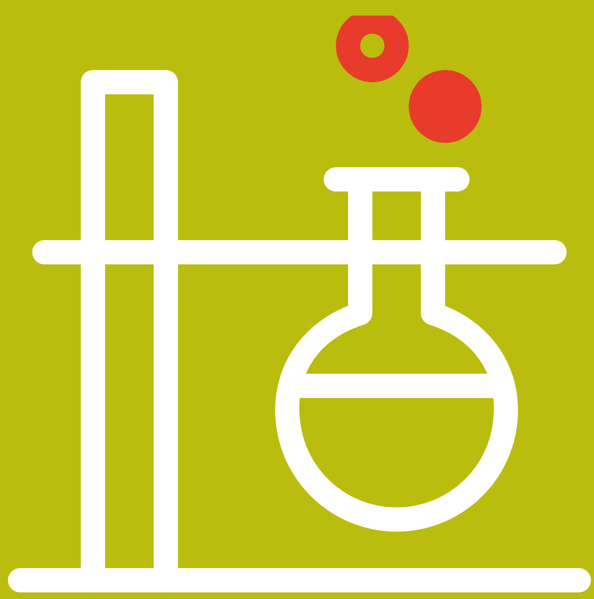
ASPIRES 3

Young People's STEM Trajectories, Age 10-22

CHEMISTRY

Summary of Contents



1. Executive Summary

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

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

Key Findings

Who studies chemistry at advanced and degree level in England?

Analyses of HESA and National Statistics data show that:

- **Participation in chemistry A level has remained fairly stable** during the decade from 2012 to 2022, at an average of 19.8% of the cohort. **It is the third most popular STEM A level (after maths and biology)**;
- 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. **Chemistry is one of the most gender-balanced STEM subjects** (e.g. 55.4% of those taking chemistry A level in 2020/21 were female);
- **The percentage of students taking chemistry at degree level is comparatively lower,** being consistently the 5th most popular STEM degree subject between 2015 and 2021, and showing **a slight decline in enrolment from 2015/16**;
- **Participation in chemistry degrees remains the most gender balanced of all STEM degrees.** For instance, in 2020/21 in England, 47.7% of chemistry undergraduates were women, compared with just 14.1% in computing (and with women being overrepresented in biological sciences);
- As is the case for a number of other STEM degree areas**, students from the most socially deprived quintile are underrepresented in undergraduate chemistry** and those from the most advantaged quintile are overrepresented;
- At degree level, **Black students remain underrepresented in STEM,** although the percentage of Black students varies considerably between STEM subject areas, being lowest in physics and highest in computing. Chemistry sits between these and is **slightly more ethnically diverse compared with the average for all STEM subjects**;
- **Rates of non-completion are relatively low among chemistry degree students, compared with other STEM degrees.** For instance, in 2019/20, **4.3% of first-year chemistry undergraduates aged 18 to 24 in from England withdrew from their degree** with no award (compared with 7.4% in computing and 6.5% in engineering in 2019/20);
- Most withdrawals happen within the first year but ASPIRES survey data suggests that a notable proportion of students in later years of study *also* express concerns about completion, although this figure is lower in chemistry than for many other STEM subjects (18% of chemistry students, compared with 27% of all STEM students). Across all subjects, concerns most often relate to academic issues and are **most frequently expressed by women, minoritised students, and students from low IMD backgrounds.**

What shapes young people's chemistry trajectories?

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

- The **primary reason given by chemistry students for their degree choice is subject liking/interest/passion** (33%). This is similar – albeit at a slightly lower level – to reasons given by computing (50%) and engineering (50%) students for their degree choices (but differs from maths students, who primarily chose their degree because they felt good at the subject);

- Chemistry students' **second most popular reason for their degree choice was feeling good at the subject** (23%), whereas engineering and computing students cited positive views of jobs, and maths students cited subject liking/interest/passion;
- Similarly to other STEM subjects, over half (54%) of the reasons given by suitably qualified young people for *not* taking a chemistry degree reflect subject dislike/no interest/hate. Secondary reasons for not taking chemistry related to not feeling good at it (26%) – there were no clear patterns between different STEM subjects with regard to secondary reasons for not taking these subjects;
- Analyses of the longitudinal qualitative data show how **students' choices are influenced by the extent of the fit between their identity, capital and the field in question, which shapes the extent to which chemistry qualifications and pathways are felt to be 'for people like me', or not**. In particular:
  - **Chemistry-related social, cultural and economic capital is important for making a chemistry identity and trajectory possible and desirable**. Where young people experienced a personal connection with chemistry, this facilitated a chemistry trajectory. Positive experiences of chemistry outreach were also beneficial, although not widespread;
  - Generally, young people who took chemistry A level but chose not to pursue it at degree level **still found chemistry interesting, but had less access to chemistry-related capital, often found the subject 'harder' than other subjects, and received less explicit encouragement to pursue it**;
  - The association of **chemistry with masculinity,** and the existence of **other options that felt easier to access**, had preferable job prospects, resonated personally with young people and/or were areas in which young people benefitted from greater support, were additional reasons why A level students who found chemistry interesting chose not to pursue it at degree level;
  - Despite being a fairly gender-balanced degree route, young women in the qualitative sample still experienced the field of chemistry as being gendered and aligned with masculinity, which mediated their identification with the subject and was associated with decisions not to pursue the subject after graduation.
- Generally, chemistry degree students expressed relatively positive views of their courses, particularly in terms of feeling comfortable and a sense of belonging. For instance, **over half (59%) of chemistry degree students felt well prepared for their courses by A levels, which was broadly in line with other STEM degree areas;**
- **The majority (78.3%) of chemistry students felt comfortable and that they belonged on their course –** a figure that was **notably higher than found among STEM degree subjects** (which ranged from 55% in computing to 65% in mathematics);
- While only **22% of chemistry degree students felt that their course was good value for money,** this was broadly in line with those studying for other STEM or medicine degrees (average 28%);
- Of those students who were studying for, or had recently completed, a chemistry degree, **most (67%) planned to enter the workforce after graduation –** a figure that is slightly lower than found among maths (75%), engineering (71.4%) and computing students (73%);
- Chemistry students differ considerably from other STEM students in the **comparatively low proportion (21%) planning to stay within their field of specialism** (compared with around two thirds of computing and maths students, and 82% of engineering students).

Key Recommendations

From the overall study findings, we identify six main recommendations for policymakers and practitioners who want to support increased and more diverse participation in STEM. These also apply to supporting young people's chemistry trajectories:

1. Support, value and grow young people's chemistry identities and capital 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 and 'masculine' culture within chemistry and STEM degrees.

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

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

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

Chemistry

2. What are the patterns in participation in A level and undergraduate chemistry?

In the UK, there are concerns about skills gaps in chemistry, particularly among chemists with digital and business skills, and gaps resulting from poor retention of teachers and researchers.[1] A level and undergraduate chemistry courses are the most gender balanced of all STEM subjects. They also have similar patterns of participation by social class and race/ethnicity as other STEM subjects. However, chemistry becomes increasingly elite at higher levels, with falling numbers of women, Black people and people from lower IMD quintiles. For example, as cited by the Royal Society of Chemistry: "At professorial level, the representation of women falls to only 9% – even lower than physics, where, even though 20% of undergraduates are female, 10% of professors are female".[2]

In this report, we summarise findings from the ASPIRES project which provide evidence that the factors shaping engagement in chemistry are structural rather than individual, relating to economic stratification and to cultural ideas about who can do chemistry, rather than reflecting learners' innate interest or skills in chemistry.

