS4. Nevertheless, STEM careers are viewed as high status, financially rewarding and broadly desirable by the young people we spoke to. It is therefore vital that practitioners and policymakers take action to improve the accessibility of STEM pathways for underrepresented young people, following the recommendations that we set out.

Conclusions

Across three strands of work, we have built up a more complete picture of how pupils progress from secondary school into the post-16 study of STEM subjects. We have focused on pupil groups that are currently underrepresented, understanding the key drivers and unpacked the role secondary schools play using both quantitative and qualitative methods.

In our first strand we reviewed the existing literature on the evolution of STEM education in England and the likely drivers of STEM participation post-16. We identify three key drivers of participation – pathway, prior qualifications and preferences – constituting the 'three P's' model. These three drivers are found to produce differences in the progression rates by pupil characteristics such as gender, ethnicity and socioeconomic status. The independent effects of these three different factors are though not always easy to delineate. However, prior attainment is found to often being the largest driver, particularly for disadvantaged pupils. In fact, high-achieving disadvantaged students are found to be more likely to progress to post-16 STEM than other high-achieving students.

The differences in progression by gender are perhaps best understood, and there are substantial differences in patterns of uptake between life and 'hard' sciences. For instance, girls are more likely to study A level Biology, equally likely to study Chemistry, and less likely to study other STEM subjects. White British pupils are among the least likely to study science A levels, alongside some Black pupils. Pupils from Black Caribbean backgrounds are particularly unlikely to choose STEM. This pattern seems to repeat across some vocational qualifications. The new T level qualifications are the exception to this rule, being disproportionately studied by White British pupils in their first year.

In our second strand, we used administrative data to establish patterns of progression by pupil and school characteristics, as well as identifying schools level effects on pupils' likelihood of progressing to STEM related courses post-16. We estimated a series of statistical models to identify both patterns of progression to post-16 STEM qualifications and further identify schools that for unobservable reasons are found to increase or decrease the likelihood of pupils progressing.

We estimate the odds of progressing to level 3 STEM are 42% lower for girls, compared to boys, and 44% lower for disadvantaged pupils compared to their more well-off peers. Black Caribbean pupils (same odds), White and Black Caribbean (25% lower odds), Gypsy/Roma and Traveller of Irish heritage (75% lower odds) have the same or lower odds of progressing to level 3 STEM than White British pupils.

We find that in aggregate secondary schools have a role to play in pupils' likelihood of progressing to post-16 STEM. After adjusting for observable pupil characteristics, around 6.6% of the remaining variance in the likelihood of progressing to STEM level 3 is due to differences in the school attended. In most cases though the differential effect of schools on different pupil groups is relatively small, when compared to the overall effect schools have on all their pupils.

The school a pupil attends is found to have more bearing on their likelihood of progressing to level 3 STEM for girls than it does for boys, for disadvantaged compared to non-disadvantaged pupils, and for all major ethnicity groups compared to White pupils. Which school a pupil attends appears to matter most for those who are ethnically Chinese, so whilst for gender and disadvantage schools appear to have a larger effect for underrepresented groups, the same does not hold true for ethnicity.

Higher KS4 attainment is one driver of these differences. The higher attainment of girls compared to boys reduces the observed differences in the likelihood of progressing to level 3 STEM. Conversely the lower attainment of disadvantaged pupils accounts for most of the reason disadvantaged pupils progress to level 3 STEM at a lower rate than their peers. In general, the difference between the likelihood of pupils from different ethnic backgrounds of progressing to level 3 STEM is narrower if they have similar levels of GCSE attainment. However, Black Caribbean pupils are identified as particularly hindered by low GCSE attainment, whilst White Irish pupils the opposite is true - GCSE attainment appears to hide other unobserved factors that lead to lower rates of progression to level 3 STEM qualifications.

In our final strand, we took a closer look at the activities within schools, through interviews with school leaders and pupils. We gained further insight into why certain pupils are underrepresented and what actions schools are taking to try and mitigate these differences in uptake. The schools we studied tended to have broadly the same approach to interventions, although the specific barriers to, and enablers of, post-16 STEM participation varied. In particular we observed that schools often have whole school interventions but do not often specifically target underrepresented groups.

Again, prior attainment was identified as a key driver of pathways. Both in determining the options available to students due to a lack of clear pathways to post-16 STEM qualifications for middle attainers at key stage 4 and also linked to perceptions of subject interest, as students were more likely to express a preference for subjects that they saw themselves as being successful in. Disadvantage was found to extend beyond the classroom, influencing the availability of local opportunities, as well as the capacity of staff to deliver the full range of guidance and support they and students desired. This is particularly important as students we spoke to in our research had quite a restricted understanding of STEM careers, focusing primarily on traditional careers such as medicine or engineering.

Appendices

Appendix 1: Policy timeline and environment

In this appendix we review a range of changes to education policy in England that might affect progression to post-16 STEM. We start with changes to the school system in the last 20 years and then review more specifically changes to the science curriculum, followed by a similar review for post-16 provision. We aim to summarise changes to how science is taught and assessed in schools and post-compulsory education and how this might affect student progression to post-16 STEM courses.

