ASPIRES 3

Young People's STEM Trajectories, Age 10-22

MAIN REPORT

Introduction by the ASPIRES Project Principal Investigator (PI)

Increasing and diversifying participation in science, technology, engineering and mathematics (STEM) remains a key international priority for many reasons. This report summarises the most recent findings from the ASPIRES3 research project, exploring the factors shaping young people's trajectories into, through and out of STEM between the ages of 20 and 22.

The ASPIRES study comprises three consecutive funded stages, tracking a single cohort of young people (born between September 1998 and August 1999) over time to understand the factors shaping their trajectories: ASPIRES (age 10 to 14), ASPIRES2 (age 14 to 19) and ASPIRES3 (age 20 to 22). Together, the ASPIRES project has studied the educational and employment aspirations, choices, experiences and outcomes of thousands of young people in England from age 10 to 22. This research has generated new understandings of how young people pursue trajectories both into and out of science, technology, engineering and mathematics, and how their experiences and pathways are shaped by gender, race/ethnicity and social class.[1]

Using mixed methods, ASPIRES combines large-scale quantitative surveys with in-depth longitudinal interviews with young people and their parents/carers. Since the initial ASPIRES focus on children's science aspirations, ASPIRES2 and ASPIRES3 have broadened in scope to include computing, engineering and maths. Our award-winning research draws attention to the shifting influence of families, schools, careers education, disciplinary cultures, luck, education policy, and social identities and inequalities – examining how these variously shape who aspires and chooses to study and/or work in STEM fields, and who does not.

This report summarises key findings and contains links to blogs, videos, resources and academic outputs, and four subject-specific reports, which dive into the findings in these areas in more depth.

We hope you find the report of interest and use – and that it can help inform more equitable, inclusive and engaging STEM education for all young people.

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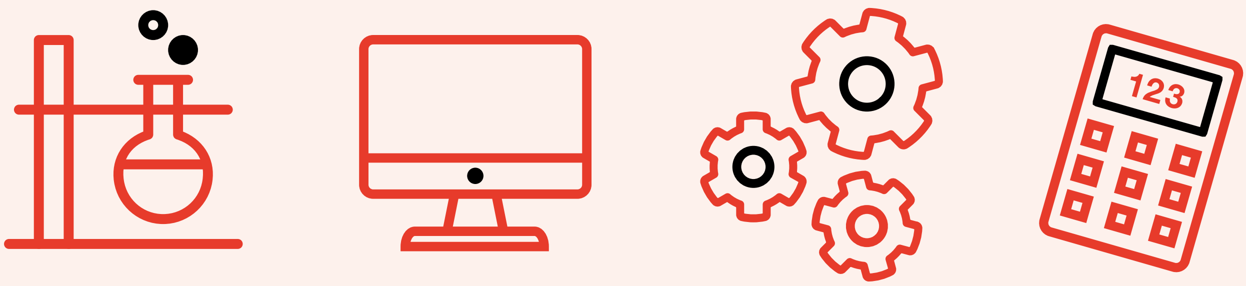
Summary of Contents

1. Executive Summary

In the UK, there are widespread policy concerns about the need to increase and diversify participation in science, technology, engineering and mathematics (STEM). These concerns relate to current and predicted skills gaps in key STEM employment areas, and the poor recruitment and retention of science and mathematics teachers and researchers.[2] Moreover, despite many years of interventions, key communities such as women, racially minoritised and working-class people remain persistently and acutely underrepresented in STEM, particularly at senior levels and in disciplines such as the physical sciences, engineering and computing.

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

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



Key Findings

Who studies STEM at advanced and degree level in England?

Analyses of HESA and National Statistics[3] data show that:

- Participation in STEM subjects at advanced level (A Level) is high, with mathematics consistently being the most commonly taken (by around 30% of students). Of the science subjects, physics has the lowest take-up (approximately 13%). A smaller number of students (approximately 5%) study computer science or further mathematics, and engineering is a relatively uncommon A level.
- These trends change at undergraduate level: analysis[4] of HESA national data shows that engineering and computing are consistently the most popular type of STEM degrees in England (excluding medicine), with mathematics and physics the least popular.
- At both A level and degree level, STEM subjects remain relatively gendered, with women being overrepresented in biological science and underrepresented in physics, engineering and computing. Participation in chemistry is relatively gender-balanced. In 2020/21, women comprised around 32% of STEM and 62% of non-STEM degree undergraduates – and just 14.1% of computing students.
- At degree level, Black students remain underrepresented in STEM, with the percentage varying considerably between STEM subject areas, for instance in 2020/21, being lowest in physics (2.6%) and highest in computing (11.0%).
- Students from the most socially deprived backgrounds are underrepresented in both STEM and non-STEM degrees. Participation varies between STEM degree areas, for instance in 2020/21, the lowest percentage of students from the most deprived quintile was found in physics (10.4%) and the highest in computing (23.1%).
- Within STEM degrees, non-completion rates among first-year undergraduates in England vary between STEM subject areas. For instance, in 2019/20, the lowest non-completion rate was in Physics (4.2%) and the highest in computing (9.4%).
- Students from the most deprived IMD quintile leave STEM at around double the rate of those in the most privileged quintile. A slightly higher percentage of male STEM undergraduates do not complete, compared with women.
- Racially minoritised students tend to record higher rates of non-completion than White students. For example, in 2019/20, 5.1% of White students left their degree with no award, compared with 8.4% of Black students.

What shapes young people's STEM trajectories?

Analyses of the ASPIRES survey and longitudinal interview data identified three main factors:

Factor 1: Identity

The extent to which a young person's identity aligned, or not, with a STEM discipline varied over time and by gender, race/ethnicity and social class, and strongly shaped their STEM trajectory.

- Where a young person experienced alignment between their (gendered, classed, racialised) identity and a given STEM discipline, this strongly supported their STEM trajectory. Conversely, experiences of misalignment were associated with dropping or changing a given STEM trajectory, even when a young person was highly interested and capable of pursuing this route.
- The dominant discursive association between subjects such as mathematics and physics with exceptional 'natural talent' makes it hard for many young people, but particularly young women, to see themselves, and/or be recognised by others, as viable students in these fields, even when they are interested and attain highly.

- Forms of capital (cultural, social and economic resources) are important for supporting and sustaining STEM identity over time.
- On average, most students report feeling comfortable and a sense of belonging on their degree courses, although this varies considerably between subjects, being lowest among computing students. Over a quarter of STEM degree students worry about not completing their degrees, particularly those from underrepresented communities and those taking computing degrees.

Factor 2: Capital

The 'right sort' of STEM capital supports STEM identity development and progression within a given field.

- Higher status 'Triple Science' GCSE routes are a form of capital that is significantly associated with taking A level Science and degree level science.
- Greater STEM capital is associated with (smoother) progression but access to the most valuable forms of capital is unevenly distributed, contributing to unequal participation patterns.
- Young people from less privileged backgrounds, who have less (of the most valuable forms of) capital, were often more reliant on luck to open up access to key forms of capital that enable socially mobile trajectories.
- Careers education and support is a form of facilitating capital that is inequitably distributed and accessed.

Factor 3: Field

Practices in STEM education can undermine young people's identification with, and progression in, STEM.

- Specific assumptions, practices and behaviours circulating in the fields of STEM education (from primary through to secondary and university levels) make it harder for young people from underrepresented communities to engage in STEM – even when they are highly interested and motivated to pursue STEM. These factors also increase the risks and costs of STEM participation for those from underrepresented communities.
- Restrictive entry requirements, assumptions about who STEM is 'for' and the costs of HE participation can limit access to STEM qualification routes, particularly for those from less privileged social backgrounds.
- STEM education can negate some young people's STEM capital and make them feel out of place, particularly those from underrepresented communities.
- Peer sexism is an ongoing issue that negatively impacts women STEM students.

Summary Recommendations

We identify six main recommendations for policymakers and practitioners who want to support increased and more diverse participation in STEM.

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

2. Challenge ideas of STEM competence (but particularly in mathematical areas) as being based on 'natural talent'.

3. Address the impact of Double/Triple science GCSE qualification routes on STEM progression.

4. Challenge peer sexism on STEM degrees.

5. Support more equitable experiences and retention on STEM degrees, particularly among students from underrepresented communities.

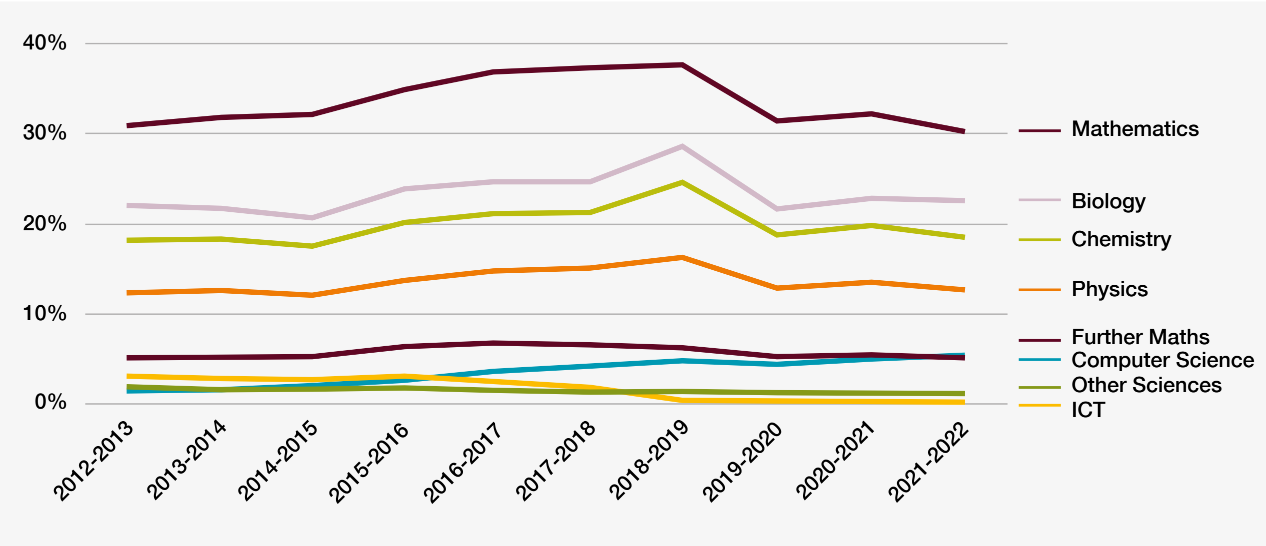
6. Facilitate greater access to key forms of STEM-related social and cultural capital for young people from underrepresented communities, to support social mobility in STEM and beyond.

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

2. Who studies STEM at advanced and degree level in England?

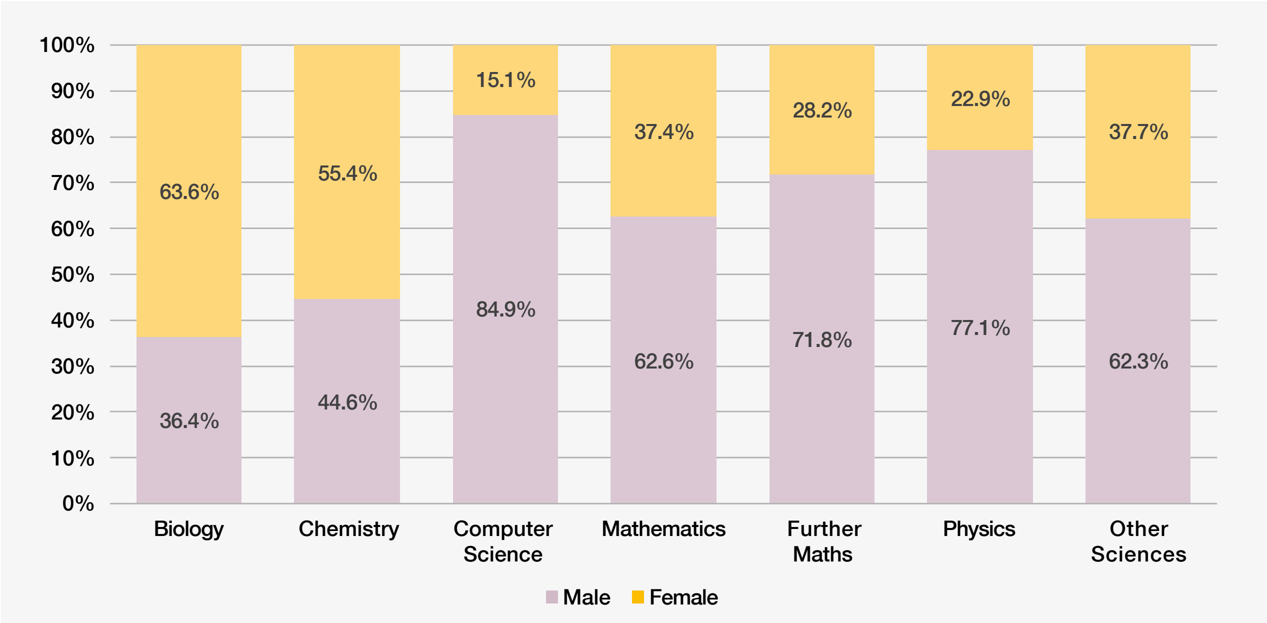
As detailed in Figure 1, analysis of National Statistics data from advanced level (A level) show that overall participation in STEM subjects is high, with Mathematics consistently having the highest entry of any A level – above 30% of the cohort. In 2021/22, Physics had the lowest take-up among the three main sciences (12.6%). Just 5.3% of students studied Computer Science and 5.0% took Further Mathematics, although the latter two qualifications are not prerequisites for degree entry in their respective degree fields (indeed, A level Mathematics is the most common qualification requested for progression to a computing degree).