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

As Figure 1 shows, **participation in A level Chemistry has remained at around 19.8%**, consistently below Mathematics and Biology and above Physics, Computer Science and Further Mathematics. Its position above Physics may be due to A level Chemistry's role as a gatekeeper into popular fields of study such as medicine, which likely also contributes to the low take-up of undergraduate chemistry courses relative to A level.

As Figure 2 shows, **Chemistry is the most gender balanced of STEM A levels, with 55.4% of those undertaking A level Chemistry in 2021/22 being female**.

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

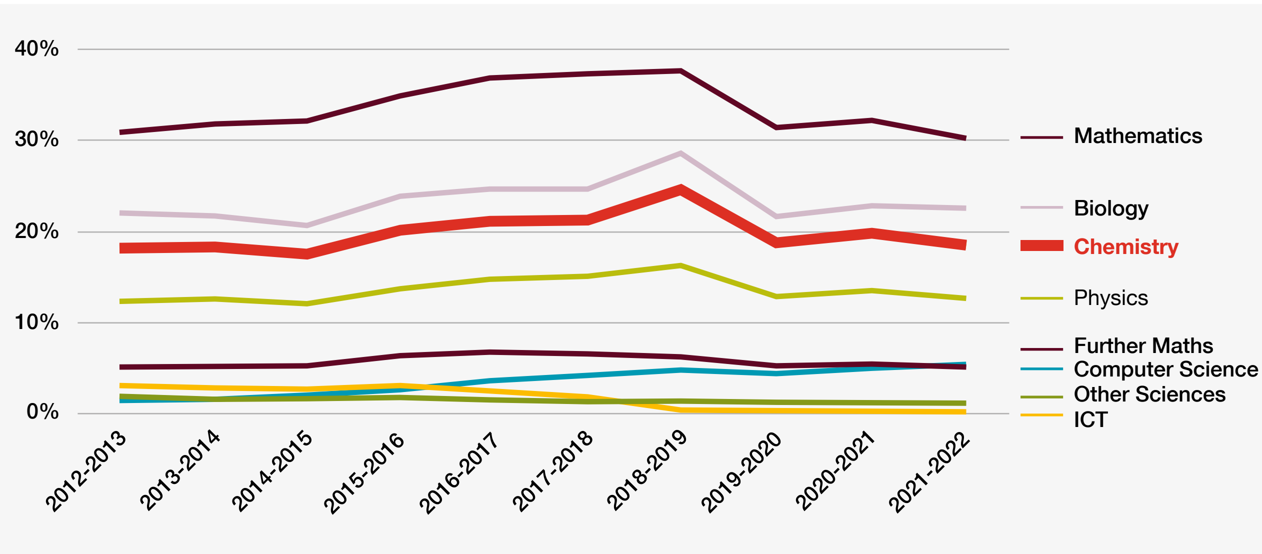
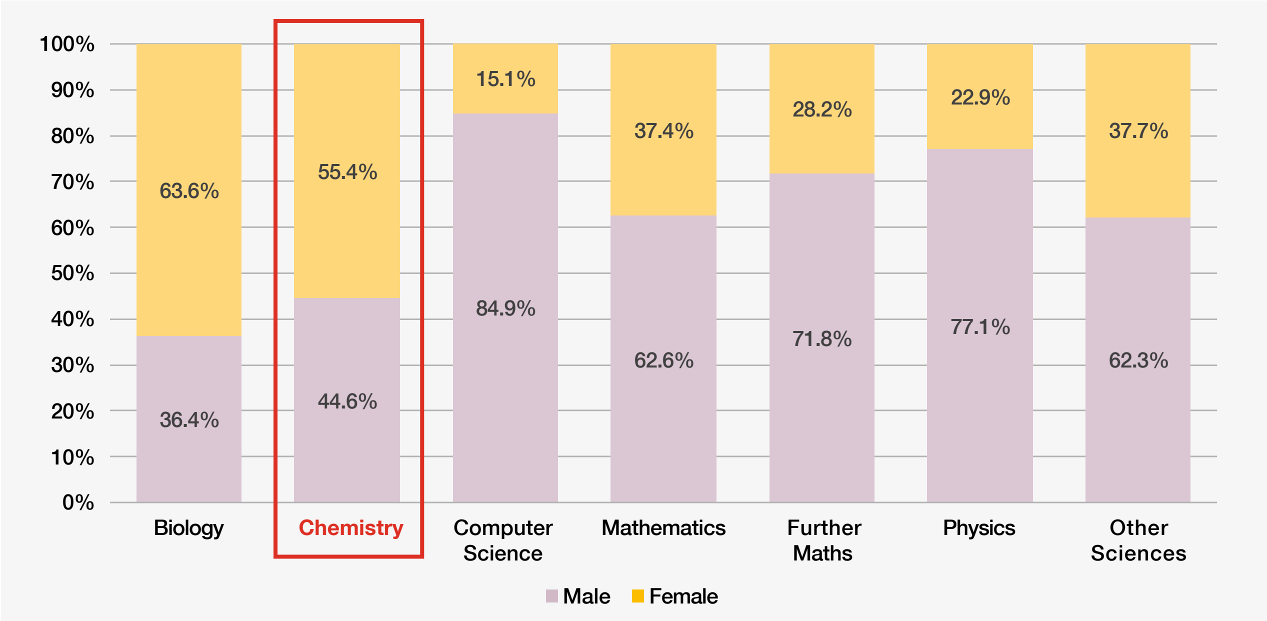


Figure 2: Percentage of male and female students making up each STEM A level cohort in 2021/22



Moving to undergraduate level, in 2020/21, 2.1% of first-year undergraduates from England were studying chemistry,[5] representing – as Figure 3 shows – a slight decline from 2015/16. Figures 4, 5 and 6 show breakdowns of chemistry undergraduates by gender, race/ethnicity and IMD quintile for 2020/21, relative to other STEM subjects and non-STEM undergraduates.

As at A level, undergraduate chemistry is the most gender-balanced of all STEM subjects, with women constituting a little under half of UK chemistry degree enrolments. However, studies have drawn attention to barriers to women's postgraduate progression in chemistry. These include unconscious bias and difficulties in creating networks, choosing a subfield in which to work, managing financial and career insecurity, and the negative impacts of academic culture on women's progression and self-esteem as a result of exclusion, bullying, harassment and caring responsibilities.[6]

Chemistry degrees are slightly more ethnically diverse than the average for STEM degrees overall. As with gender, issues of underrepresentation become more acute at higher levels. For instance, in 2020/21, 9.5% of chemistry undergraduates identified as Black, compared with 7.8% of all STEM degree students. The Royal Society of Chemistry collated evidence on this in 2022, finding that: although "Black students are well-represented at the undergraduate level compared to the UK population", there is a significant decline in representation between undergraduate and PhD level, which continues through academic employment levels, with "0% professors who are Black". The report concludes that chemistry is "losing Black students earlier as compared to the rest of STEM".[7]

As is the case for a number of other STEM degree areas, **students from the most socially deprived quintile are underrepresented in undergraduate chemistry** and those from the most advantaged quintile are overrepresented.