Changes to the school system

The English school system has undergone substantial structural change in the last 20 years, notably the proliferation of academies and free schools (henceforth referred to simply as academies). Rather than being the responsibility of local government, academies are funded directly by central government. Launched in 2000, the academies programme initially focussed on a small number of under-performing city schools. However, academisation expanded substantially under the Coalition government when eligibility to convert to an academy was expanded. In May 2010 there were 203 academies (all secondaries) but by May 2023 41 per cent of state-funded primary schools, 81 per cent of state-funded secondary schools, and 45 per cent of state-funded special schools, were academies.[75] In March 2022 the government signalled its intention for all schools to become academies in "strong" multi-academy trusts, although the target of achieving this by 2030 has been dropped.[76]

A key freedom of academies is that they are not required to follow the national curriculum, although must offer a broad and balanced curriculum which includes science. When reading the following section it is therefore important to remember that changes to the national curriculum no longer necessarily affect the majority of schools, although in practice many academies do broadly follow it.[77] Academies are also subject to the same accountability measures as maintained schools (for example national curriculum assessments for primary schools and metrics such as Progress 8[78] for secondary schools) so while they can be understood to have greater freedoms in education delivery, they are relatively constrained in terms of the overall objectives of their provision.

University Technical Colleges (UTCs) are a type of academy school that combine technical, practical, and academic learning. The curriculum is intended to reflect regional skills needs in areas such as engineering, manufacturing or digital technology. Local universities and employers contribute to curriculum development and to teaching. The first UTC opened in 2010, numbers peaked at 49 in 2017/18 and 47 are in operation today. UTCs were originally intended to teach students aged 14-19 but may now recruit from age 11. UTCs have attracted some controversy as they have received substantial public funding but typically not met recruitment targets and

[75] Department for Education (nd) 'Open Academies, Free Schools, Studio Schools and UTCs'.
[76] Dickens (2023) 'Academy Policies from Schools White Paper Ditched by DfE'.
[77] Roberts (2016) 'The school curriculum and SATs in England: Reforms since 2010'.
[78] Progress 8 is a type of value-added measure. It aims to capture the progress that pupils in a school make from the end of KS2 to the end of KS4.

several closed shortly after opening.[79] UTCs currently educate around 19,000 pupils in total and in 2022 pupils at UTCs made up 0.6% of GCSE entries, indicating a limited impact on the overall education system.[80]

Changes to the school curriculum

The pupils we follow in our quantitative analysis (see strand 2) started their primary education between 2006 and 2008, coinciding with a relative de-prioritisation of science in primary schools. Science has formed one of three 'core' subjects in the national curriculum since its 1989 introduction. Curriculum reforms at the turn of the millennium increased time available for English, Maths and Science at the expense of other subjects.[81] However, in 2009 key stage 2 exams were scrapped in science (to be replaced by teacher assessment) but retained for English and maths. This meant science results were no longer included in headline accountability measures and resulted in less time being spent on science and less importance being placed on complete curriculum coverage.[82] Removing national tests coincided with a relative decline in the performance of 10-year-olds in science component of the 'Trends in international mathematics and science study' (TIMSS) international benchmarking test and this seems to have fed through into secondary attainment: In 2019, England recorded its lowest Year 9 science score in TIMSS and the proportion of Year 9 pupils performing below the lowest TIMSS science measure has doubled since 2015.[83]

A new primary curriculum was introduced in September 2014, with science retained as a core subject. Renewed emphasis was placed on learning concrete scientific knowledge over developing general scientific understanding and computing became a compulsory subject. However, national tests in science were not reinstated. Few primary schools now meet the benchmark of providing two hours of science education per week, particularly for younger pupils. In 2018, 83 per cent of pupils were reported as meeting the expected standard in science through teacher assessment but only 21 per cent of around 8,000 pupils who took part in a sample assessment reached this benchmark.[84] Only 5 per cent of primary science teachers hold a science degree and teaching qualification.[85]

Pupils in our quantitative work started their secondary education between 2012 and 2014 and finished between 2017 and 2019. During this time curriculum and qualification reforms meant a greater focus was placed on scientific knowledge over understanding and changes to performance metrics encouraged schools to focus on the provision of academic, rather than vocational qualifications at key stage 4.

A new secondary national curriculum had been implemented in 2008 and gave schools significant freedom to design their own programme of study. The 1999 science curriculum contained 94

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[79] Long et al. (2020) 'University Technical Colleges'.
[80] Department for Education (nd) 'School Performance Tables'.
[81] James (2018) 'National curriculum in England: The first 30 years'.
[82] Wellcome Trust (2011) 'Primary Science Survey Report'.
[83] Ofsted (2023) 'Finding the optimum: the science subject report'.
[84] Ofsted (2021) 'Research review series: science'
[85] Ibid

bullet points setting out expected knowledge at key stage 3; this was reduced to 14 in the 2007 version.[86] At key stage 4 a new core science GCSE focussed on developing scientific literacy, for example the ability to *"read simple newspaper articles about science, and to follow TV programmes on new advances in science with interest, [to] enable them to express an opinion on important social and ethical issues"*.[87] Additional and triple science options remained for those intending to pursue higher scientific study whereas GCSE Additional Applied Science focused on applying science in work-related contexts.