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



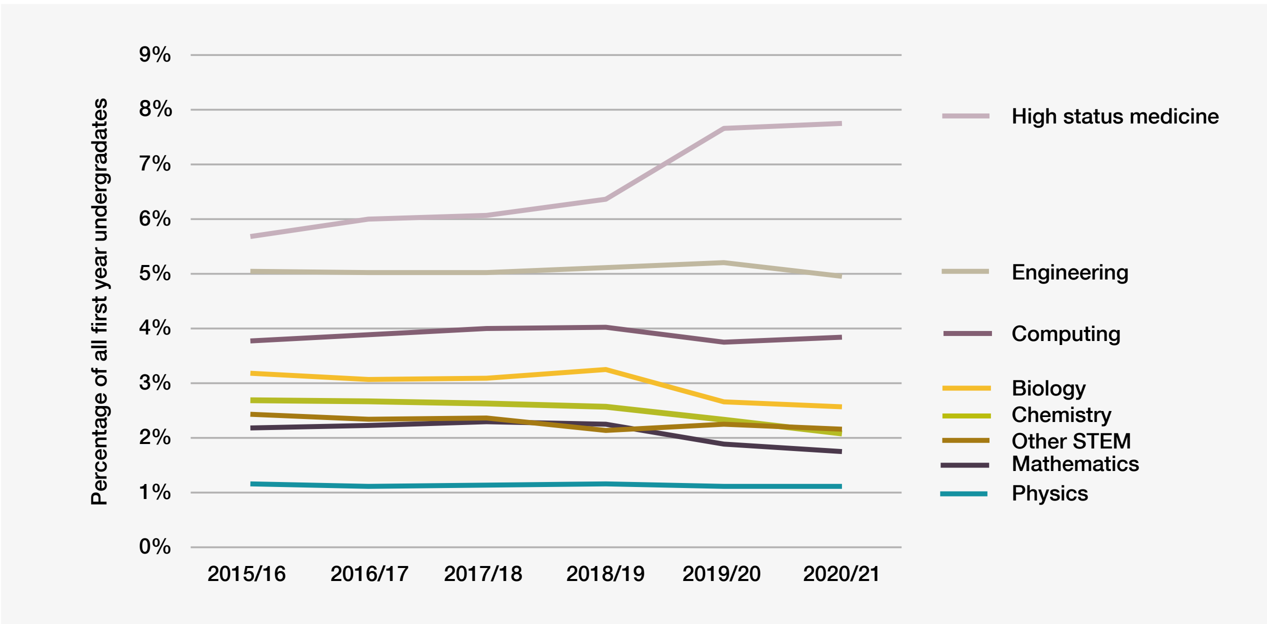
As detailed in Figure 2, analyses of trends between 2016 and 2022 show that Chemistry is the most gender-balanced STEM A level, with just over 50% of students taking the subject being women. Biology A level has even more women participants (consistently over 60%), whereas slightly over 60% of Mathematics students are men. Physics and Computer Science A levels are the most male-dominated subjects. In 2021/22, women accounted for 22.9% of Physics entrants and just 15.1% of those studying Computer Science.

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



As per Figure 3, at undergraduate level, analyses of national data from the UK Higher Education Statistics Agency (HESA)[5] show that **engineering and computing are consistently the most popular type of STEM degrees** in England, with physics and maths the least popular.

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



In terms of trends in participation by gender, race/ethnicity and indices of multiple deprivation (IMD):

- Gender patterns persist from A level into degrees. In 2020/21, **women comprised around 32% of STEM and 62% of non-STEM degree undergraduates**, respectively – see Figure 4;
- **Computing and engineering are the most male-dominated STEM degree subjects.** On average between 2015/16 and 2020/21, men constituted 86.5% of engineering students and 87.4% of computing students;
- Undergraduate **chemistry is the most gender-balanced STEM degree subject**, with women constituting, on average, a little under half (45.5%) of UK chemistry degree enrolments between 2015/16 and 2020/21;
- On average, between 2015 and 2021, 7.2% of first-year STEM undergraduates in England were Black (7.8% in 2020/21, as per Figure 5, as opposed to 8.3% in non-STEM subjects). While there is no direct comparison figure, the 2021 national census data records 11% of the population in England aged18 to 24 as Black, suggesting that **Black students remain underrepresented in STEM**. As noted in Figure 5, **the percentage of Black students varies considerably between STEM subject areas, being lowest in physics (2.6%) and highest in computing (11.0%);**
- In 2020/21, **students from the most socially deprived backgrounds were underrepresented in both STEM and non-STEM degrees** (Figure 6). There is variation across the STEM degree subject areas, with **physics recording the lowest percentage (10.4%) of students from the most deprived quintile and computing the highest (23.1%).**

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

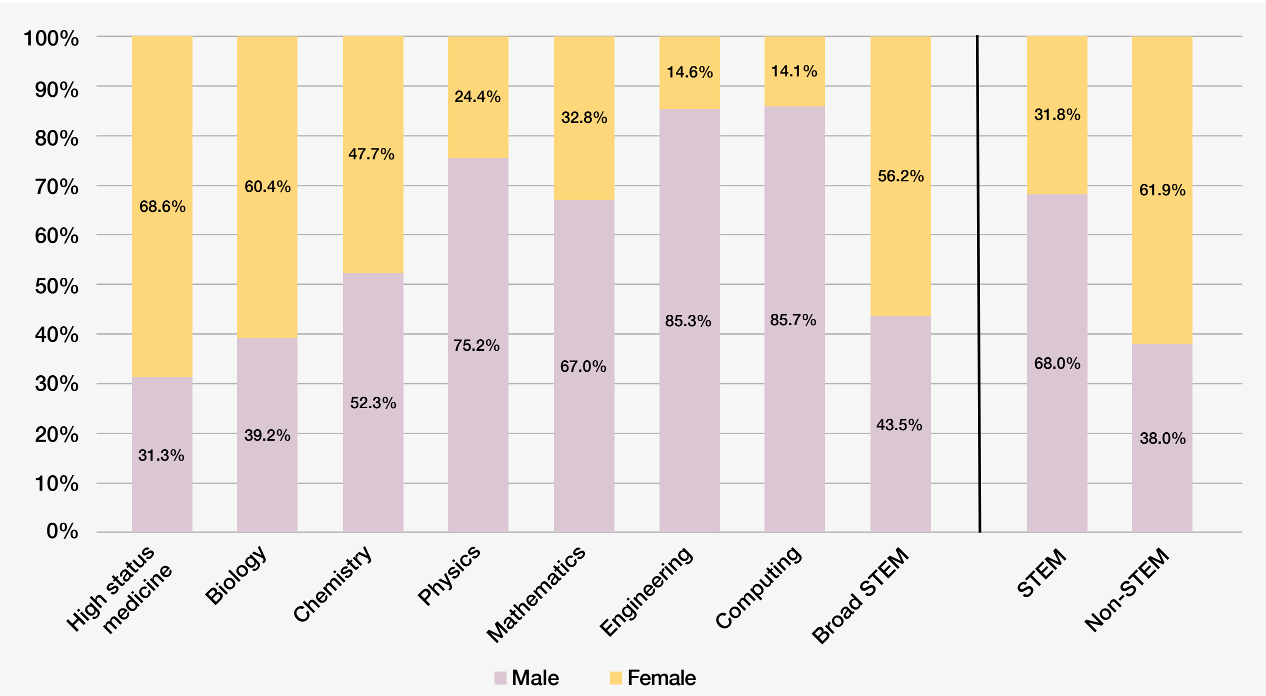


Figure 5: Breakdown by race/ethnicity of first-year undergraduates in England 2020/21

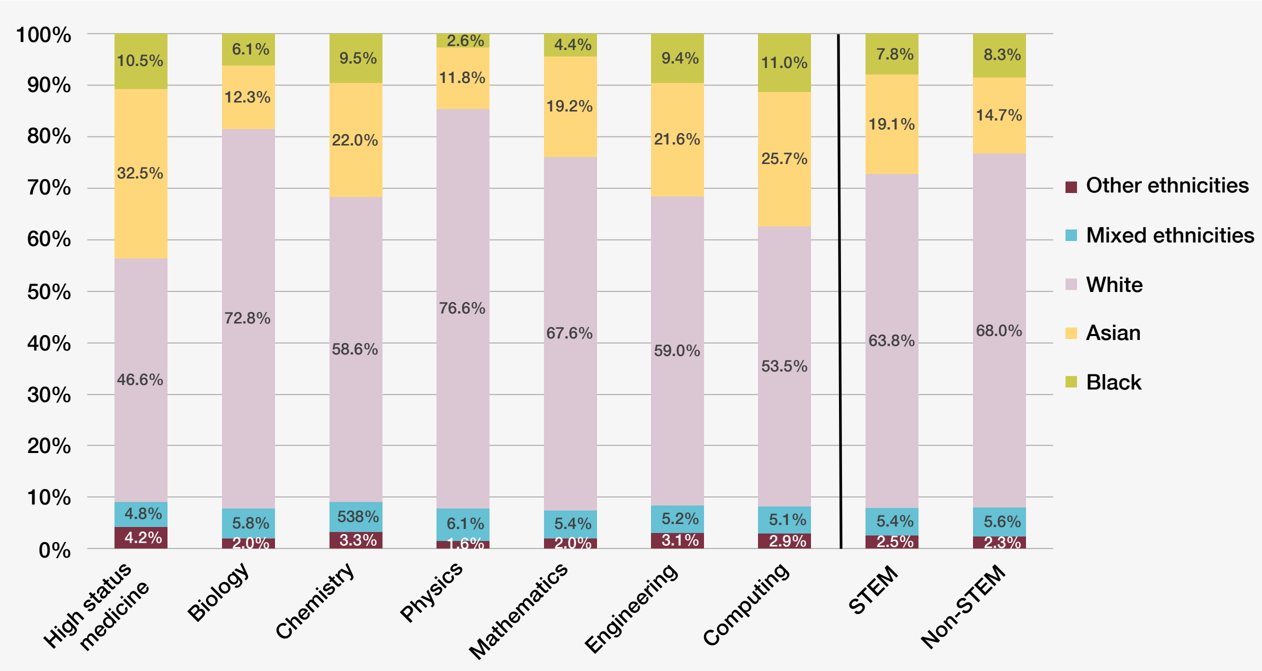
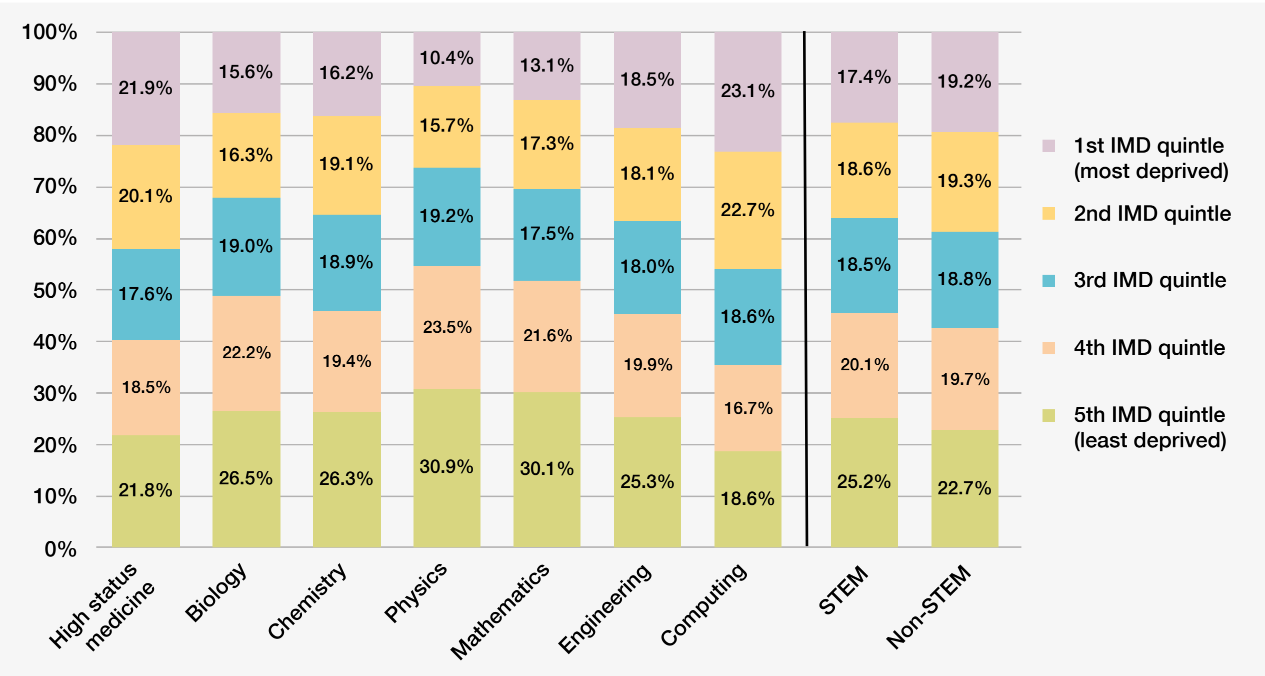