For instance, in 2020/21, 16.2% of chemistry undergraduates were from IMD1, whereas 26.3% were from IMD5.

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

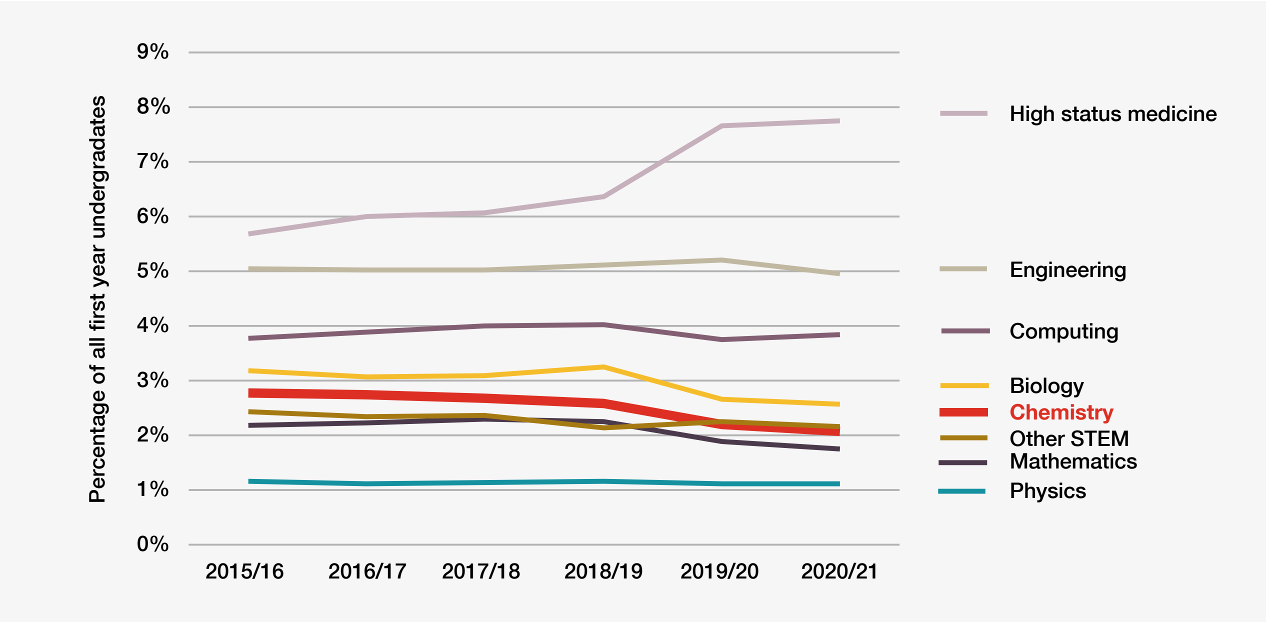


Figure 4: Breakdown by gender of first-year undergraduates in England 2020/21

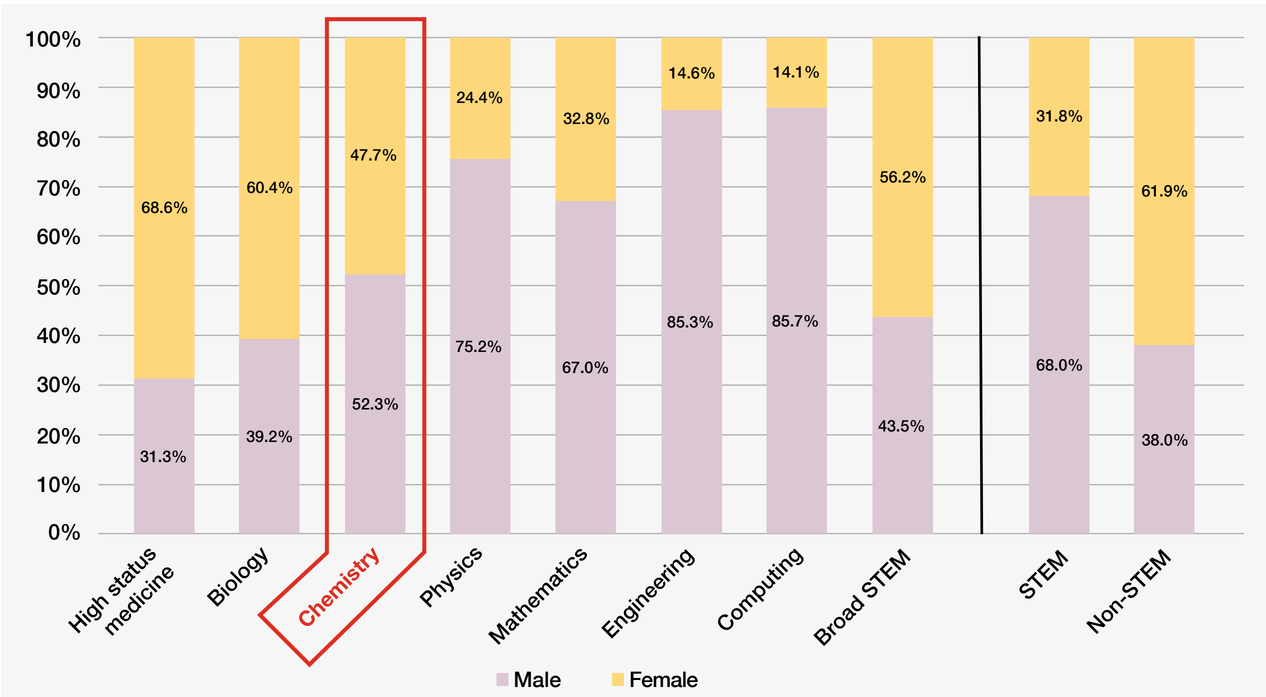


Figure 5: Breakdown by race/ethnicity of first-year undergraduates in England 2020/21