The period between 2008 and 2013 also saw an increase in the number of students studying for vocational science qualifications, such as BTEC Level 2 Applied Sciences. The proportion of key stage 4 students entering these qualifications rose from less than 5 per cent in 2006 to nearly 20 per cent in 2012.[88] Fewer than 5 per cent of the candidates following an applied route progressed to study science at level 3, although it is not clear to what extent this is due to pupil choice compared to schools sorting pupils into STEM and non-STEM pathways at the start of key stage 4.[89] The number of students entered for vocational science qualifications at level 2 fell dramatically after 2014 when they were removed from performance tables following the Wolf review of vocational qualifications.[90]

Concerns around a move away from offering traditional academic subjects at key stage 4 also led to the introduction of the English Baccalaureate (EBacc) in 2011. The EBacc is a performance measure achieved by pupils who gain GCSE-level qualifications in English, mathematics, history or geography, the sciences (double science or three of biology, chemistry, physics, and computer science) and a language at grade 4/C or above. A target for 90 per cent of key stage 4 pupils to complete the EBacc by 2025 exists but looks unlikely to be met as the rate was only 39 per cent in 2021/22.[91] The introduction of the EBacc is associated with a reduction in the amount of time available for non-EBacc subjects. Entries to design and technology GCSE, for example, have fallen since the introduction of the EBacc, although this is a continuation of a longer-term trend.[92]

Significant changes to the secondary curriculum, assessment, and school performance tables were introduced between 2013 and 2015. New GCSE qualifications were expected to be more demanding and more focused towards preparation for further study. Terminal exams rather than modular assessment or coursework became the default assessment method. An increase in mandatory content saw schools reduce the amount of teaching time available for non-core subjects. The GCSE grading system was changed from letters (A*–G) to numbers (9–1).

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[86] Mansell (2009) 'Tories herald new curriculum wars'.
[87] Ryder, Banner, and Homer (2014) 'Teachers' experiences of science curriculum reform'.
[88] Plaister and Thomson (2023) 'The long-term outcomes associated with Key Stage 4 science options'.
[89] Vidal Rodeiro (2013) 'Comparing progression routes to post-16 Science qualifications'.
[90] Plaister and Thomson (2023) 'The long-term outcomes associated with Key Stage 4 science options'.
[91] Thomson (2019) 'If the EBacc were scrapped, would anything change?'; Department for Education (2022) 'GCSE and Key Stage 4 vocational qualifications data explained'.
[92] Thomson (2019) 'If the EBacc were scrapped, would anything change?'

GCSE maths was reformed, placing a greater emphasis on problem-solving. The reformed qualification included more content which teachers reported as requiring more time to teach but prepared students for A level "*at least as well, if not better*" than the old course.[93]

The science curriculum shifted in focus towards scientific knowledge over literacy and more mathematical content was included. The available science qualifications also changed: GCSE Core ('single') and Additional ('double') Science were replaced by a new double-sized qualification, GCSE Combined Science, with no 'single' science qualification. GCSE Applied Science was removed. ICT was replaced by a new GCSE in Computer Science.

Changes to headline performance metrics for secondary schools were also introduced. The previous measure had been the proportion of students achieving five A*-C GCSEs or equivalent, latterly requiring the inclusion of English and maths and with some adjustments to what was considered a GCSE equivalent. This measure was criticised for encouraging schools to focus on pupils near the threshold at the expense of others and for being open to 'gaming' when a wider range of qualifications were included. From 2015/16 the two headline measures became Attainment 8 and Progress 8.

Attainment 8 considers each pupil's attainment in their best 8 qualifications, made up of maths and English, three other EBacc subjects and three other qualifications (which can be EBacc subjects, non-EBacc GCSEs or approved vocational qualifications). English and maths are double weighted. Progress 8 is calculated by comparing a pupil's Attainment 8 score with the average Attainment 8 score for students with similar prior attainment at key stage 2.

Since the introduction of Attainment and Progress 8, pupils are entering slightly fewer GCSEs overall.[94] As five of eight slots are reserved for EBacc subjects it is not surprising entries to these subjects, as a proportion of GCSE entries, have increased. This includes computer science, which has seen entries grow from 62,500 in 2016 to 81,000 in 2022, and triple science which was taken by 27 per cent of pupils in 2019 compared to just 6 per cent in 2009.[95] Entries to design and technology subjects have suffered the worst decline, falling from 6.4 per cent of the total GCSE entries in 2009 to just 2.7 per cent in 2019.[96]

Entries to non-GCSE courses now make-up only a small part of qualifications offered to pupils aged 14-16. In 2022 there were around 65,000 entries to non-GCSE qualifications in computer appreciation/introduction, 25,000 entries to non-GCSE engineering qualifications and less than 10,000 entries to similar courses in construction or computer architecture and systems across around 625,000 pupils completing key stage 4.[97]

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[93] Howard and Khan (2019) 'GCSE reform in schools: The impact of GCSE reforms on students' preparedness for A level maths and English literature'.
[94] Hepworth (2019) 'GCSE Entries: How are non-EBacc subjects faring since the introduction of Progress 8?'.
[95] FFT Education Datalab (nd) 'GCSE and A-Level Results Analysis: Computing'; Plaister and Thomson (2023) 'The long-term outcomes associated with Key Stage 4 science options'.
[96] Hepworth (2019) 'GCSE Entries: How are non-EBacc subjects faring since the introduction of Progress 8?'.
[97] FFT Education Datalab (2022) 'Key Stage 4 2022; The national picture'.