Figure 6: Breakdown by IMD quintile of first-year undergraduates in England 2020/21



In terms of undergraduate retention and completion:

- Between 2015 and 2020, on average **6.5% of first-year STEM undergraduates from England aged 18 to 24 left their course** with no award during, or at the end of, their first year; 2.4% withdrew during, or at the end of, their second year; and 0.9% left during, or at the end of, their third year;

- **Non-completion rates varied between STEM subject areas.** In 2019/20, the lowest rate (4.2%) was recorded among physics students and the highest (9.4 %) among computing students;

- In 2019/20, **students from the most deprived IMD quintile left STEM degrees in their first year at around double the rate of those in the most privileged quintile** (8.3% vs. 3.8%). Male STEM undergraduates had a slightly higher rate of non-completion than women (6.3% vs 4.5%);

- **Racially minoritised students tend to record higher rates of non-completion than White students.** In 2019/20, 5.1% of White students left their degree with no award, compared with 8.4% of Black students.

3. Prior evidence base and conceptual approach

Internationally, increasing and diversifying participation in STEM is a priority for government, industry and STEM education policy and practice. These concerns are driven by a number of motivations, the most commonly cited being the need to safeguard national economic competitiveness. While we recognise such concerns, the ASPIRES project prioritises the value of increased and diversified STEM participation for supporting active citizenship and social justice. The capacity to use STEM skills, knowledge and understanding, and to participate in shaping STEM agenda, is an important basis for democratic participation in everything from local planning decisions to climate action, and from making personal health decisions to working out how to reduce your energy bills.

One finding from the first ASPIRES project was that popular views of the value of science being narrowly focused on a 'pipeline' from school science to science careers are associated with many children and parents feeling that science is less relevant to their lives, and so being less likely to continue with the subject.

To date, many initiatives to raise STEM participation have focused on trying to change individuals – often by addressing a perceived 'lack', such as a lack of knowledge, information, motivation or aspiration. For instance: increasing girls' confidence; providing children with information about engineering jobs and the labour market returns of STEM jobs; and providing Black young people or girls with STEM role models. The ASPIRES research adopts a sociological approach, foregrounding the role of structural and systemic inequalities, and the role of STEM cultures and practices, in creating and sustaining unequal patterns of participation, rather than focusing on deficits in individual learners.

Contrary to popular policy discourse around a culture of low aspirations, the ASPIRES research found that young people from all backgrounds hold high aspirations, with the majority wanting to go to university and attain professional careers. We also found that most young people, from primary through to secondary school, find school science and mathematics interesting. However, this interest does not translate into post-16 participation and careers – with, for example, over 60% of 10-to-14-year-olds finding school science interesting, but only 15% interested in becoming a scientist. This gap is most stark for Black students, who throughout schooling report higher levels of science aspiration than white students yet record lower levels of participation in science degrees and employment.

The ASPIRES project is informed by sociological and educational research that shows how interactions of identity and capital (social and cultural resources) shape young people's trajectories through schooling and into further and higher education, and employment.[6] We use the term 'trajectory' as it conveys the sense that young people's educational and occupational lives may follow non-linear pathways that are acted on by a variety of forces, reflecting our sociological approach and interest in the role of social identities, inequalities, capital and field as key forces that influence and shape young people's lives and outcomes.

Young people can accrue capital from home, family, school and other educational contexts.[7] In the ASPIRES research, we explore how STEM-related capital is translated into resources and practices that help produce and sustain young people's high interest, attainment and aspirations. We show that interactions of identity and capital are key to producing and sustaining STEM trajectories, and that where there is close alignment between STEM-related identity, resources and the field of (school) science and mathematics, they are more likely to feel competent and interested in STEM subjects, and so are more likely to pursue a STEM trajectory.

ASPIRES found that many young people enjoy learning science and mathematics, but few of them aspire to be scientists or mathematicians. There is a gap between *doing* science and mathematics and *being* a scientist or a mathematician, with most young people not identifying strongly with STEM. Young people's choices are influenced by the fit between their identity and the field in question – that is, how far specific STEM pathways are felt to be 'for people like me'. The ASPIRES research uniquely tracked 50 participants from age 10/11 to 21/22, showing how STEM identities emerge, or not, in primary schooling and are sustained by children and young people through access to STEM-related capital.

We developed the concept of science capital during the first ASPIRES study as a way of encapsulating all the science-related knowledge, attitudes, experiences and social contacts that an individual may have. We subsequently extended this to encompass the other STEM subjects. This concept of STEM-related capital helps us to understand why some people do not engage with STEM and others do. It can also help educators to use more-inclusive STEM pedagogies, as evidenced by the success of our Science Capital Teaching Approach.

Find out more:

Videos explaining science capital:
https://youtu.be/A0t70bwPD6Y (short);
https://youtu.be/YqT40OUSwm8 (long)

Video on science capital and the informal learning sector:
https://youtu.be/mziJEbb6ETs

Video of teachers using the Science Capital Teaching Approach:
https://youtu.be/XDCekYVTkws

4. ASPIRES Project Methodology

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

Table 1: Summary of ASPIRES project data collection

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

A large-scale postal survey of young people in England was conducted by obtaining a sample of young people born between 1st September 1998 and 31st August 1999 who were registered on the Open Electoral Roll. Following data cleaning, the overall achieved sample of 7,635 young people was roughly proportional to (though not fully representative of) official government population estimates in England for 21 – and 22-year-olds based on sex, ethnicity, region, Index of Multiple Deprivation, Urban/Rural classification and long-lasting health conditions.[8]

The survey itself drew on the those from previous waves of ASPIRES (DeWitt et al., 2011; 2014) and explored: young people's aspirations and expectations, and the influences on these; actual destinations post-18; learner identities and relationships to learning; general views on science and careers in, and from, science; experiences of science education and the STEM labour market; extra-curricular activities; qualifications being studied; attainment; and socio-demographic factors. It was revised and piloted with 300 students before being administered to a national sample of 21 – and 22-year-olds in England.

Of the 7,635 students making up the achieved sample used in the ASPIRES analyses, 35.9% identified as men, 59.3% as women, 4.8% reported non-binary, other or preferred not to say. Students reported their ethnicities as follows: 78.2% identified as White; 9.2% as South Asian (Indian, Pakistani, Bangladeshi heritage); 3.7% as Black (Black African, Black Caribbean heritage); 1% as Middle Eastern; 0.8% as Chinese or East Asian; 5.4% as mixed or other; and the remaining preferred not to say. IMD (Indices of Multiple Deprivation, a government measure based on respondent postcodes) data reflected that 47.5% of respondents were in quintiles 1 or 2 (most deprived), 19.2% in quintile 3 and 33.3% in quintiles 4 or 5 (least deprived). Of perhaps more relevance to respondents at this age, 30.4% reported that at least one parent had attended university.

Out of our sample of 7,635 young people, 4092 took A levels (53.6%) and 3310 were studying for, or had completed, a university degree. Of the latter group, 523 (15.8%) were studying for, or had completed, a STEM degree (rising to 732, or 22.1%, when medicine is included).[9] [10] Although survey respondents were all in a single cohort, they were at different educational stages when they completed the survey, due to having started university (or not) at different points in time.

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

To help identify the factors shaping young people's reasons for choosing, or not, to pursue a STEM degree, the ASPIRES3 survey analysed open-ended response data from students who had qualifications and attainment that would have enabled them to apply for a degree in the sciences, computing, engineering or mathematics. Figure 7 details the reasons STEM degree students gave for their choice of degree subject, and Figure 8 shows the reasons for *not* taking a particular subject given by young people who had the A levels needed to apply for a degree in that subject.