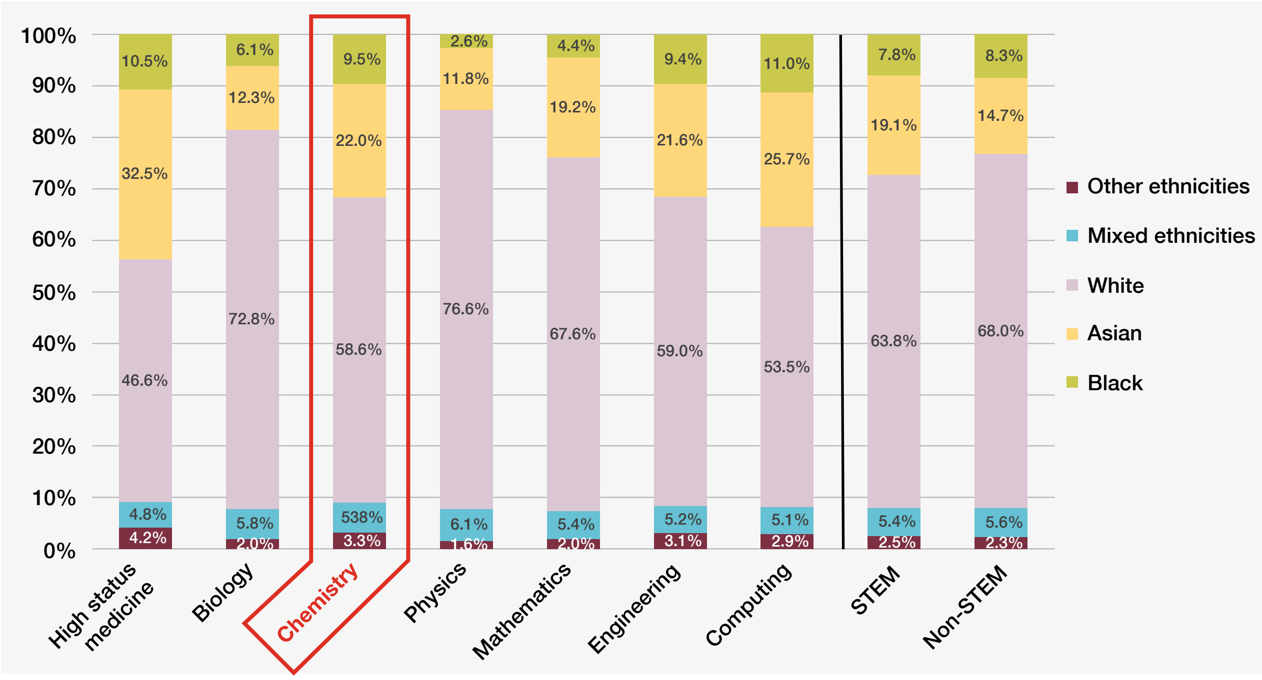
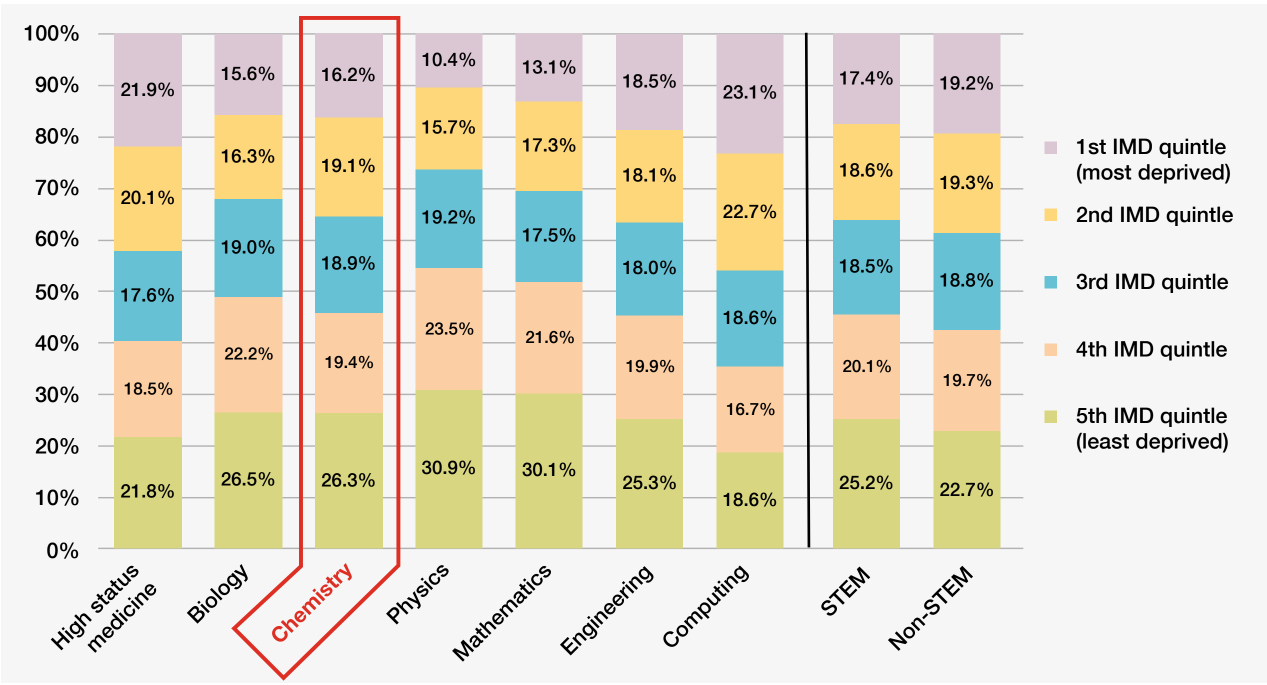


Figure 6: Breakdown by IMD quintile of first-year undergraduates in England 2020/21



Between 2015 and 2020, on average 4.4% of first-year chemistry undergraduates from England aged 18 to 24 left their course with no award during, or at the end of, their first year; 1.5% withdrew during, or at the end of, their second year; and 0.6% left during, or at the end of, their third year. **These non-completion rates are lower than for other STEM degrees**. In 2019/20, a higher percentage of students from the most deprived IMD quintile left their chemistry degree in their first year (5.4%) compared with those in the most privileged quintile (3.3%). Male chemistry undergraduates had a slightly higher rate of non-completion than women (4.9% vs. 3.7%).

3. Prior research base and conceptual approach

Research focusing on chemistry participation and engagement is sparse. That which does exist largely comes from the German didactic tradition,[8] and involves quantitative psychological studies of young people's intentions to study chemistry or retrospective studies of the motivations of chemistry professionals.[9] In contrast, research into STEM participation generally has included more qualitative and/or sociological studies evidencing the impact of: family resources and support; schools, teachers and curricula; the dominant image and practice of STEM fields; and being able to see oneself, and be recognised by others, as 'good at science' and/or 'good at maths'.[10]

The ASPIRES project is informed by sociological and educational research that shows how interactions of **identity and capital** (social, economic and cultural resources) shape young people's pathways through schooling and into further and higher education, and employment.[11] Young people can accrue capital from home, family, school and other educational contexts.[12]

In the ASPIRES research, we explore how chemistry-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 chemistry trajectories, and that where there is close alignment between chemistry-related identity, resources and the field of (school) chemistry, young people are more likely to feel competent and interested in chemistry, and so are more likely to choose to continue with the subject.

We also argue that despite the relatively even gender balance in the proportion of men and women students studying for chemistry degrees, the **gendered nature of the field of chemistry** still entails particular challenges for women's participation and the extent to which women experience chemistry as fitting, or not, with their ways of being.