In summary, over the last 20 years the school system has experienced significant re-organisation but the element most focussed on STEM provision (University Technical Colleges) has not scaled and represents only a very small part of the school system. The science and maths curriculum first became looser and more focussed on mathematical and scientific literacy and understanding but then reverted to a more centrally specified, knowledge-focussed curriculum. Maths has become more important in primary and secondary accountability measures. Science has become less important in primary accountability, but perhaps more so for secondary schools. A focus on academic qualification in key stage 4 means pupils now take a narrower range of courses. There has been an increase in entries to some STEM courses, such as triple science and computing, but a decrease in others such as D&T.

Changes to the post-16 landscape

Since pupils taking level 3 qualifications today started school, the leaving age has been raised twice (to 17 in 2013 and 18 in 2015), although young people can choose to spend their last two years either in full-time education, completing an apprenticeship or traineeship or working alongside part-time education or training.

Alongside changes to GCSEs between 2015 and 2017 there were significant changes to A levels. Reforms aimed to make the qualification more rigorous and better prepare students for higher education. Much like the changes to GCSEs this included the incorporation of more mathematical content into science subjects, a greater proportion of assessment by exam (including the removal of practical work from the overall science subject grade), and the replacement of modular assessment with terminal exams. This final change meant that A level and AS courses became 'decoupled': AS exams could no longer be used towards a larger A level qualification but were instead a standalone qualification.[98] Between 2016 and 2019 the average number of qualifications taken by students in 16-19 education fell from five to three. The proportion with qualifications from three or more subject groups has halved since 2010 and the proportion of students taking qualifications from only one or two subject groups has increased by 8 and 6 percentage points respectively.[99]

Post-16 vocational qualifications are also undergoing reform. Following the Wolf Review in 2011 and the Sainsbury Review in 2016 the government aimed to simplify the vocational qualification offer, ensuring qualifications were of high quality, easily understood and held in high regard. They proposed to introduce a new qualification, the T level, and defund many other post-16 vocational courses.[100] T levels are two-year technical courses equivalent in size to three A levels, which means they are normally the only qualification taken by learners on this pathway, rather than being one of several subjects studied. They include a 45-day industry placement alongside school-based learning. T levels in construction, digital, and education and childcare were launched in

[98] Sutch, Zanini, and Benton (2015) 'A Level Reform: Implications for Subject Uptake'.
[99] Robinson and Bunting (2021) 'A Narrowing Path to Success? 16-19 Curriculum Breadth and Employment Outcomes'.
[100] Lewis and Bolton (2023) 'Technical education in England: T Levels'.

September 2020 with 1,235 full-time students. Eventually over 20 courses will be available, covering 11 vocational areas including construction, digital, science, and engineering.

There has been early praise for T levels from students and providers, but concerns have also been raised.[101] In March 2023 the Department for Education announced the delivery of four T Levels would be deferred due to concerns about quality. It is also not clear whether the intended destination for those completing the qualification is skilled employment (graduates are unlikely to be able to access a level 4 apprenticeship directly after completion) or higher education (institutions increasingly accept T levels, but for a limited range of courses). Concerns have also been raised about the accessibility of T levels given they are large qualifications with no intermediate certification. Following a campaign by students, colleges and universities, plans to defund alternative level 3 vocational qualifications were delayed by a year.[102]

To summarise changes to the post-16 landscape, students now need to stay in education employment or training until 18. However, qualification consolidation means that programmes of study are narrower. Therefore, choices made at 16 may now be more important in determining future study and work options.

STEM teacher shortages

An ongoing concern across both pre- and post-16 STEM education is a shortage of STEM teachers. Under-recruitment and higher-than-average leaving rates for maths and science has occurred for many years, primarily due to STEM graduates having relatively attractive career options outside of teaching, compared to teachers of other subjects.[103] In schools, the biggest concerns are over the number of physics, computing, maths and chemistry teachers. Physics struggles most to recruit new teachers: admissions to physics teacher training were 79 per cent below target for 2021/22 and 83 per cent below in 2022/23.[104] In the vocational sector almost three quarters of FE college principals rank engineering as the most difficult subject in terms of recruitment.[105]

A particularly concerning aspect of STEM teacher shortages is that they are more acute in some regions of the country and in schools serving disadvantaged pupils. In London, 56 per cent of maths teaching hours are taught by a subject specialist in the least deprived schools, compared with 45 per cent for the most deprived set of schools. Outside of London, the gap in specialist maths teaching between more and less deprived schools is even larger, and this is true across STEM subjects. This disadvantage gap is largest for the provision of specialist physics teaching outside of London, in the most deprived schools only 17 per cent of teacher hours are taught by a specialist.[106]

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[101] House of Commons Education Committee (2023) 'The Future of Post-16 Qualifications'.
[102] Lewis and Bolton (2023) 'Technical education in England: T Levels'.
[103] Tang and Worth (2023) 'Policy Options for a Long-Term Teacher Pay and Financial Incentive Strategy: An Assessment of Options and Their Impacts and Costs'.
[104] STEM Learning (2023) 'Solving the Mystery of the Missing Physics Teachers'.
[105] Armitage et al. (2020) 'Engineering UK 2020: Engineering UK 2020: Educational pathways into engineering'.
[106] Sibieta (2018) 'The teacher labour market in England: Shortages, subject expertise and incentives'.