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

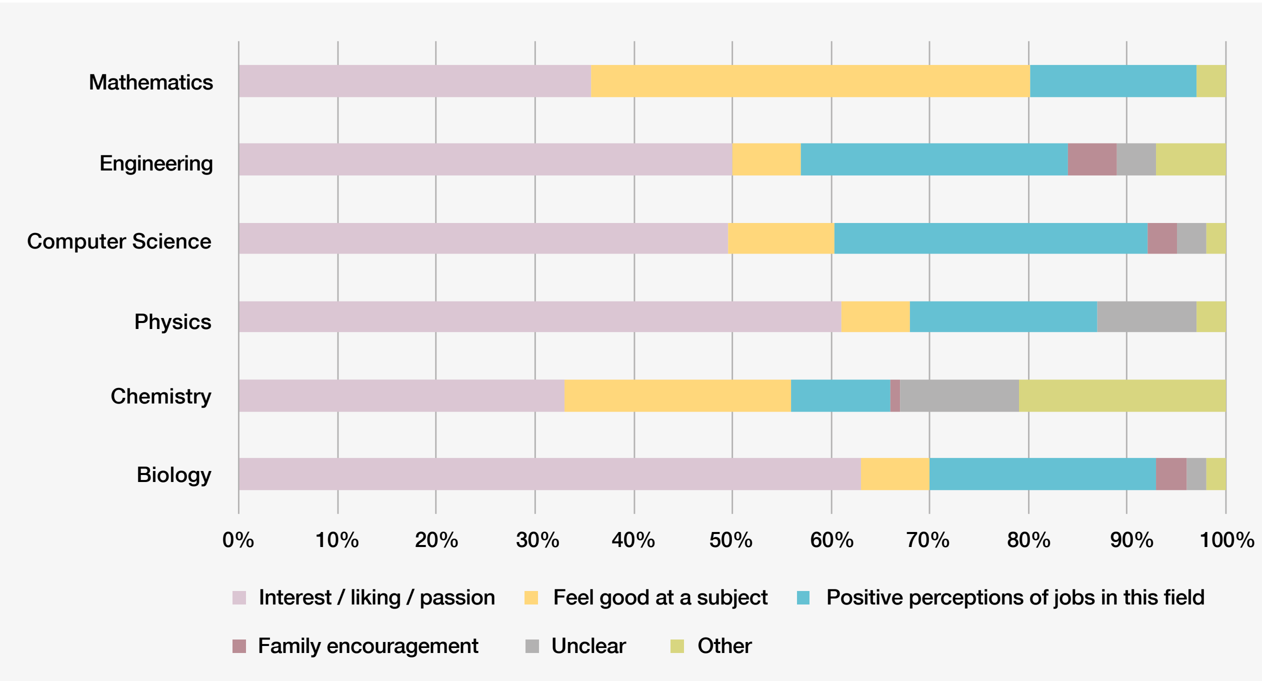
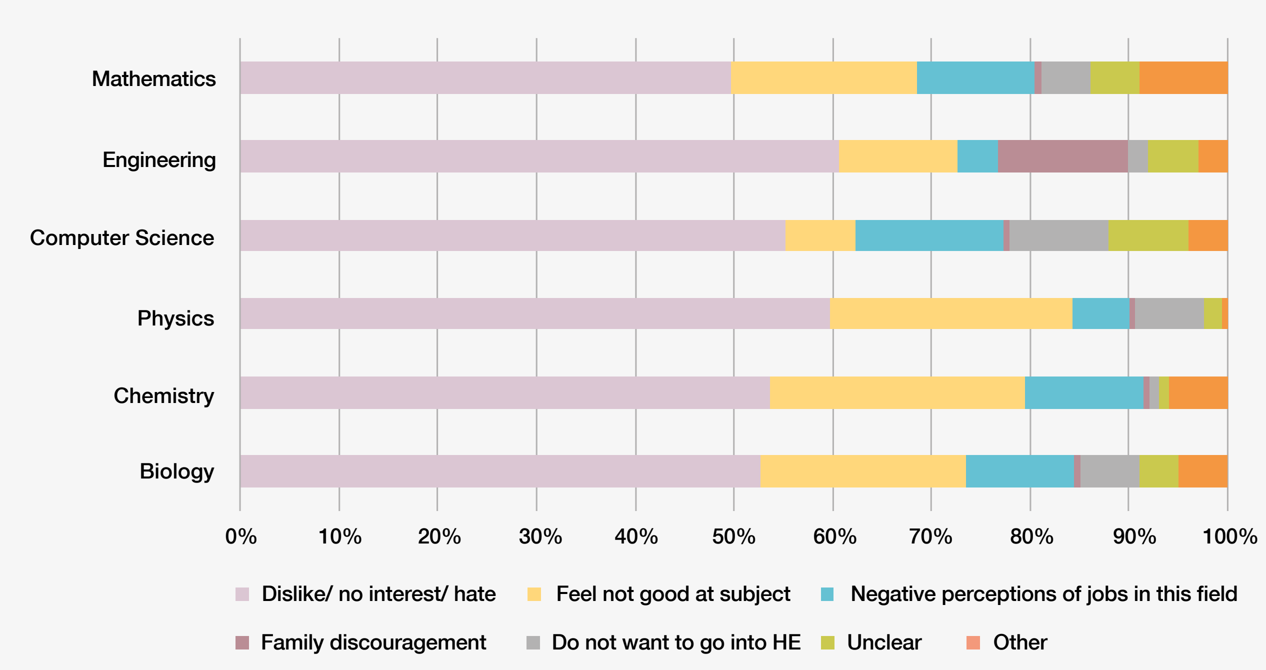


Figure 8: The reasons young people who had taken A level subjects that would have enabled them to apply for STEM degrees gave for their decision not to pursue these subjects



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

- **Subject liking/interest/passion was the most common primary reason** given by students in most of the STEM disciplines (from 33% of chemistry students to 63% of biology students), apart from mathematics, where this was only the second most popular reason (though still cited by 36% of students);
- **Feeling competent and 'good at' the subject was the primary reason** (45%) given for choosing to pursue a mathematics degree and was the second most popular reason given for chemistry degree choices (23%). However, it was also notable that the popularity of this response among maths students was primarily driven by responses from socially privileged maths undergraduates – namely White male students, and from the most affluent social quintiles (IMD4 and IMD5). The reasons given by other maths students more closely matched their peers in other STEM fields;
- **Positive views of STEM jobs** were cited more often as primary reasons for choosing degrees in computing (32%), engineering (27%), biology (23%) and physics (19%);
- A relatively small number of students also cited a range of other factors, including family encouragement, with other responses being particularly prevalent among chemistry degree students.

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

- **Subject dislike/lack of interest/hate was the primary reason given for not pursuing a STEM degree – this applied to all subjects,** with 50% or more of young people citing this reason for each of the degree areas;

- **Feeling 'not good' at the subject was the second most common reason given in relation to most subject areas**, apart from computer science and engineering, where negative views of computer science jobs and family discouragement from pursuing engineering (13%) were more common, with women particularly reporting family discouragement from pursuing engineering. The prevalence of family discouragement in relation to engineering was notable, given that this reason was relatively uncommon (approximately 1%) in other STEM fields;
- **Computing recorded the highest percentage (10%) of young people who said that they had not pursued a degree in this field because they did not want to go to university.**

Overall, our findings show that young people explain the reasons for their STEM degree choices primarily in terms of a combination of **subject interest/liking/passion** (and, conversely, subject dislike/lack of interest/hate); **feelings of subject competence** (feeling good/not good at a subject); and **perceptions of jobs relating to that field**. But what shapes these reasons? The next section considers the range of factors and influences that shape young people's relationships and views of STEM subjects and their subsequent trajectories.

6. Factors shaping STEM trajectories, interest and attitudes

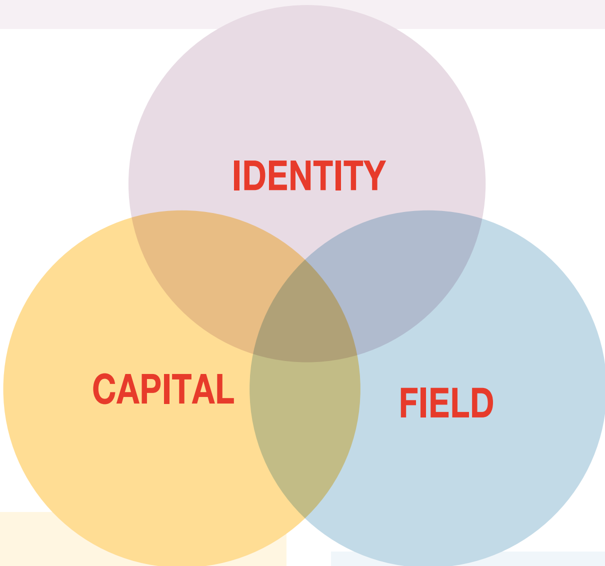
Statistical modelling of ASPIRES3 data from 3,310 young people aged 21/22 who had undertaken an undergraduate degree – 523 of whom studied a STEM subject – showed that science capital and STEM identity were significantly related to studying a STEM degree.[11]

As discussed next, our conceptual approach helps us to understand that identity and capital interact with each other, and with the wider fields of education and the separate STEM disciplines, to shape young people's trajectories into, through and out of STEM. These intersecting relationships are illustrated by Figure 9 and are detailed in the following sections.

Figure 9: Key factors shaping young people's STEM trajectories

Factor 1: Identity

- Misalignment between a young person's identity and a discipline can hinder participation even when attainment is high
- Popular associations of STEM disciplines with 'cleverness' and 'natural talent' impede diverse participation
- Capital is important for growing and sustaining STEM identity over time
- Misalignment between student identity and disciplinary culture negatively impacts retention



Factor 2: Capital

- Taking the elite 'Triple Science' route at GCSE is associated with taking A level and degree level science route
- STEM capital smooths progression but is unequally distributed – absence of capital makes progression more precarious
- Careers education support can facilitate trajectories but is inequitably distributed, accessed and activated

Factor 3: Field

- Dominant cultures and practices in STEM fields make it harder for young people from under-represented communities to access and persist in STEM
- Young people from less privileged backgrounds may depend more on luck to access key forms of capital to become socially mobile
- Inequalities in the STEM field can negate young people's STEM capital, particularly those from under-represented communities
- Peer sexism is an ongoing issue that negatively impacts women STEM students

Factor 1: Identity

ASPIRES found that the extent to which a young person's identity aligned, or not, with a STEM discipline varied over time and by gender, race/ethnicity and social class, and strongly shaped their STEM trajectory.

Specifically, analysis of the longitudinal interview data revealed that:

- **Where a young person experienced alignment between their (gendered, classed, racialised) identity and a given STEM discipline, this strongly supported their STEM trajectory. Conversely, experiences of misalignment were associated with dropping or changing a given STEM trajectory, even when a young person was highly interested and capable of pursuing this route.**

Young people experienced different, shifting alignments and/or disjunctures between their own identity and the different STEM disciplines, which were inflected by relations of gender, race/ethnicity and social class. For instance, the physical sciences, engineering, computing and mathematics were widely seen as having a masculine culture. In response to this, young women who aspired to, and pursued, these areas were more likely to identify as being "less girly", or conventionally feminine, to fit in (and, conversely, those who did not identify in this way were less likely to pursue or maintain trajectories in these areas). Negotiation of this relationship between femininity and different science disciplines is exemplified by the case of Davina, whose evolving identifications and aspirations in relation to the different sciences is matched by shifts in her own gender 'identity work' and negotiations of femininity. In particular, it highlights how prevalent gendered associations of science – but particularly the physical sciences – with 'cleverness' can be particularly difficult for young women to identify with.

Case Study 1: Davina is a middle-class young woman of White British and European heritage. From age 10 to 21, she expressed a long-term interest and aspiration towards science. From a young age she was recognised by others as being intelligent and attained highly. Her family were supportive of her science aspirations and possessed considerable science-related capital.

Around ages 12 to 14, she aspired to a biology-related career and described girls who are into science as either "geeky" or "normal girls", like herself. At age 15/16, she developed an interest in physics, which she saw as a field for "extremely intelligent people". At this time, her sense of her own femininity also shifted, to what she described as "not particularly feminine". At age 17/18 she decided to pursue a chemistry degree, explaining that while she was still interested and competent at physics, she did not feel "clever enough" to take it at university ("no way I could do physics at university") and that, while she was able to attain well in the subject at A level, "I don't think that necessarily means that I'm actually that good at physics".

At age 21, part way through her chemistry degree at a high-status university, Davina was working hard but found that the intensity of study was somewhat reducing her passion and interest in the subject. She reflected that she felt only "kind of a chemist", worrying that "everyone else is so much smarter than me". At the time of her last interview, she was planning to move into the finance sector after graduation.

These issues can be amplified further by social class, as illustrated by Case Study 2, in which Danielle's identification with 'glamorous' White, working-class femininity is not recognised by others as being commensurate with a legitimate/authentic physics identity and, in particular, popular (gendered, classed) stereotypes of 'cleverness'.

Case Study 2: Danielle is a White, working-class young woman who defines herself as a "glamorous", "girly" girl. No one in her family has been to university and the family is not particularly 'science-y'. From an early age, Danielle expressed a strong interest in science and aspired to be a scientist up until the age of 16. At age 10, she described enjoying some informal science learning activities and experiences outside school.

Over the years, Danielle's science trajectory has been closely interlinked with her negotiations of cleverness and femininity. She states that "all of my family is not clever" and over the years often worried that her family, teachers and others always assume that she is not clever because of the way she looks. At 17, she said: "I'm a bit of a party girl… I like make-up and hair… but then I do like the school side. Everyone thinks I'm really dumb, but I'm not. I seem quite dumb I suppose… because I do all my make-up and hair, and just seem a blonde bimbo".

Though she was placed in the bottom attainment sets at secondary school, she worked hard and moved up to the "top sets". She took the non-elite Double Science route, worrying that Triple Science would have been "too hard" – "I wouldn't have done it, I'd have failed, so there was no point". She attained B grades at GCSE and applied to do A level Physics but was discouraged by the school, on the basis that she might struggle academically. She took other A level subjects and eventually pursued a social science degree.