4. What data did the ASPIRES research collect?

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

Table 1: Summary of ASPIRES project data collection

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

The ASPIRES3 survey comprised a large-scale postal survey of young people in England and was conducted by obtaining a sample of young people born between 1st September 1998 and 31st August 1999 who were registered on the Open Electoral Roll. Following data cleaning, the overall achieved sample of 7,635 young people was roughly proportional to (though not fully representative of) official government population estimates in England for 21- and 22-year-olds based on sex, ethnicity, region, Index of Multiple Deprivation, Urban/Rural classification and long-lasting health conditions.[13]

The sample included 7,635 young people. 4,092 (53.6%) had taken A levels, of whom 506 (12.4%) had taken A Level Chemistry and replied to the relevant questions.[14] 70 of these had pursued a degree in chemistry (based on HESA degree classifications[15]), starting in 2018.[16] The breakdown of chemistry undergraduates was: 50% Women, 50% Men; 60% White, 19% Asian, 6% Black, 16% Other ethnicities and Prefer not to say; 41% IMD1 and IMD2 quintiles, 31% IMD3, 27% IMD4 and IMD5.[17]

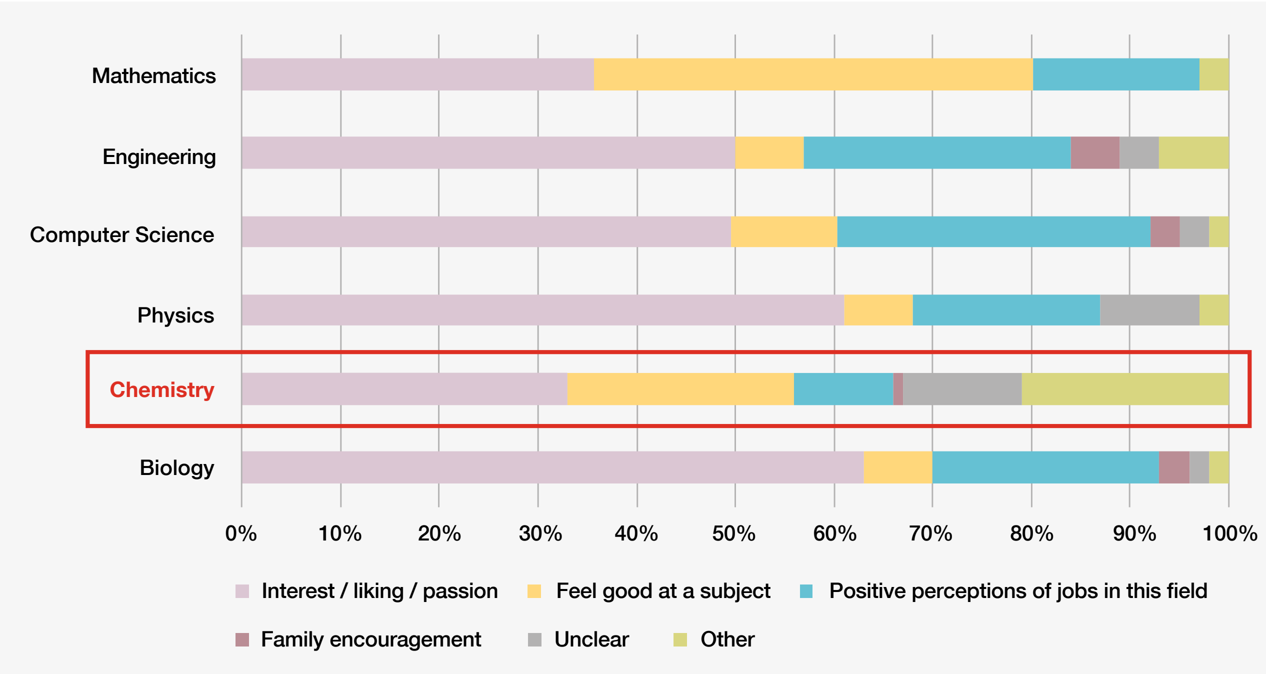
Of the 50 participants that we tracked from age 10 to 22,[18] 18 took A/AS level Chemistry. Of these, five studied a chemistry, or chemistry-based biochemistry degree; 12 took other STEM degrees; and one went straight into employment in a non-STEM job.

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

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

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

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



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

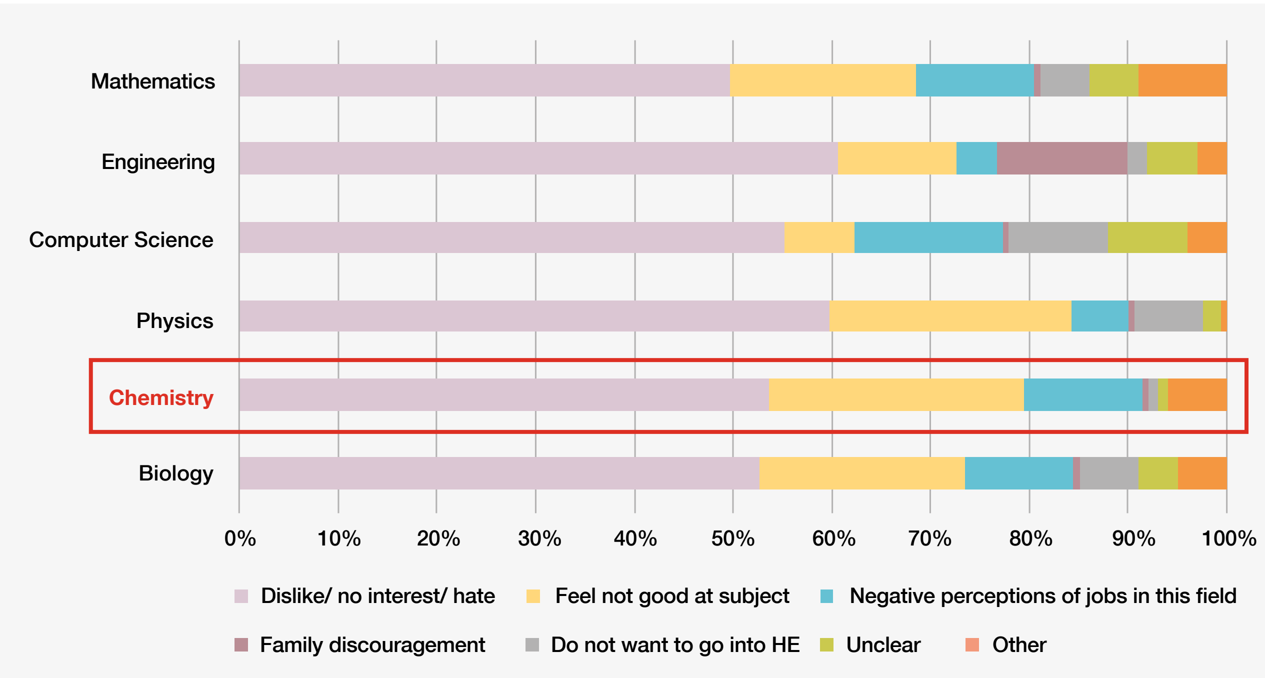
- **Interest or passion was the top reason given by 33% of chemistry undergraduates for choosing the subject.** However, this was a lower rate than found in relation to other STEM degrees, which ranged from 36% in maths to 63% in biology;
- Chemistry students were also the most likely (23%), after mathematics students (45%), to cite **feeling 'good at' the subject as a primary reason for pursuing the subject at degree level, whereas** just 7-11% of students gave this reason in relation to biology, engineering, physics and computing;
- Chemistry students were the **least likely of all STEM degree students to cite positive views of jobs in the field (10%)** as the main reason for their choice;
- Generally, young people undertaking chemistry degrees had **more heterogeneous reasons for their choice than those studying most STEM disciplines.** This is reflected in the 11% of responses classified as 'other', which largely consisted of young people taking interdisciplinary chemistry qualifications (where chemistry was not the main component), as a 'second choice' or as a route to a preferred option.