Concerns have been raised that non-specialist teachers may deliver a lower quality of education, reducing pupil enjoyment and attainment so that pupils are less likely to choose to study science later on.[107] There is some evidence that being taught by a subject specialist improves pupil attainment, but it is not always clear that this is more important than pedagogical skills.[108] Studies in the US have also shown that pupils taught by a teacher of the same ethnicity as them increases attainment and enrolment in college.[109] This highlights the additional importance of having diversity in the STEM workforce.

The next section shows that most schools are still able to offer STEM courses at level 3 (likely through prioritising specialist teaching resources for key stage 5 courses) the effect of being taught by a non-specialist on pupils' enjoyment of and engagement with STEM is not clear.

Uptake of post-16 STEM qualifications

STEM A levels are an increasingly popular choice for those staying in academic education post-16. Maths is the most popular of all A levels, with 88,000 entries in 2022. Four of the top five subjects, by entry numbers, sit under the broad banner of STEM (psychology, biology, chemistry and English complete the top 5).[110] Figure A1.1 shows STEM A levels as a proportion of A level entries in England. Consistently over the past five years, more than forty per cent of A levels entries are in STEM subjects. Since 2004 all of maths, physics, chemistry, biology and computing A levels have seen an increase in entry numbers, although computing has not yet returned to the particularly high entry numbers of its 2002 peak.[111]

Students can only choose subjects that are available to them. The availability of many maths and science courses have increased in recent years, but access is not universal. In 2004-05, less than 40% of the state-funded A level Mathematics providers in England had students taking A level Further Mathematics but this increased to 73% in 2021-22.[112] Of 2,591 English school sixth forms that entered at least one student for an AS- or A-level qualification in 2014 9.1 per cent had no entries for physics AS- or A-level but, as these were disproportionately small schools, only 1.9 per cent of the total A level student cohort studied in sixth forms that did not offer Physics.[113] In 2018/19 around 1,600 sixth forms or colleges offered A level Computer Science.[114]

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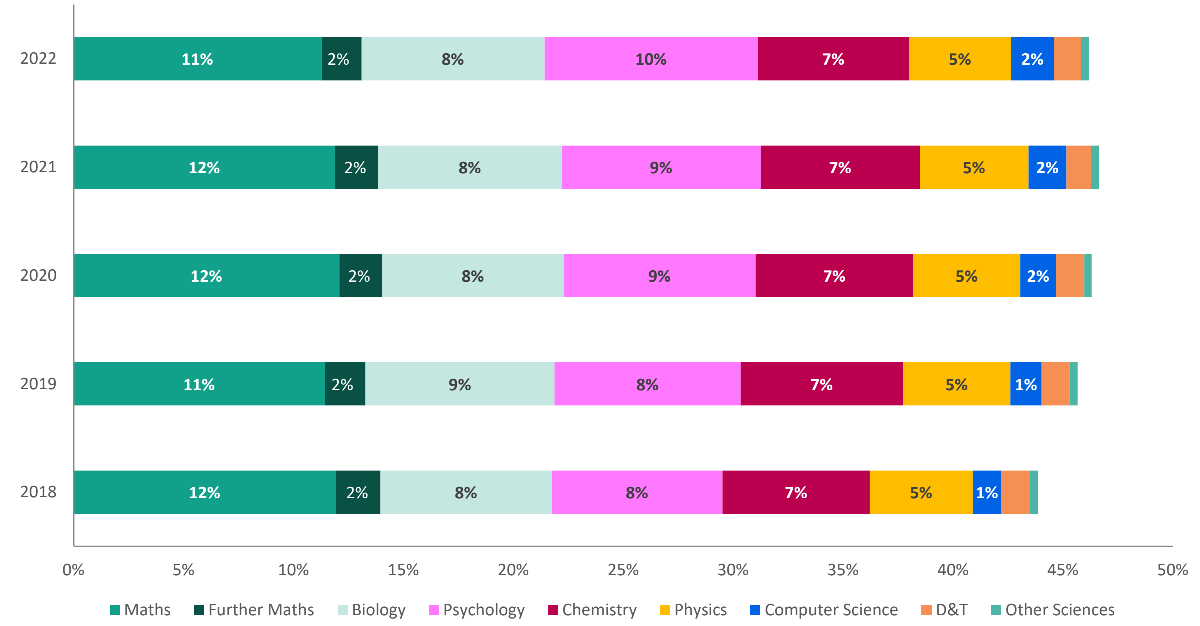
[107] Harland et al. (2022) 'TLIF Evaluation: The Institute of Physics Future Physics Leaders Project'.
[108] STEM Learning (2023) 'Solving the Mystery of the Missing Physics Teachers'; Allen (2015) 'Teachers with a Physics Degree May Improve Entry Rates to GCSE Physics, but Don't Appear to Affect Attainment'.
[109] Delhommer (2022) 'High school role models and minority college achievement'; Gershenson et al. (2022) 'The Long-Run Impacts of Same-Race Teachers'.
[110] Plaister (2022) 'Which A-Level Subjects Are the Most Popular?'.
[111] Ibid
[112] Advanced Mathematics Support Programme (2023) 'Level 3 Maths Update 2022-23'.
[113] Royal Academy of Engineering, Institute of Physics, and Gatsby Foundation (2015) 'School sixth forms with no entries for A-level physics: A data report'.
[114] British Computer Society (2022) 'England: Computer Science GCSE, AS, and A Levels'.