Danielle's example underlines how the alignment of disciplines, such as physics, with middle-class masculinity make it difficult for 'glamorous', working-class young women like herself to be recognised as authentic physics students. It also highlights how, practices within the field of science education (such as grade severity in physics) result in gatekeeping in these subject areas that both formally and informally restricts access for students with good (but not 'top') attainment, and how, as others have noted, 'exclusion works most powerfully as self-exclusion'.[12]

The tensions and challenges for young women to see themselves, and be recognised by others, as viable physicists is further underlined by Kate, a White, middle-class young woman who liked physics and had taken it at A level, but who did not consider pursuing a physics degree because she worried that it would be "too hard". This was despite attaining top grades in the subject, underlining how identity can mediate both interest and attainment within young people's degree choices.

In contrast, where young people experienced an alignment and meaningful connection between their own identity and a particular field, this provided strong support and impetus for a particular subject trajectory. For instance, Mienie, a mixed heritage (South Asian and White), middle-class young woman, recounted a pivotal experience around the age of 15, when she developed a strong connection with an ethical beauty brand, which powerfully resonated with her identity and values, and which she felt was key to shaping her subsequent chemistry degree trajectory. Likewise, Hailey (a White, middle-class young woman) talked about the significant impact that a family member's serious illness had on shaping her pursuit of medical biochemistry. While a number of STEM students recounted the importance of such connections for motivating and sustaining their STEM trajectories, these were most often voiced by young women.

Find out more:

Archer, L. et al. (2023). Reasons for not/choosing chemistry: Why A level chemistry students in England do/not pursue chemistry undergraduate degrees: https://onlinelibrary.wiley.com/doi/full/10.1002/tea.21822

Archer, L. et al. (2020). Learning that physics is 'not for me': Pedagogic work and the cultivation of habitus among A level physics students: https://www.tandfonline.com/doi/abs/10.1080/10508406.2019.1707679

- **The dominant discursive alignment of disciplines such as mathematics and physics with exceptional 'natural talent' makes it hard for many young people, but particularly young women, to see themselves, and/or be recognised by others, as viable students in these fields, even when they attain highly**

It has been extensively noted in the literature that mathematical competence ('being good at maths') is popularly seen as the result of 'natural ability/talent', intellectual exceptionality and notions such as the 'maths brain'. This applies to different extents to a range of STEM subjects, but as the survey analyses reported earlier showed in relation to students' reasons for choosing their particular STEM degree, such ideas are particularly prevalent and popular among maths degree students, with being 'good at' the subject being the most prevalent reason given for their course choice.

Evidence also points to how such notions of 'natural maths talent' are aligned with White, middle-class masculinity, in ways that make it harder for others, such as women/girls[13] and Black and racially minoritised students,[14] to see themselves, and/or be recognised by others, as being 'good at maths'. For instance, as Josh put it at age 12/13: "women have something in their brains that makes them better at stuff like English, Art and all of that, and then men are Maths and stuff".

The ASPIRES longitudinal analyses of young people who took A level Mathematics and then pursued, or not, a maths degree found that over time, almost all of these young people articulated both these stereotypical ideas about 'natural' maths brilliance. As one South Asian, middle-class young man, Kaka, put it at age 13/14: "I'm very intelligent in Maths, that's what I've been told... because of all my grades… When people look at me, they think 'maths'". However, most of them also articulated counter ideas (e.g. that 'working hard' can make someone good at maths). However, there was a shift in balance over time, with those who did not continue with maths being more likely to articulate dominant, stereotypical ideas when younger (as compared with after the age of 16), while those who continued onto maths degrees were more likely to espouse stereotypical ideas around natural maths ability more consistently over time.

Case Study 3: Joanne is a White British young woman whose parents are from working-class backgrounds but had become socially mobile. At 10, she enjoyed maths and was recognised as a high attainer and 'naturally good' at maths. Her exceptional performance was underlined by her being "the first person in school to get through the finals of the Primary Maths Challenge".

However, at secondary school her sense of herself as a 'natural' mathematician started to waver, for instance when she represented her secondary school in a maths competition and did not win, due to her team being unprepared compared with some private school competitors who had been "training for three months". She enjoyed maths through most of her schooling and decided to study A levels in Mathematics and Further Mathematics. She described people who take Mathematics as "very smart… I think you've got to have a mind that's right for" it.

Joanne later dropped Further Mathematics because it was "too much maths", and had started to find greater recognition and meaningful connections between her own identity the fields of biology and chemistry – subjects in which she also attained very highly. She took a degree in natural sciences and, at age 21, when she reflected on how maths attainment is closely related to the quality of maths teaching, said, "I think [our] maths teachers realised kids don't want to do maths for longer than they have to".

Find out more:

Archer, L. and Francis, B. (forthcoming). A longitudinal analysis of discursive constructions of 'being good at maths' among high-attaining students who choose not to pursue a mathematics degree.

- **Capital is important in supporting and realising STEM identity over time**

The ASPIRES longitudinal analyses show how young people's identification with, and persistence in, a particular STEM field is strongly shaped and supported by the extent of subject-relevant capital that they can possess and deploy. This is exemplified by Case Study 4, which focuses on Tom, a young man who went on to take a maths degree.

Tom's case shows how his sense of being 'good/exceptional at mathematics' developed at an early age and was facilitated over time by his continued access to considerable mathematics-related capital through his family, school and out-of-school experiences. This capital helped develop and sustain his sense of self (and being seen by others) as 'naturally able' at maths, which was sustained and transformed into a decision to undertake a maths degree. As the case study illustrates, interactions of identity and capital can create a virtuous circle that can help develop and sustain a young person's recognition as 'gifted' at mathematics, which can, in turn, generate access to further opportunities to accrue more mathematics-related capital, and ultimately support a maths degree trajectory.

Case Study 4: Tom is a South Asian, middle-class young man. His family have rich forms of STEM-related capital, including STEM-related qualifications and careers. Tom described his father and brother as both "interested" and "good at maths", and his uncle as "phenomenal" at the subject.

Tom and his father enjoyed doing maths together. At age 10, Tom described how he loved his father setting him "really hard maths sums" for fun, and talked warmly about how the two enjoyed doing mental maths speed challenges on a popular TV game show – a practice that continued up until he went to university.

Over the years, Tom returned to a pivotal experience in primary school, aged 6 or 7, when he won a class maths competition, being victorious in the final round against the "cleverest boy in the year above". This experience helped develop and reinforce Tom's sense of himself as a natural mathematician who found mathematics "easy", "something I can excel at" and a subject that he "loved doing". His teachers designated Tom as 'Gifted and Talented' at maths at an early age, giving him access to extra workshops, resources and opportunities, which helped further support his maths attainment and identification.

At 14, Tom was selected to attend a two-day mathematics programme at one of the UK's most elite universities, where he enjoyed meeting peers who "love maths as much as I do". He was also given opportunities at school to motivate and tutor younger students in maths and physics, again providing recognition of his maths competence.

Aged 21, Tom was studying for a maths degree, which he was very much enjoying. He expressed a strong, confident identification with maths, describing how he felt he had "a knack" for it, was "becoming a mathematician", and was looking forward to seeing "where maths will take me".

Cases like Tom's exemplify how both capital and recognition can be important facilitators of a young person's STEM identity and trajectory. However, an absence of these can render STEM trajectories more precarious and difficult – as illustrated by the cases of Danielle (Case Study 2) and Brittney (Case Study 9).

Find out more:

Archer, L. and Mendick, H. (forthcoming). Becoming exceptional: The role of capital in the development and mediation of mathematics identity and degree trajectories.

- **While most students feel like they 'belong' on their degrees, this varies considerably between degree subjects. Worries about completing are most notable among students from underrepresented communities**

ASPIRES survey analyses showed that most (70%) of STEM and medicine undergraduates said they felt comfortable and that they belonged on their courses. This is broadly in line with non-STEM undergraduates (62%) and suggests a generally positive picture, albeit recognising that there is a significant minority of students who feel out of place on their courses and who may benefit from greater support. However, these averages hide a considerable range of variation between different subject areas, with **just 55% of computing students, compared with 78% of those taking chemistry, agreeing that they had felt comfortable and had belonged** on their respective degree courses.

While national data shows that most students who withdraw from their degrees do so during their first year of study, the ASPIRES survey analyses also revealed that 27% of continuing STEM students expressed concerns about completing their degree. Across all subjects, students gave similar reasons for these concerns, with academic issues being paramount, alongside financial worries, health problems, the impact of COVID and, for a small number, caring responsibilities and/or social integration issues.

As a general pattern across all STEM areas, those from underserved groups – **women, minoritised students, and students from low IMD backgrounds – were the most likely to worry about not completing**.

Concerns about completion were highest among computing degree students (37%) and much lower among maths and chemistry students (both 18%).

In Case Study 5, Bethany exemplifies these issues, as she felt that her identity and experiences did not fit with a computer science degree. This left her unprepared for the demands of the course, with a sense of not belonging and of having the 'wrong' identity ("I'm not a coder"), which led to her withdrawing from university. Notably, her case underlines the disjuncture between the course entry criteria (where coding experience and knowledge were not required) and her experience on the degree itself, where not having these skills was a strong disadvantage – a point also noted in Gerrard's case study (Case Study 8).

Case Study 5: Bethany is a White woman from a working-class background.She does not have a family history of university participation or working in computer science. At 17/18, she took A levels in English Literature, Sociology and Applied ICT. Her interest in pursuing computer science first emerged around this time.

She started a computing degree but withdrewduring the first year. She described being surprised, but not put off, by the gender imbalance on her degree course and explained that her main reason for withdrawing was because – lacking key skills and experiences – she felt ill-prepared for the course demands. She also described feeling that she "did not fit" with the course and, in particular, did not have the right identity ("I'm not a coder"), which she felt was a requirement for doing well on the course, although coding experience was not among the degree entry criteria.

After leaving, she pursued a successful non-graduate career in retail. While she remained interested in STEM, she reflected at age 21/22: "I don't know if I'd want to work in that field now. I just don't think I'm smart enough to work in it".

Find out more:

Archer, L. et al. (2023). Misfits or misrecognition? Exploring STEMM degree students' concerns about non-completion: https://onlinelibrary.wiley.com/doi/full/10.1002/sce.21794

Holmegaard, H. et al. (accepted with revisions). Feeling the weight of the water: A longitudinal study of how capital and identity shape young people's computer science trajectories over time, age 10 to 21. Computer Science Education.

Godec, S. et al. (accepted with revisions). A missing piece of the puzzle? Exploring whether science capital and STEM identity are associated with STEM study at university. International Journal of Science and Mathematics Education.

Factor 2: Capital

ASPIRES found that the 'right sort' of STEM capital supports STEM identity development and progression within a given field.

Specifically, we found that:

- **Higher status 'Triple Science' GCSE routes are significantly associated with taking A level Science and degree level science**

ASPIRES statistical analyses of data from 6,053 students found that the study of Triple Science[15] at GCSE is closely associated with future science study. Holding other variables constant, including attainment, those students that took Triple rather than Double Science are significantly more likely to pursue A Level Science, and to study science at degree level. Hence Triple Science is significantly associated with an increase in undergraduate participation in science. However, for Double Science (the majority route), the reverse is true. We can interpret this finding as suggesting that taking Triple Science can constitute a form of capital that is significantly associated with pursuing a STEM degree trajectory.

- **Greater (STEM) capital is associated with (smoother) progression but access to the most valuable of capital is unequally distributed, contributing to unequal participation patterns. An absence of facilitating capital can close down progression and/ or make it more precarious**

Longitudinal analyses of young people's trajectories show how possession of valuable forms of STEM-related capital can encourage and support young people's STEM trajectories. This was noted as a factor that (i) supported dominant participation patterns, whereby young people from more socially privileged backgrounds were more likely to possess and deploy STEM-relevant forms of capital, leading to a greater likelihood of pursuing a STEM trajectory (as exemplified by Tom in Case Study 4 and Josh in Case Study 7); and (ii) enabled some students from underrepresented communities to 'buck the trend' and access degrees in disciplines in which they were underrepresented, as illustrated in Case Study 6 by Hannah, a young woman who benefitted from considerable family physics-related capital as well as high attainment, and went on to take a physics degree.