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

- **The reasons given by young people for not choosing chemistry are broadly in line with those for other STEM subjects**. 48% of survey respondents cited their dislike or hatred of chemistry, along with feeling less connection with, or interest in, chemistry compared with other subjects;
- 21% cited feeling 'bad at' or 'not good enough at' chemistry, 12% had negative experiences of A level Chemistry, and 12% held negative views of jobs in the field;
- Although the reasons for *not* taking chemistry do not stand out from other STEM fields, the relatively pragmatic motivations of chemistry undergraduates may suggest a lack of passion for the subject compared with those following other routes.

As discussed next, the qualitative interview data help us to understand how interactions between young people's identity and capital with the field of chemistry education helped shape their trajectories into, and away from, chemistry degrees.

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



6. What factors shape chemistry trajectories?

Analyses of the longitudinal qualitative data show how **students' choices are influenced by the extent of the fit between their identity, capital and the field of chemistry, which shapes the extent to which chemistry qualifications and pathways are felt to be 'for people like me', or not**.

Analyses of the ASPIRES data show how a range of factors come together to shape pathways into, and out of, chemistry, including feeling more connected to, or more able in, other subjects. Generally, young people who took chemistry A level but chose not to pursue it at degree level **still found chemistry interesting, but had less access to chemistry-related capital, often found the subject 'harder' than other subjects, and received less explicit encouragement to pursue it.**

The association of chemistry with masculinity and the existence of other options that felt easier to access, had preferable job prospects, resonated personally with young people, and/or were areas in which young people benefitted from greater support, were additional reasons why A level students who found chemistry interesting chose not to pursue it at degree level. These issues are exemplified by two case studies of Brittney and Demi – young women from similar backgrounds who both had a strong interest in chemistry, but pursued different trajectories after chemistry A level.

Factor 1: A 'wrap-around' of chemistry-related social, cultural and economic capital is important for making a chemistry identity and trajectory possible and desirable

Brittney's case study illustrates the important role of significant adults in shaping her choices, along with the impact of financial pressures on her family and no prior family history of going to university, which made a chemistry degree a risky and less 'thinkable' option, despite her interest and attainment in the subject. Hence, the extent to which a young person's social, cultural and economic capital align with the field of chemistry impacts their progress.

For instance, where students possessed knowledge of the potential value and transferability of a chemistry degree in the job market, this supported their progression to a chemistry degree. Likewise, where young people had the motivation and support to continue with chemistry from significant adults, particularly teachers and family members, this could influence their degree trajectories either towards (e.g. Demi), or away from (e.g. Brittney), chemistry.

As exemplified by Brittney's case, the potential for some students, particularly those from low-income families, to take a chemistry degree (or any higher education course) is impacted by their lack of access to economic capital, and exacerbated by the absence of chemistry-related cultural and social capital, such as not knowing what you can do with a degree in chemistry. For working-class young people like Brittney, as for some racially minoritised young people, 'safe choices' are crucial.[19]

Factor 2: Experiencing a 'fit' between one's identity and the field of chemistry facilitates a chemistry trajectory – developing a personal connection with chemistry is valuable

When young people developed meaningful connections with chemistry (or other subjects), feeling that it resonated with their values and goals (particularly through a personal experience such as Demi's with acne), this strongly facilitated a chemistry trajectory, making it a desirable option that is 'for me'. It is possible that opportunities to develop a meaningful connection with chemistry may be restricted when teachers have to balance high workloads and prepare students for content-heavy, high-stakes examinations – rather than having the time and scope to support students' own lines of interest within chemistry and the joy of learning the subject.

Case Study 1: Brittney is a White, working-class young woman. Since we first met her at age 10, she had loved chemistry and aspired to "something to do with chemistry… because that's my favourite part of science". She did well throughout school, taking A levels in Chemistry, Mathematics and History, but decided not to go to university. At the time of Brittney's final interview, aged 21, she was working full-time as a team manager at a local supermarket.

Brittney was the only one out all 20 A level Chemistry students in the sample, irrespective of whether they chose chemistry or not, who had neither strong family support to continue with science at degree level nor generally supportive teachers. It is likely because of this lack of support that Brittney told us she did not know what careers chemistry might lead to, beyond becoming a high-street chemist.

Although she was performing well in her A levels, 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". The tutor validated this advice by sharing her own experience of delaying entry to higher education. Similarly, Brittney's mother, Carolyn, a single parent who had left school at 16, was concerned about Brittney accruing debt by going to university and did not want her daughter to study chemistry or any other subject that she perceived as having unclear employment opportunities.

After her examinations at 18, Brittney took up full-time employment at the supermarket where she had been working for two years. In her final interview, three years later, she shared that, "I've been there ever since", gaining promotion to team manager. Carolyn reflected on her daughter's trajectory and the alternative routes she could have taken: "Brittney had a real focus with chemistry. I think it was her own aspiration inside, she really enjoyed it". She believed that her daughter could have gained a chemistry degree but recognised that Brittney had taken a different path largely because of the family's financial situation, which led to the perception that a degree was too risky, as it had for Carolyn in the past. This financial hardship had also led Brittney to give up a range of after-school clubs during secondary school, and to work part-time throughout her A levels.

For Brittney, even a long-standing love of chemistry was not sufficient to realise a chemistry degree trajectory.

Case Study 2: Demi is a White, lower-middle-class young woman. At age 12, her earlier chemistry aspirations disappeared due to "terrible" science teachers "who just give out generic worksheets and who don't check your work or help". These aspirations reappeared at 16 when Demi started Chemistry A level alongside Biology and Mathematics. Her A level teaching was one of a range of factors that made chemistry a viable choice for her at university.

Demi spoke of a personal connection with chemistry at age 17, explaining her growing fascination with the chemistry behind acne treatments, a condition she experienced: "For the past… six months I've been mainly looking at cosmetic chemistry [careers]… It links to the extended project I've been doing, which is on acne treatments… I'm just interested in the science behind it". She also enjoyed the experiments and the mathematics, but identified that "the application to real life is the main thing that interests me".

Demi, like the other four young women among the ASPIRES interviewees who chose chemistry degrees, and unlike eight of the 12 who chose other STEM degrees, felt that, although A level Chemistry was "hard", she was "naturally good at it", so it did not "stress" her and "it's easier and you tend to enjoy it more". Also like the other four chemistry undergraduates, Demi had strong encouragement from her family to continue with science at university, and she constructed a non-girly femininity that could align with the perceived masculine culture of the physical sciences.

At age 10, Demi explained how she stood out from many of her female peers in both her love of science and being "different… I'm not girly. I don't like pink… they're all wearing that girly stuff and I don't really". This theme continued through her interviews at secondary school, where Demi reflected that most of the girls she knows do not like science because they "all like girly stuff, like singing and hairdressers. There's some girls in our class who are really bright, but they aren't interested in the practical subjects".