Figure A1.1: STEM A levels as a proportion of all A level entries in England, 2018 to 2022

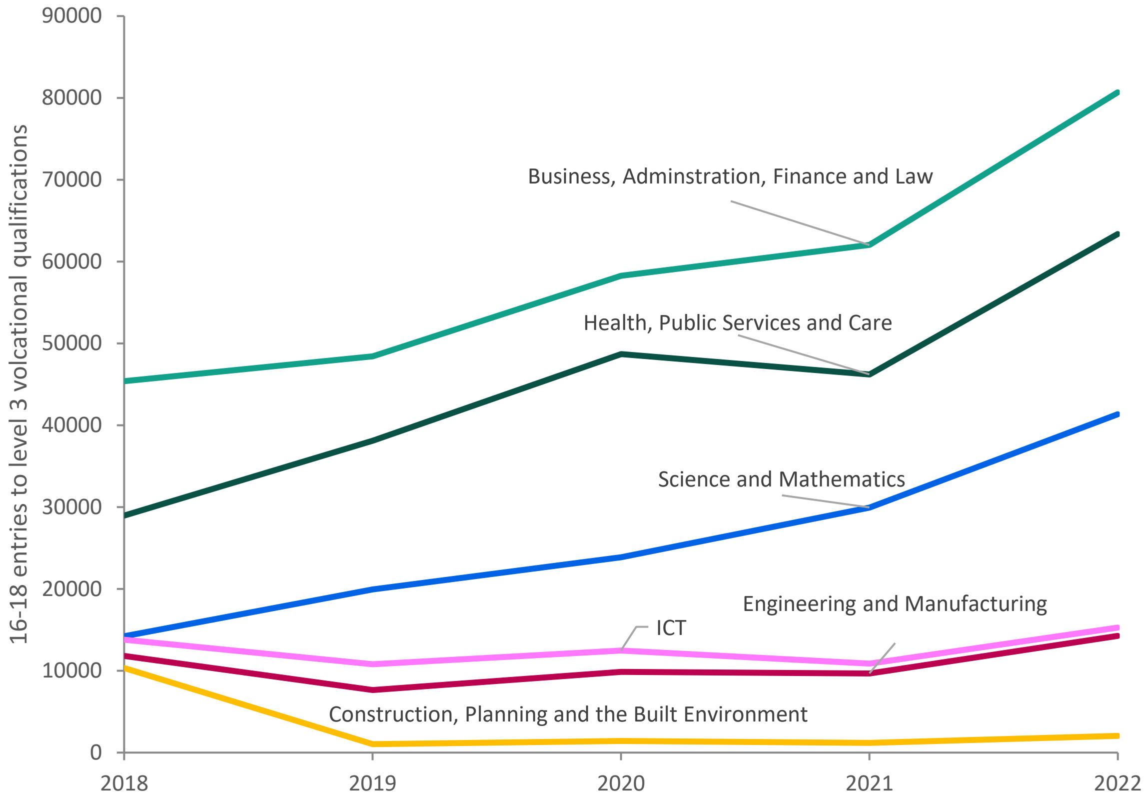


Source: Department for Education[115]

STEM subjects are comparatively less popular among students choosing vocational qualifications. For qualifications that appear in the 16-18 performance tables; business, administration, finance and law, alongside Health, public services and care are the most popular subject groups. Figure A1.2 shows entries numbers for these two subject groups alongside the four STEM subject groups (in order of size): Science and Mathematics, Information and Communication Technology, Engineering and Manufacturing Technology and Construction, Planning, and the Built Environment.

[115] Department for Education (2023) 'A Level and Other 16 to 18 Results, Academic Year 2021/22'.

Figure 1.2: Level 3 vocational qualification entries in England, 2018 to 2022



Source: Department for Education[116]

In all, the last 20 years has seen various changes to the school system, the science curriculum, and post-16 provision in England. The impact of these changes in isolation is difficult to unpick but overall, there has been an increase in post-16 STEM participation, in particular STEM A levels are an increasingly popular choice for those staying in academic education post-16. Below we develop a model to better understand which factors are driving changes and then apply this to patterns of uptake observed for different pupil groups.

[116] Department for Education (2023) 'A Level and Other 16 to 18 Results, Academic Year 2021/22'.