Case Study 6: Hannah is a White, middle-class young woman. Her family possesses considerable STEM-related capital, but particularly physics capital, with Hannah's sibling and sister-in-law both holding postdoctoral physics degrees. From a young age, Hannah aspired to a degree and career in STEM.

At school, Hannah attained highly and coped well with being the "only girl" in her A level Physics class. Like other young women, she saw physics as being a "hard", "difficult" and masculine field ("I guess because it has that connotation of manliness", age 16). However, she also described how, as a young woman, she was proud to be different ("I guess I like surprising people… breaking boundaries").

During her A levels, she explained how she would "like to feel" that she is "good at physics", but worried that she did not "breeze through" the subject like some other, male students. At university, she enjoyed her physics degree but described having to navigate experiences of everyday sexism from some male peers. She navigated these issues by working even harder and becoming one of the top attaining students in her class, which grew her confidence and helped "prove" her physics competence and identity to both herself and others.

Case Study 7: Josh comes from a White British, middle-class background. Neither of Josh's parents attended university, but his dad and brothers worked in IT, and his mum ran an online business. Josh recounted experiences of coding and building a computer at home in his spare time. He told us that his grandparents wanted him to become a mathematician, and his parents encouraged him to maintain maths alongside computing.

He took A levels in Computer Science, Mathematics, Further Mathematics and Physics, achieving top grades in Computer Science and Mathematics. He went on to complete a degree in computing and gained a coveted job in cybersecurity. Aged 20/21, he reflected that his success, and his experience of working less hard than his peers during his degree, had been facilitated by his prior computing experiences, including having the "right set of A levels", with both Mathematics and Computer Science.

In contrast, restricted access to, and possession of, key forms of STEM capital was found to hinder the STEM trajectories of young people from underrepresented communities, even when the young people in question were highly interested and motivated to pursue STEM. This is exemplified by Gerrard in Case Study 8. Like Josh (Case Study 7), Gerrard had high grades in relevant A levels. However, whereas Josh had additional STEM and computing-related capital through his family and extracurricular experiences with computer hardware and software that helped build both his identity and expertise in coding, Gerrard did not. Nor did Gerrard have capital in the form of knowledge of the employment opportunities connected with a maths degree, a subject with which he had a strong affinity – to the extent that he did not realise pursuing maths might have fitted with his working-class, masculine commitment to being a family breadwinner. Due to this absence of capital, Gerrard's computing degree trajectory was more precarious than Josh's.

Find out more:

Francis, B. et al. (2023). An exploration of the impact of science stratification in the English school curriculum: the relationship between 'double' and 'triple' science pathways and pupils' further study of science: https://discovery.ucl.ac.uk/id/eprint/10181214/

Case Study 8: Gerrard comes from a White Eastern European, working-class background. His parents did not have much connection with science or computer science (e.g. at age 10, he said, "They don't really talk about science and stuff"). From an early age, Gerrard loved maths, but this became particularly notable following the family's migration to the UK, when he was in early primary. He described how he began to stand out as a good maths student because of his mathematical competence and his lower attainment in other fields, due to having only just started to learn to speak English.

Over the years he continued to love maths but aged 17/18, he rejected doing a single honours maths degree "because I want to be successful financially as well, just so that I support my parents and give back to them. Because if I only studied what I want to enjoy… I think that's a bit selfish". He felt computing would offer better job opportunities, achieving top grades in A level Mathematics, Further Mathematics and Physics, and going on to a degree in Mathematics with Computer Science. However, he struggled with the course and had to repeat the first year, due to struggling with the computing aspect of his degree.

At age 21/22, Gerrard was questioning whether he still wanted to work in computing and reflected on how he felt at a disadvantage in his degree due to his lack of coding experience: "The skills that you get from computing aren't really learnt from lectures, they're more from just your own practice. Basic stuff is a big hurdle for someone who hasn't done it".

Find out more:

Archer, L. et al. (2017). The "exceptional" physics girl: A sociological analysis of multimethod data from young women aged 10-16 to explore gendered patterns of post-16 participation: https://journals.sagepub.com/doi/abs/10.3102/0002831216678379

- **Young people from less privileged backgrounds, who have less (of the most valuable forms of) capital, were often more reliant on luck to open up access to key forms of capital that enable socially mobile trajectories**

The longitudinal interview sample included 20 working-class young people, of whom 13 became the first in their family to go to university. Analyses of the reasons for these young people's success challenge popular views that attribute social mobility to meritocracy, individual talent and hard work. Rather, most of these young people, as Case Study 9 illustrates, had benefited from a lucky break or relationship (as in CM's fortunate encounter with a restaurant manager who went on to become a lifelong mentor) that opened up new forms of valuable capital, enabling them to go against the grain of social reproduction.

This also applied to overcoming challenges associated with other aspects of inequality, such as gender, as exemplified by Case Study 12, in which Laylany's lucky encounter with a supportive female college tutor was important for supporting her engineering trajectory. As illustrated by CM's case study, the role of luck was not particular to STEM trajectories, but was an important facilitator of social mobility across multiple subject and occupational areas.

Case Study 9: CM is a White British, working-class young man. His mother and father left school aged 16 and 14, respectively. From a young age, CM dreamed of becoming a chef – a goal his parents strongly supported, working hard to encourage his aspirations and give him supportive experiences that they had not had.

At school, CM received much less support. He was placed in "bottom sets" with undiagnosed dyslexia. He experienced "unsupportive teachers" and high staff turnover, and was denied access to high-status science qualification routes and extracurricular provision. As the only boy on his food technology course, he felt isolated. At age 15, while shopping with his mum, CM went into a high-street restaurant to ask for two days of work experience. The manager offered him a week, which led to further work and, over the years, he became CM's close friend and mentor, supporting him at key junctures in his life and career.

By age 21, CM had achieved his dream, becoming a chef de partie in a London restaurant. Reflecting back, CM recognised the key role of his mentor, explaining, "he has given me so many options in life".

Find out more:

Archer, L. et al. (2023). Get lucky? Luck and educational mobility in working-class young people's lives from age 10 to 21: https://www.tandfonline.com/doi/full/10.1080/01425692.2023.2211234

- **Careers education and support is a form of facilitating capital that is inequitably distributed, accessed and activated**

As noted in previous ASPIRES phases, the cohort that we tracked reported patchy and patterned access to Careers Education, Information, Advice and Guidance (CEIAG) during their secondary schooling, whereby students from more privileged backgrounds enjoyed the most and 'best' provision. At age 21, statistical analyses of the ASPIRES survey data showed that access to quality CEIAG was associated with positive outcomes. Specifically, young people who recalled experiencing more and better CEIAG activities at school were more likely to be in education, work or training at age 21/22, and more likely to report life satisfaction, positive future outlooks, and to feel prepared for the future.

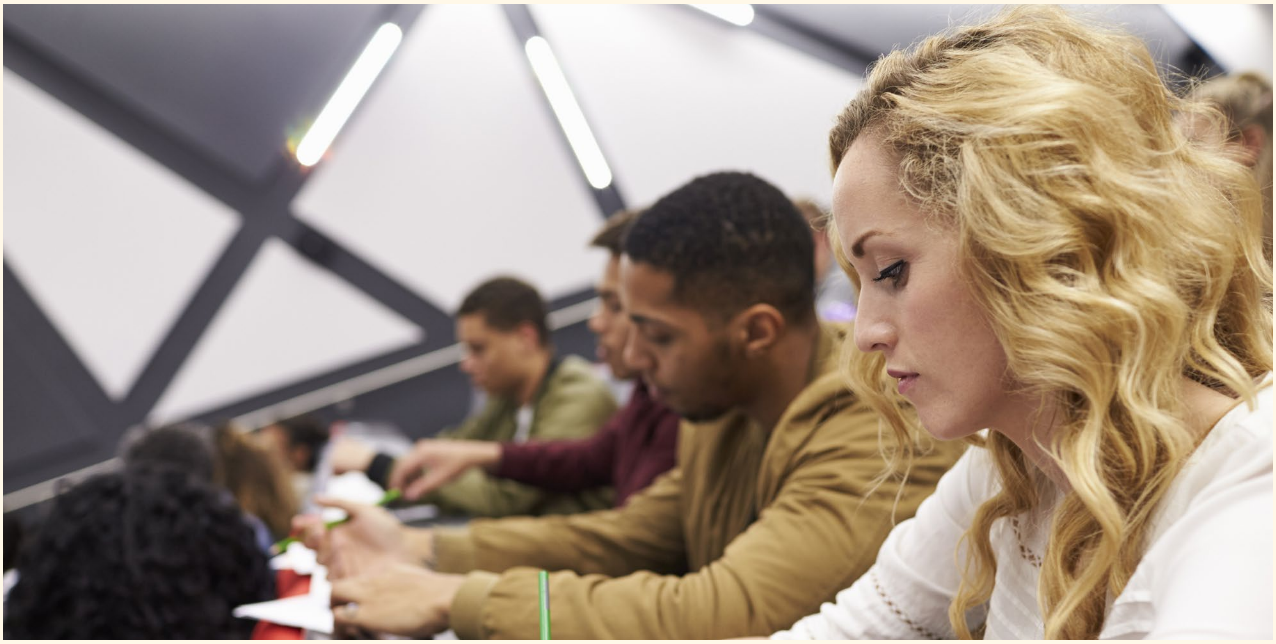
We interpret this as reflecting how the field of school CEIAG is not an equal playing field, and that this potentially valuable resource is not equally experienced by all. In this way, the differential distribution of CEIAG may arguably play a role in reproducing unequal life outcomes, with those who could benefit most from it having the least access to it – particularly young women, racially minoritised, working-class and lower-attaining young people, and those who plan to leave education at 16.

Within the longitudinal qualitative sample, degree students reported differing levels of careers support from their departments and universities, with the most positive accounts relating to CEIAG that was subject-specific and provided through departments. Those who reported being most satisfied and finding the provision most valuable identified high-quality, varied, regular careers provision. This included information, talks and meetings with employers and STEM graduates working within a range of sectors; contacts and opportunities for placements and work experience; plus personalised advice and support for them as an individual.

Find out more:

Moote, J. et al. (accepted subject to revisions). More is more: The relationship between young people's experiences of school-based career information, advice and guidance at age 14 to 16 and wider adult outcomes at age 21/22 in England. Research Papers in Education.

Archer, L. and Moote, J. (2016). *Year 11 students' views of careers education and work experience.* London, KCL. ASPIRES 2 Project Spotlight: https://kclpure.kcl.ac.uk/portal/en/publications/aspires-2-project-spotlight-year-11-students-views-of-careers-edu



Factor 3: Field

ASPIRES found that practices in STEM education can undermine young people's identification with, and progression in, STEM.

The ASPIRES analyses show how specific assumptions, practices and behaviours circulating in the fields of STEM education (from primary through to secondary and university levels) make it harder for young people from underrepresented communities to engage in STEM – even when they are highly interested and motivated to pursue STEM. These factors also increase the risks and costs of STEM participation for those from underrepresented communities. For example:

- **Restrictive entry requirements, assumptions about who STEM is 'for' and the costs of HE participation can limit access to STEM qualification routes, but particularly for those from less privileged social backgrounds**

Longitudinal analyses highlighted how the dominant culture and practices found within STEM disciplines and the education system can make it difficult for all young people, but particularly those from non-dominant backgrounds, to persist in STEM. These barriers can take many forms, including educational practices such as grade severity (where A levels in Physics and Chemistry are graded more harshly than other subjects, leading to stricter educational gatekeeping for access to these subjects, as exemplified by Danielle in Case Study 2); more informal and interpersonal practices (such as when teachers or family members may offer more encouragement to those who 'fit' the traditional profile of a STEM student); and the ways in which the dominant culture and ethos of a discipline can create a 'chilly climate'[16] for those who do not fit the mould of the White, male, privileged subject student.

As noted in wider research,[17] the risks and costs associated with university study are also differentially structured, with those from less privileged communities experiencing university as disproportionately costly and risky, compared with their more privileged peers. These issues are exemplified by Brittney in Case Study 10. Her experiences illustrate how the decision of whether or not to go to university is not made on an equal playing field.