Finally, Demi, like the others who chose a chemistry degree, reported specific support from a Chemistry A level teacher at a key moment, and positive outreach experiences. They had all enjoyed talks delivered by chemistry university departments, and Demi also recounted how useful and engaging she had found a work shadowing placement that she had undertaken with a chemistry researcher who worked for a commercial science company.

Factor 3: Feeling 'not clever enough' hinders chemistry trajectories

On the survey, over a quarter (26%) of students who did not continue onto a chemistry degree said that a reason they had not continued with chemistry was because it is a "hard", "difficult" subject and they did not feel "clever enough" to continue with it further – a theme that also came out strongly in the longitudinal data. Students who identified as women were almost ten times more likely than men to express such views, with typical responses being, "I found it too difficult" and "too hard", with many feeling that they "struggled" and were "not good" at chemistry. The interviews also revealed that many found Chemistry A level to be not only "hard", but "harder" than their other subjects, requiring disproportionate effort to do well. As one high-attaining young man, Josh, put it, chemistry was "the one [A level subject] I had to work hardest for".

We found that 'not feeling good' was a reason not only for not continuing with chemistry, but also featured prominently among the reasons given by students for not pursuing mathematics and physics. Since attainment was broadly similar across young people who did, and did not, opt for chemistry degrees, the capacity to see oneself as being good at chemistry was more important than actual attainment within their choices.

Part of the reason for the perceived difficulty may relate to what students termed the "jump" between GCSE and A level, and the practice of grade severity in A level Chemistry and Physics (e.g. Ofqual 2018), a point that was raised by several students, for example: "Chemistry at A Level is kind of notoriously one of the hardest A Levels you can take" (Samantha, interview participant).

Factor 4: Less favourable perceptions of chemistry jobs

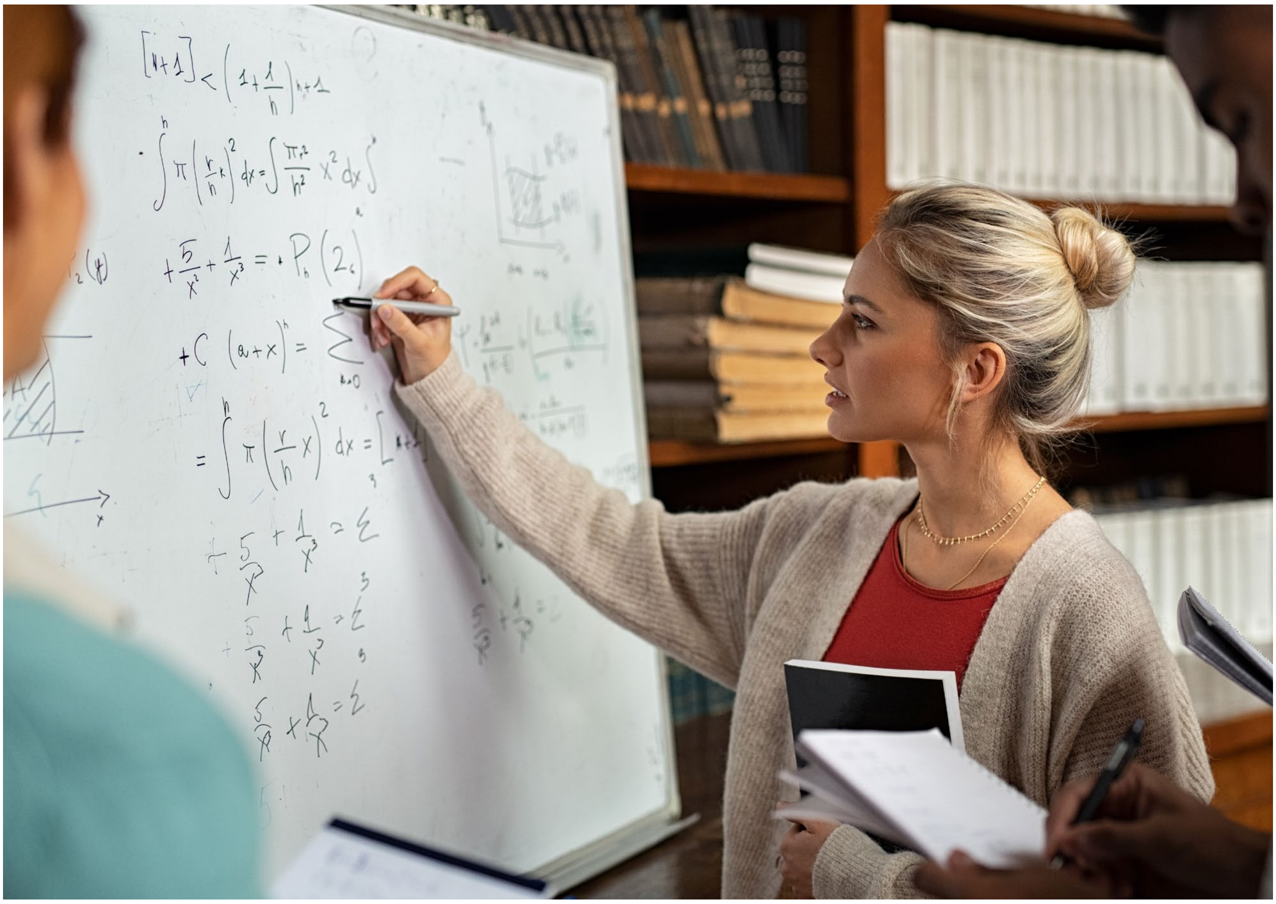
As noted in Figure 8, 12% of those who did not pursue chemistry after A level cited negative views of chemistry jobs, with many also conveying more positive perceptions of jobs in other STEM fields. As exemplified by Preeti, students who chose not to continue with chemistry at degree level did not necessarily lack interest in chemistry *per se*, but rather had greater interest and capital in relation to other fields, such as medicine. Through schooling, Preeti consistently identified chemistry as her favourite subject, and remained enthusiastic in her interest in, and enjoyment of, chemistry over time. She went on to take advanced-level qualifications in chemistry, biology, physics and maths, in which she experienced good-quality teaching and obtained top grades. However, she never considered pursuing chemistry at degree level due to a long-term aspiration to study medicine.

Factor 5: Associations of chemistry with masculinity restrict young women's chemistry trajectories

Associations of chemistry with masculinity deterred some young women from pursuing chemistry further. This was found both in relation to students deciding not to pursue a chemistry degree, and among those who had taken a chemistry degree and decided to leave the field after graduation. For instance, one mother, Claire, explained how chemistry was less appealing for young women due to the perception that chemistry careers are incompatible with childcare, noting sadly, "you can't do part-time chemistry".

Factor 6: Access to good-quality, engaging chemistry work experience and outreach can help, but is often limited

Our data suggest that engaging and accessible chemistry-related work placements and science enrichment were not widespread, but where students reported such experiences, these tended to support their chemistry trajectories. For instance, within the interview sample, the interest of three young women in pursuing a chemistry degree had been reinforced and boosted by positive experiences of engaging chemistry outreach and work experience activities.