Appendix 2: Tables in support of quantitative analysis

Table A2.1. Summary statistics

Characteristic	N = 1,568,920
KS4 final academic year	
2016/17	519,025 (33%)
2017/18	515,618 (33%)
2018/19	534,277 (34%)
Month of birth	
Sep-Nov	395,140 (25%)
Dec-Feb	378,607 (24%)
Mar-May	391,524 (25%)
Jun-Aug	403,649 (26%)
Gender	
Male	792,510 (51%)
Female	776,410 (49%)
FSM6	398,628 (26%)
Ethnicity (Major)	
White	1,184,416 (75%)
Asian	164,230 (10%)
Black	86,150 (5.5%)
Mixed	73,610 (4.7%)
Chinese	5,864 (0.4%)
Any other ethnic group	26,170 (1.7%)
Unclassified	28,480 (1.8%)
Ethnicity (Minor)	
White British	1,091,126 (70%)
Any other white background	85,045 (5.4%)
Pakistani	57,256 (3.6%)
Black - African	43,871 (2.8%)
Indian	43,551 (2.8%)
Any other Asian background	35,676 (2.3%)
Any other mixed background	28,486 (1.8%)
Bangladeshi	27,747 (1.8%)
Any other Black background	21,305 (1.4%)
Black Caribbean	20,974 (1.3%)
White and Asian	15,323 (1.0%)
White and Black African	8,761 (0.6%)
White and Black Caribbean	21,040 (1.3%)
Any other ethnic group	26,170 (1.7%)
Unclassified	28,480 (1.8%)
White - Irish	4,918 (0.3%)
Traveller of Irish heritage	330 (<0.1%)
Chinese	5,864 (0.4%)
Gypsy / Roma	2,997 (0.2%)

Characteristic	N = 1,568,920
Special Educational Needs (SEN)	
None	1,375,771 (88%)
SEN Support	164,380 (10%)
EHCP/Statement	28,769 (1.8%)
English as an additional language (EAL)	
English as first language	1,300,207 (83%)
English as an additional language	256,777 (16%)
Unclassified language	11,936 (0.8%)
GCSE outcomes	
Attainment 8 score	47 (34, 61)
Progress 8 score	0.00 (-0.70, 0.79)
Triple Science	420,791 (27%)
GCSE maths 5+	781,486 (50%)
STEM Level 3	298,758 (19%)
STEM Level 3 (alternative)	325,649 (21%)
School type	
Academy converter	784,736 (50%)
Academy sponsor led	284,863 (18%)
Community school	219,605 (14%)
Foundation school	112,872 (7.2%)
Free Schools	31,536 (2.0%)
Voluntary aided school	116,033 (7.4%)
Voluntary controlled school	17,573 (1.1%)
Unknown	1,702
Admissions	
Non-selective	1,464,609 (95%)
Selective	70,106 (4.6%)
Unknown	34,205
Sixth form	
Does not have a sixth form	523,212 (33%)
Has a sixth form	1,045,604 (67%)
Unknown	104
Single sex	
Mixed	1,412,049 (90%)
Girls	94,707 (6.0%)
Boys	62,164 (4.0%)
Ofsted grade	
Good	996,286 (64%)
Outstanding	242,305 (16%)
Requires improvement	204,157 (13%)
Serious Weaknesses	45,112 (2.9%)
Special Measures	66,834 (4.3%)
Not inspected	14,226

Table A2.2. Rates of progression by pupil characteristics

		% Level 3 STEM *Preferred definition*	*Alternative definition*	Number of pupils
Overall		**19.0%**	**20.8%**	**1,568,920**
Gender	Girls	15.1%	17.8%	776,410
	Boys	22.9%	23.6%	792,510
Free School Meals	No	21.5%	23.5%	1,163,415
	Yes	12.2%	13.1%	398,628
	N/A	3.0%	3.2%	6,877
SEND	None	20.5%	22.4%	1,375,771
	SEN Support	8.8%	9.2%	164,380
	EHCP/Statement	7.0%	7.2%	28,769
EAL	English as first language	17.1%	18.9%	1,300,207
	English as an additional language	29.2%	30.8%	256,777
	Unclassified language	7.1%	7.4%	11,936
Major Ethnicity	Any other ethnic group	29.8%	31.2%	26,170
	Asian	36.6%	38.4%	64,230
	Black	23.0%	24.8%	86,150
	Chinese	54.9%	56.6%	5,864
	Mixed	19.9%	21.6%	73,610
	Unclassified	13.8%	14.8%	28,480
	White	16.0%	17.7%	1,184,416
Minor Ethnicity	Bangladeshi	31.1%	33.2%	27,747
	Indian	44.4%	46.3%	43,551
	Any other Asian background	40.4%	42.1%	35,676
	Pakistani	31.0%	32.6%	57,256
	Black - African	27.8%	29.8%	43,871
	Black Caribbean	11.6%	13.1%	20,974
	Any other Black background	24.3%	26.0%	21,305
	Chinese	54.9%	56.6%	5,864
	Any other mixed background	23.8%	25.5%	28,486
	White and Asian	26.4%	28.4%	15,323
	White and Black African	19.1%	20.7%	8,761
	White and Black Caribbean	10.2%	11.7%	21,040
	Any other ethnic group	29.8%	31.2%	26,170
	Unclassified	13.8%	14.8%	28,480
	White British	15.7%	17.4%	1,091,126
	White - Irish	20.1%	22.4%	4,918
	Traveller of Irish heritage	2.4%	2.7%	330
	Any other white background	20.4%	21.9%	85,045
	Gypsy / Roma	2.0%	2.2%	2,997