Young people from low-income families may start at a disadvantage, as they have not had the same access to knowledge and experience of HE and STEM-related forms of capital. They may receive less encouragement and support from key adults to apply and, importantly, the financial and social risks and costs of participation are disproportionately high for these young people. For instance, the risks of debt and 'failure' are much higher because they do not have the financial, social and cultural 'safety nets' of their more affluent peers. For these young people, not pursuing a STEM degree trajectory can constitute a pragmatic, rational strategy for managing disproportionate risk.

Case Study 10: Brittney is a White British, working-class young woman. Since we met her at age 10, she had loved chemistry and aspired to do "something to do with chemistry… because that's my favourite part of science". At school, she was unable to participate in science-related extracurricular enrichment opportunities because, as her mother – a single parent on a low income – explained, the cost and logistics were unfeasible.

Brittney took A levels in Chemistry, Mathematics and History. She had to work part-time throughout her A levels in order to contribute financially to the family, although she worried this might affect her grades. She attained well in her A levels, but Brittney's college tutor advised her against applying to university at 18, suggesting she "leave it for a bit and then come back to it when you're ready", as the tutor herself had done. This decision chimed with Brittney's mother, who had left school at 16, as she worried about Brittney accruing debt by going to university.

At age 18, Brittney took up full-time employment in the supermarket where she had worked for the past couple of years, and was working her way successfully up the management structure. Reflecting back on her daughter's trajectory at age 21, her mother explained: "Brittney had a real focus with chemistry – I think it was her own aspiration inside, she really enjoyed it". However, she was pleased that Brittney was carving out a good path for herself, with enough money to allow her to take holidays and enjoy life.

- **STEM education can negate some young people's STEM capital and make them feel out of place, particularly those from underrepresented communities**

As noted earlier, STEM-related forms of capital can be important facilitators of a STEM trajectory. However, ASPIRES analyses also found that even when young people possessed valuable and significant forms of STEM capital, these could be negated by their experiences of school science. This is illustrated in Case Study 11 by Vanessa, whose science-related Black African cultural capital strongly facilitated her interest in science and aspiration to become a forensic scientist. Yet this capital was devalued by inequitable practices within school science, which closed down her desired STEM trajectory. Educational gatekeeping, such as the A grade requirement for progression to A level Chemistry, paralleling the devaluing of her father's pharmacy degree from Nigeria, plus her experiences in school science, all played a part in persuading her to give up her aspirations.

Case Study 11: Vanessa is a working-class young woman of Black African heritage. From her first interview aged 10, she was enthusiastic about science, which she ascribed to her African heritage and her father, who had a pharmacy degree from Nigeria and strongly supported her science aspiration – buying her science kits, paying for private tutoring and personally encouraging her.

Vanessa described herself as not "girly" and became particularly interested in forensic science through the American TV series, *CSI: Miami*, appreciating the diverse cast, which included a Black female scientist role. Despite studying triple science at GCSE, the college that she attended dissuaded students with B grades from continuing with subjects like Chemistry A level. She started Biology A level, but felt that her B grade attainment was not sufficient and withdrew.

At 18 she reflected back on her thwarted science trajectory, saying, "my love for it just wasn't enough to get me through… I wish my grades were a bit better and I found it easier, but… I just don't like how I'm feeling". She studied sociology instead and her interest in forensics morphed into an interest in criminology, which she pursued at university.

Find out more:

Archer, L., Godec, S. and Moote, J. (2023). "My love for it just wasn't enough to get me through": A longitudinal case study of factors supporting and denying black british working-class young women's science identities and trajectories: https://link.springer.com/chapter/10.1007/978-3-031-17642-5_2

- **Peer sexism is an ongoing issue that negatively impacts women STEM students**

Analysis of ASPIRES survey data from STEM degree students showed that women STEM undergraduates reported more sexism than those studying non-STEM fields, with women in physics (50%) and engineering (30%) the most likely to do so. Experiences of sexism were most frequently attributed to male peers.

Interviews with women STEM students in the longitudinal sample revealed that peer sexism usually involved everyday acts of disdain and disrespect by male peers, such as questioning women's academic legitimacy, and ignoring and/or patronising them. For instance, as Mienie (a chemistry degree student) explained: "In labs, when I'm partnered up with a male lab partner, I feel like they sometimes don't take you that seriously". Likewise, Hannah (physics degree student) reflected: "Sometimes I'll say something and they [male students] don't listen properly. It's really frustrating. It's not a super-diverse course, it's mainly white men. And if I say something, they just assume that it's wrong".

Experiences of sexism were not only found on degree courses, but were also reported in school and college settings, as exemplified by Laylany in Case Study 12. Her experiences underline (i) the importance and value of support from key adults in noticing and challenging sexism; and (ii) how such experiences place a burden of effort and responsibility on young women to endure and navigate sexism in order to maintain a STEM trajectory.

The wider literature also draws attention to barriers to women's postgraduate progression in STEM. For example, the RSC 'Breaking Barriers' report highlights the negative impacts of a masculine academic culture on women's progression and self-esteem, as a result of exclusion, bullying, harassment and caring responsibilities.[18]

Find out more:

Free print and digital copies of "Step up! Be an Anti-Sexism Ally in STEM" poster and information leaflet are available from: www.ucl.ac.uk/ioe/aspires

Archer, L. et al. (2023). Misfits or Misrecognition? Exploring STEMM degree students' concerns about non-completion. Science Education: https://onlinelibrary.wiley.com/doi/full/10.1002/sce.21794

Case Study 12: Laylany is a White British, working-class young woman who took a vocational route, gaining a diploma in engineering, followed by an apprenticeship and a full-time job in a local engineering company. She described engineering as a "more manly" field but felt that it fitted well with her own "not girly" gender identity. Her interest in engineering was initiated and fostered through her many years in Air Cadets, where she also became accustomed to being in a predominantly male environment.

At college, she experienced persistent sexism from her male engineering peers, as she recalled: "things like [saying] 'oh, go back to the kitchen'… horrible, stereotypical sexist comments like 'oh, you don't belong in an engineering world'". A female tutor in the college supported Laylany and helped address the behaviours. In the workplace, Laylany experienced similar sexism from male colleagues: "various sexual remarks and their girly comments: 'Why are you here?'". However, Laylany was strong and determined, challenging and quashing these behaviours: "since I've been there, they've completely changed their attitude… They wouldn't dare to do that now – they'd get a blast for it from me").

Laylany continued to enjoy her work, although she expressed frustration when she was moved into a less 'hands-on' department in the company. However, she remained highly motivated and determined to progress her engineering career and at the time of her last interview, she was successfully progressing.

7. STEM students' plans for life after graduation

Analyses of the ASPIRES survey responses from STEM degree students showed that most were planning to enter full-time work or postgraduate study, and to stay within their subject area. There was some variation between specific subject areas (see Table 2), ranging from around two thirds (67%) of chemistry students to three quarters (75%) of maths students planning to get a full-time job after graduation.

There were more notable differences between students in terms of whether or not they planned to stay within their own disciplinary area after graduation. The highest percentage was found within engineering, where 82% of students planned to stay in engineering (with a further 13% indicating that they might do so, and only 3% wanting to work in a different sector). In comparison, just 21% of chemistry students anticipated continuing within a chemistry-related route after graduation.

Table 2: Students' plans for full-time work after graduation by STEM degree subject

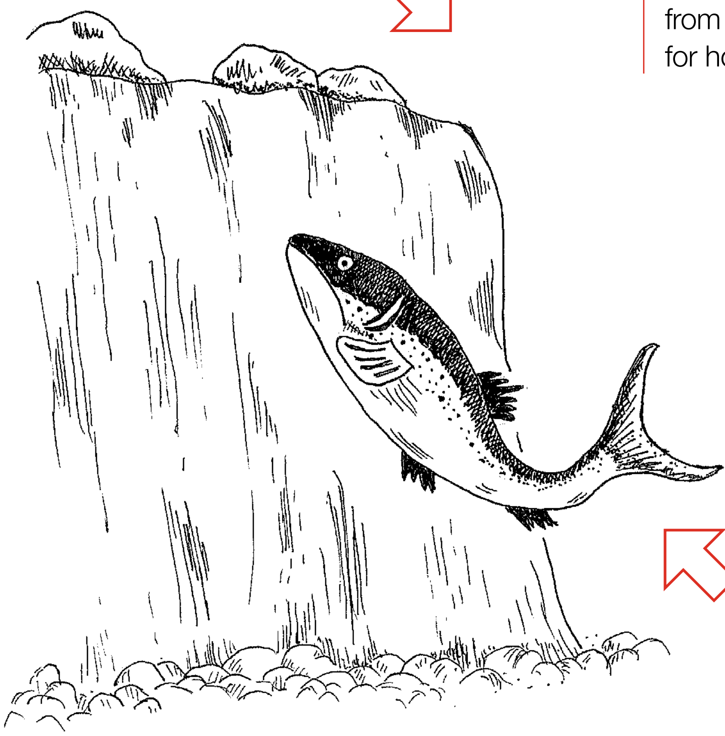
Students' plans after graduation	Degree subject			
	Mathematics	Chemistry	Computing	Engineering
Enter workforce	75%	67%	73%	71%
Stay within subject discipline	66%	21%	64%	82%

8. Recommendations for policy and practice

This report has summarised findings from the ASPIRES3 study, concerning the factors shaping young people's STEM trajectories from age 10 to 22. In this section, we consider the potential of these insights to inform STEM education policy and practice.

Over the years, there have been many interventions and initiatives designed to foster increased and diversified participation in STEM. Often these have focused on trying to support individuals to aspire to and choose STEM routes by providing them with relevant knowledge, information, motivation and/or experiences. While there may be merit in such approaches, we suggest that to achieve more sustainable change at scale, it is important to consider the ways in which STEM education systems, relations and practices also need to change. That is, we need to understand and address the factors that underpin the barriers to increased and wider participation in STEM, and which sustain inequities.

STEM education practices and social inequalities constantly push back and make progress difficult



Young people must exert considerable, constant effort to make progress in their STEM trajectories

One way of thinking about this is through the **analogy of salmon swimming upstream**. The salmon (representing a young person attempting to pursue a STEM trajectory) has to exert constant, considerable effort to navigate a fast-flowing river with steep cascades (representing the STEM educational field) that are constantly pushing back against their progress. Initiatives designed to support more (and more diverse) young people to successfully navigate and achieve a STEM trajectory could follow the strategy of trying to strengthen individual salmon, but these efforts will need to be constantly remade for future generations.

In contrast, **efforts to change the waterway (to smooth the journey) may support greater success for all**. As detailed here, many of our recommendations are based on the idea that improved participation in STEM might be best facilitated through changing 'the field' (e.g. STEM education practices, relations and conditions) and addressing the practices that sustain inequitable patterns of STEM participation, rather than solely trying to change or support individual young people's attitudes, aspirations and choices.

As detailed, we identify six main recommendations for policy and practice from our study findings, and suggest ideas for how these might be operationalised.

Recommendation	Ideas for how to address this in policy	Ideas for how to address this in practice
1 Support and value young people's STEM identities over time and across contexts	Funders might usefully review the balance of support offered for short vs. longer-term interventions, and consider shifting towards longer-term interventions with key communities. STEM organisations of all sorts might explore the potential to create a better connected, more comprehensive and coherent STEM engagement 'ecosystem', in order to offer all young people clearer 'pathways' over time and across spaces that can enable and support STEM trajectories. This could include mapping provision geographically and demographically to ensure equitable distribution and provision, and to support the establishment of both local and national engagement pathways (to enable young people to better access and navigate provision). STEM careers education, work experience and outreach providers might consider how to mitigate the patchy and patterned distribution of this form of capital, and how this is exacerbated by self-referral models of provision. Instead, strategic planning could consider how to best reach those who could most benefit. Partnership working with other community organisations may be helpful in this respect. STEM education policymakers might consider how to increase support for, and uptake of, opportunities and resources that (i) promote critical professional reflection among educators and practitioners; and (ii) offer insights into how to support learner STEM identities and capital.	Teachers, educators and pedagogical trainers might find pedagogical approaches and resources such as the Equity Compass and the (Primary) Science Capital Teaching Approach (P/SCTA) helpful for building understanding of the issues and scaffolding critical professional reflection towards action. In particular, they may use such approaches to identify and implement ways to actively support and augment young people's STEM identities and capital, helping them to find meaningful connection with STEM and see the relevance of STEM learning to their current and future lives.[19]

Recommendation	Ideas for how to address this in policy	Ideas for how to address this in practice
2 **Challenge ideas of STEM competence (but particularly in areas such as maths) as being based on 'natural talent'**	Policymakers could usefully review the extent to which these ideas are reinforced and perpetuated by a range of common educational practices (such as pedagogy, attainment-based grouping practices, Gifted and Talented programmes, tiered examination entry) and develop action plans to address this at both strategic levels (e.g. in England, ending grade severity in A level Chemistry and Physics[20]) and operational levels (e.g. providing professional development to enable educators to be aware of, and challenge, everyday practices that reinforce such ideas).	Practitioners and those who support initial and continuing professional learning can draw on existing resources and approaches to (i) increase their understanding of how such ideas sustain unequal patterns of STEM participation and damage many young people's relationships with the subject; (ii) help them to identify changes to their practice that can enable more young people to feel good at STEM by centring ideas of equity,[21] broadening ideas about who/what counts and gets recognised as being good at STEM, and using assets-based approaches (e.g. P/SCTA); (iii) clearly communicate to others how ideas of 'natural brilliance/ability'[22] and the 'science/maths brain' are myths that hinder more inclusive STEM participation.
3 **Address the impact of Double/ Triple science GCSE qualification routes on STEM progression**	Policymakers in England could usefully: i) undertake further research into the reasons for poor STEM progression outcomes from Double Science, including reviewing curriculum levels for parity, or otherwise; and (ii) explore the potential for alternatives, based on available evidence and feasibility analyses.	Educators and STEM organisations may wish to consider communicating to teachers and parents the evidence and implications of GCSE Double/Triple science allocations/choices for A level and degree level STEM participation.
4 **Challenge peer sexism on STEM degrees**	Higher education policymakers, professional societies, senior leaders and equality organisations might usefully consider how they can support and encourage practitioners to understand, recognise and address sexist language and behaviours among students, particularly in areas such as engineering, computing and physics. It may be helpful to integrate this work with Athena SWAN departmental task groups.	HE staff and students can support anti-sexism practice and initiatives by sharing and promoting resources such as the ASPIRES 'Step Up' anti-sexism ally poster and/or by engaging with wider anti-sexism initiatives aimed at tackling the sources of sexism. Practitioners can reflect and adapt their practice to be more inclusive using tools such as the Equity Compass.[23]

Recommendation	Ideas for how to address this in policy	Ideas for how to address this in practice
5 **Support more equitable experience and retention on STEM degrees, particularly among students from underrepresented communities**	Higher education policymakers, senior managers, professional societies and organisations concerned with equity in STEM participation might consider giving this issue greater policy consideration and prominence, especially in disciplines such as computing and engineering – both generally and specifically regarding the retention and progression of STEM students from low-income backgrounds. It may be helpful to engage, and coordinate with, charities and initiatives that focus on supporting underrepresented and first-generation students. Consideration might usefully be given to how targeted support might be directed strategically to ensure it reaches those who could most benefit – not only in terms of supporting students directly, but also ensuring that staff are equipped to recognise the issue and address it through their own practice.	Practitioners can engage in critical professional reflection and professional development, with the goal of enhancing their understanding and action to improve retention and belonging among STEM students. This will be useful and relevant across STEM areas, but is particularly valuable in disciplines such as computing, maths and engineering, which record higher levels of attrition.
6 **Facilitate greater access to key forms of social and cultural capital for young people from underrepresented communities, to support social mobility in STEM and beyond.**	Funders, policymakers and organisations concerned with supporting more inclusive STEM participation might usefully consider how they can best support young people from underrepresented communities to access to key forms of social and cultural capital to support their STEM trajectories. Funding longer-term interventions that foreground the generation of mutual trust and supportive relationships between young people and key adults may be particularly helpful, along with targeted measures to reduce the costs and risks of higher-level STEM routes for young people from underrepresented communities.	Educators and practitioners can use tools and approaches such as the SCTA to help reflect on how they might best build supportive and equitable relationships with young people that also help redistribute valuable forms of capital (e.g. knowledge, experiences, social contacts, qualification routes). Explications and the principles of 'caring' pedagogy[24] may also provide useful insights.

References

1 The ASPIRES research focuses on social identities and inequalities of gender, race/ethnicity and social class. These are conceptualised as socially constructed, embodied and intersectional phenomena, recognising that they constitute only some of a wider range of important dimensions of injustice. We recognise the plurality of expressions of gender identity, however due to data limitations, this report focuses only on the responses of participants who self-identified as men or women.

2 Royal Society of Chemistry (RSC). (2022). – Written evidence (PSU0036), available at: https://committees.parliament.uk writtenevidence/111185/pdf/

3 The A Level data are collected by National Statistics from Awarding organisations that deliver examination entries and results for all qualifications of students aged 16 to 18 in England. The A Level data analysed here are from the 'A Level and other 16 to 18 results 'release series from 2012/13 to 2021/22. The data set only gives subject entries by sex, rather than any other demographic variables.

4 This publication reports analyses of data provided by the Higher Education Statistics Agency (HESA), based on the student records from 2015/16 to 2020/21, Copyright: Higher Education Statistics Agency Limited. Analyses were conducted by Emma Watson for the ASPIRES project. Neither the Higher Education Statistics Agency Limited nor HESA Services Limited can accept responsibility for any inferences or conclusions derived by third parties from data or other information supplied by HESA Services. Only England domiciled students, aged 18 to 24 at the time of data collection were included in the analysis. People with unknown ethnicities, genders, IMD and school type were included in totals and percentage calculations. HESA data have been treated according to the HESA rounding and suppression methodology (remove counts of 22.5 for data relating to people (FTE) from the dataset) (https://www.hesa.ac.uk/about/regulation/data-protection/rounding-and-suppression-anonymise-statistics). Percentages were calculated after rounding and suppressing data. Undergraduate counts are a sum of Full-Time Equivalent (FTE) counts for those in first year of study only on a first degree or other undergraduate degree. Attrition data shows FTE sums for individuals who left their course without an award before the end of first, second or third year of study, unless specified otherwise.

5 Data provided by the Higher Education Statistics Agency (HESA) is based on the student records of England-domiciled students from 2015/16 to 2020/21. People with unknown ethnicities, genders, IMD and school type were included in totals and percentage calculations. HESA data have been treated according to the HESA rounding and suppression methodology (https://www.hesa.ac.uk/about/regulation/data-protection/rounding-and-suppression-anonymise-statistics). Percentages were calculated after rounding and suppressing data.

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

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

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

9 The ASPIRES3 sample included 732 young people who were studying for, or had completed, a STEM (523) or high-status medicine degree, with the following breakdown: Medicine, 209; Chemistry, 75; Biology, 81; Physics, 35; Computer Science, 103; Engineering, 105; Mathematics, 79; Other STEM degrees, 45.

10 Overall, the sample of STEM current and past students identified as follows (STEM + high status medicine degree student combined numbers in brackets): Gender: 197 (346) women; 305 (363) men; 21 (23) other/nonbinary/identified in another way. Ethnicity: 345 (434) White; 26 (46) Black; 83 (152) South or East Asian; 63 (92) Other; 6 (8) unknown or did not respond. IMD: 96 (145) IMD1 (most deprived); 122 (167) IMD2; 119 (162) IMD3; 95 (140) IMD4; 91 (118) IMD5 (least deprived).

11 Godec, S., Archer, L., Moote, J., Watson, E., DeWitt, J., Henderson, M., and Francis, B. (under review). A missing piece of the puzzle? Exploring whether science capital and STEM identity are associated with STEM study at university.

12 Jenkins, R. (2006). *Pierre Bourdieu.* (Rev. ed.). London: Routledge.

13 e.g. Walkerdine, V. (1998). *Counting girls out.* London: Falmer; Mendick, H. (2005) A beautiful myth? The gendering of being/doing 'good at mathematics'. *Gender and education, 17*(2), 203-219; Mendick, H. (2006). *Masculinities in mathematics.* McGraw-Hill Education (UK); Chronaki, A., & Pechtelidis, Y. (2012). "Being good" at mathematics: Fabricating gender subjectivity. *REDIMAT-Journal of Research in Mathematics Education*, *1*(3), 246-277.

14 e.g. Walker, E. N. (2011). Supporting giftedness: Historical and contemporary contexts for mentoring within Black mathematicians' academic communities. *Canadian Journal for Science, Mathematics, and Technology Education. 11*(1), 19-28; Walker, E. N. (2012). Cultivating mathematics identities in and out of school and in between. *Journal of Urban Mathematics Education, 5* (1), 66-83; Walkerdine, V. (1998). *Counting girls out.* London: Falmer.

15 In England, science courses from age 14 to 16 have been divided into 'Double' and 'Triple' science, with the latter being the higher-status route (equivalent to three GCSEs). This is taken by approximately a quarter of all students, compared with the Double award, which is taken by the majority of young people and is equivalent to two GCSEs.

16 e`.g. Shakeshaft, C. (1995) Reforming science education to include girls. *Theory into Practice*, 34, 74-79.

17 Archer, L. Hutchings, M. and Ross, A. (2003). *Higher education and social class*. London, Routledge Falmer.

18 Royal Society of Chemistry, *Breaking The Barriers* report: https://www.rsc.org/globalassets/02-about-us/our-strategy/inclusion-diversity/womens-progression/media-pack/v18_vo_inclusion-and-diversity-_womans-progression_report-web-.pdf (rsc.org)

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

20 Ofqual. (2018). *Inter-subject comparability in A level sciences and modern foreign languages*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757841/ISC_Decision_Document_20.11.18.pdf;
For data from 2023, see: https://ffteducationdatalab.org.uk/2023/08/a-level-and-other-level-3-results-2023-the-main-trends-in-grades-and-entries/

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

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

23 See The Equity Compass: A tool for supporting socially just practice: https://yestem.org/wp-content/uploads/2021/09/Equity-Compass-Teacher-Edition.pdf

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

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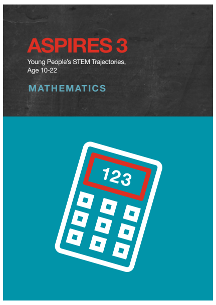
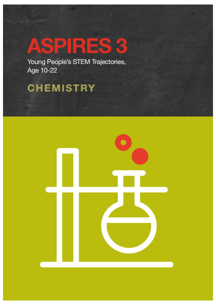
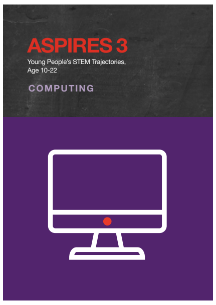
Resources

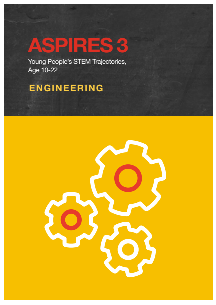
Resources for policy and practice from the ASPIRES and sister projects:

ASPIRES 3 subject-specific summary reports:



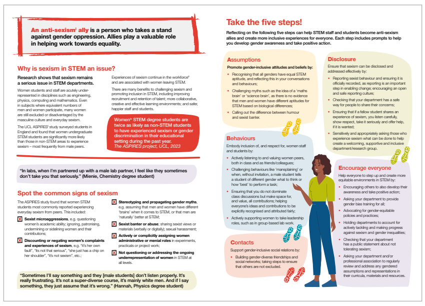






ASPIRES 3 free to print and download anti-sexism resources for university departments:

"Step up! Be an Anti-Sexism Ally in STEM" poster and information leaflet are available from: www.ucl.ac.uk/ioe/aspires



Resources to support inclusive STEM policy and practice from our sister projects:

The Science Capital Teaching Approach (available in English, Welsh and Norwegian): https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/stem-participation-social-justice-research/science-capital-teaching-approach

The Equity Compass – a framework that helps educators to reflect on their current practice and develop equitable practice, with bespoke versions for teachers, senior leaders/governors, funders, informal STEM educators and STEM Ambassadors: https://yestem.org/tools/the-equity-compass/

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