Table A2.3. Rates of progression by secondary school characteristics

		% Level 3 STEM *Preferred definition*	% Level 3 STEM *Alternative definition*	Number of pupils
Overall		**19.0%**	**20.8%**	**1,568,920**
School type	Academy converter	21.3%	23.3%	784,736
	Academy sponsor led	13.8%	14.9%	284,863
	Community school	17.9%	19.5%	219,605
	Foundation school	16.4%	17.8%	112,872
	Free Schools	24.8%	26.1%	31,536
	Voluntary aided school	20.5%	22.2%	116,033
	Voluntary controlled school	16.8%	18.7%	17,573
Admissions	Non-Selective	17.7%	19.4%	1,464,609
	Selective	47.4%	50.7%	70,106
Sixth form	No sixth form	15.7%	17.0%	523,212
	Has a sixth form	20.7%	22.7%	1,045,604
Single sex	Mixed	17.7%	19.4%	1,412,049
	Girls	27.2%	30.6%	94,707
	Boys	36.1%	37.3%	62,164
Ofsted grade	Good	18.4%	20.0%	996,286
	Outstanding	27.6%	30.0%	242,305
	Requires improvement	14.6%	15.8%	204,157
	Serious Weaknesses	14.6%	16.0%	45,112
	Special Measures	13.8%	14.9%	66,834
	N/A	23.5%	25.5%	14,226

Appendix 3: Formal regression specifications

This appendix contains the formal descriptions of the regression specifications we estimate in our strand 2 quantitative analysis. All models were estimated using the statistical software R,[117] multilevel models are estimated using the 'lme4'package.[118]

Logistic model

The logistic model is derived as follows, where π_{ij} is the probability of individual i at school j progressing to Level 3 STEM which is thought to be a function F of the x_{ij} is a vector of independent variables. In the case of the logistic regression F is the inverse logit function and converts log-odds to probability:

$$\begin{aligned}\pi_{ij} &= Pr(STEM_{ij} = 1) \\ &= F(\alpha + \beta x_{ij}) \\ &= \frac{exp(\alpha + \beta x_{ij})}{1 + exp(\alpha + \beta x_{ij})}\end{aligned}$$

$$log\left(\frac{\pi_{ij}}{1 - \pi_{ij}}\right) = \alpha + \beta x_{ij}$$

Multilevel logistic model

We extend our modelling approach to by estimating a series of multilevel models. This approach allows us to estimate both global averages and group-level effects. We first estimate a variant commonly known as the 'random intercept' model. The key difference compared to the basic logistic regression is each school is now allowed to have its own intercept $\boldsymbol{\varepsilon_j^\alpha}$:

$$log\left(\frac{\pi_{ij}}{1 - \pi_{ij}}\right) = \alpha_j + \beta x_{ij}$$

$$\alpha_j = \alpha + \varepsilon_j^\alpha, for\ j = 1, \dots, J$$

$$\varepsilon_j^\alpha \sim N(0, \sigma_{\varepsilon^\alpha}^2)$$

Finally, we estimate a different multilevel model, commonly known in the literature as a 'random slopes' model. This allows the estimated effects, β, on different pupil characteristics to vary by school. Formally, we add of a varying-slope parameter, ε_j^β. The model therefore becomes,

$$log\left(\frac{\pi_{ij}}{1 - \pi_{ij}}\right) = \alpha_j + \beta_j x_{ij}$$

$$\alpha_j = \alpha + \varepsilon_j^\alpha, for\ j = 1, \dots, J$$

[117] R Core Team (2021) 'R: A language and environment for statistical computing'.
[118] Bates et al. (2015) 'Fitting Linear Mixed-Effects Models Using lme4'

$$\beta_j = \beta + \varepsilon_j^{\beta}, for\ j = 1, \dots, J$$

$$\varepsilon_j^{\alpha} \sim N(0, \sigma_{\varepsilon^{\alpha}}^2)$$

$$\varepsilon_j^{\beta} \sim N(0, \sigma_{\varepsilon^{\beta}}^2)$$

$$Cov\left(\varepsilon_j^{\alpha}, \varepsilon_j^{\beta}\right) = \sigma_{\alpha\beta}$$

where, $\boldsymbol{x_i}$ is a vector of pupil characteristics and the school level intercepts ($\boldsymbol{\alpha_j}$) and slopes ($\boldsymbol{\beta_j}$) are themselves allowed to vary.

Appendix 4: Additional results

Table A4.1. Single and multilevel regression coefficients - secondary school characteristics

		M4	MLM4
School type (ref: Academy converter)	Academy sponsor led	-0.279*** (0.007)	-0.282*** (0.019)
	Community school	-0.084*** (0.007)	-0.082*** (0.021)
	Foundation school	-0.153*** (0.009)	-0.189*** (0.026)
	Free Schools	0.274*** (0.017)	0.230*** (0.040)
	Voluntary aided school	-0.007 (0.008)	0.002 (0.026)
	Voluntary controlled school	-0.087*** (0.021)	0.120* (0.067)
Selective		0.917*** (0.010)	0.993*** (0.034)
Sixth Form		0.134*** (0.005)	0.141*** (0.014)
Single Sex (ref: Mixed)	Girls	0.190*** (0.010)	0.213*** (0.029)
	Boys	-0.032*** (0.011)	-0.010 (0.035)

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