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

Generally, chemistry degree students expressed relatively positive views of their courses, particularly in terms of feeling comfortable and a sense of belonging.

Levels of satisfaction

Among those currently studying for a chemistry degree, **59%**[20] **felt that A levels had prepared them well**. This is broadly in line with those studying for any STEM or medicine degree (53%). However, over 40% of current chemistry university students felt that their experiences of A levels had not adequately prepared them for degree study, suggesting scope for further support and intervention.

63% said that if they could do it again, they would choose the same subject. These are broadly in line with those studying for any STEM or medicine degree (67%).

78% of chemistry students agreed that they had felt comfortable and 'belonged' on their degree course – considerably higher than found among other STEM degree students (ranging from 55% of computing students to 65% of mathematics students).

22% of chemistry students felt that their degree course had been good value for money, which was broadly aligned with other STEM degree areas.

Concerns about completion

The proportion of students who expressed worries about completing their degrees was lower in chemistry (18%) than in all other STEM degrees except mathematics.

Across all subjects, students expressed similar reasons for these concerns, with academic issues paramount, alongside financial worries, health issues, the impact of COVID and, for a small number, caring responsibilities and/or social integration issues. As a general pattern across all STEM areas, those from underrepresented groups – women, minoritised students, and students from low IMD backgrounds – were the most likely to express concerns.

Experiences of sexism on STEM degrees

Drawing on ASPIRES survey data from 798 STEM and medicine students, and 1,959 students doing other degrees on their experiences of sexism, 60 women (15%) and 5 men (1.2%) studying for STEMM degrees reported experiencing sexism in their educational setting in the past year. This is significantly more than in other fields.

14% of women chemistry students reported experiencing sexism. This compares to 3% in mathematics, 10% in biology, 30% in engineering and 50% in physics.

Women STEMM students most frequently attributed these experiences to their male peers. Interview data showed that peer sexism usually involved everyday acts of disdain and disrespect, such as questioning women's academic legitimacy, and ignoring and patronising them. This reflects the discourses linking physical sciences with masculinity discussed earlier, and broader inequalities in how men and women interact.[21]

Plans for after graduation

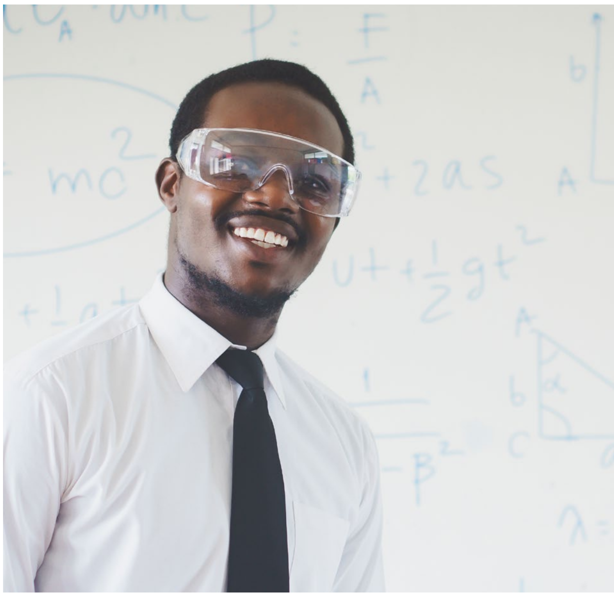
Of those who were studying for, or had recently completed, a chemistry degree:[22]

In line with other STEM fields**, most chemistry students were planning to go into, or continue in, full-time work (67%) or postgraduate study (32%)**;

The majority (65%) had either already progressed into STEM fields or anticipated doing so: 21% into chemistry-related fields; 16% into medicine; 6.7% into science; 6.7% into fields allied to mathematics; 5.3% into technology and computing; 5.3% into engineering; and 4.0% into biology. This is comparable with 18% across all STEMM fields who were progressing into the same field as their degree;

22% of chemistry students and graduates were working, or planning to work, outside of STEM (making up approximately one in three of the subgroups entering employment).

Insights from the wider qualitative data suggest that for some, this may be due to negative university experiences, negative perceptions of chemistry jobs/careers, and/or for some young women may reflect their experience of sexism on chemistry degrees. More positively, it could be interpreted as a movement of knowledge, understanding and enthusiasm for chemistry into diverse spaces.



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

Chemistry degrees are high-status qualifications with considerable *exchange value* – that is, they hold a value that can translate into a range of potential benefits, such as well-paid jobs and social prestige, both within and beyond the field of higher education. They can also support active citizenship, and encourage individual and collective mobility.

Chemistry A level uptake is among the most equitable of all STEM subjects, and higher retention at university level suggests positive engagement and support. However, there is a need to ensure that higher-level chemistry does not remain the preserve of the privileged. Initiatives to promote chemistry can usefully understand how student choices are shaped by practices and experiences within, and beyond, the subject. Ways forward might lie in ensuring young people know more about chemistry careers and have access to good-quality, relevant outreach and work experience. However, there are limits to what can be done by changing the views of individual students without addressing systemic practices in chemistry education. Our recommendations fall into six categories:

Support and value young people's chemistry identities over time and across contexts

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

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

- Offer additional guidance and resources to chemistry teachers and chemistry outreach professionals, to enable them to understand the consequential nature of longer-term, personalised encouragement for young people;

- Ensure that all young people and their families – particularly those from underserved communities – have access to high-quality chemistry work experience and outreach. The ASPIRES evidence suggests that access to chemistry-related careers education and work experience is somewhat patchy, with socially patterned distribution and uptake, so consideration could usefully be given to focusing resources (but particularly deeper, more comprehensive provision) at those in greatest need of support;

- Support practitioners, teachers and educators to access and use pedagogical approaches and resources such as the Equity Compass and the (Primary) Science Capital Teaching Approach[23] to help increase understanding of the issues and scaffold 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 chemistry identities and capital, helping young people to find meaningful connection with chemistry and see the relevance of chemistry to their current and future lives.[24]

Challenge ideas of chemistry and STEM competence being based on 'natural talent'

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

- 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 the strategic level (e.g. in England, ending grade severity in A level Chemistry[25]) and operational level (e.g. providing professional development to enable educators to be aware of, and challenge, everyday practices that reinforce such ideas);
- Support initial and continuing professional learning providers to draw on existing resources and approaches to:
  - Increase understanding of how such ideas sustain unequal patterns of chemistry participation and damage many young people's relationship with the subject;
  - Identify changes to their practice that can enable more young people to feel good at chemistry by centring ideas of equity,[26] broadening ideas about who/what counts and gets recognised as being good at chemistry, and using assets-based approaches (e.g. P/SCTA);
  - Clearly communicate to others how ideas of 'natural brilliance/ability';[27] and the 'science/maths brain' are myths that hinder more inclusive STEM participation.

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

- Policymakers in England could usefully undertake further research into the reasons for poor STEM progression outcomes from Double Science (including reviewing curriculum levels for parity, or otherwise), and 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.

Challenge peer sexism on chemistry degrees

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

- Consider how they can support and encourage chemistry practitioners to understand, recognise and address sexist language and behaviours among students. While this is particularly notable in areas such as engineering, computing and physics, it is also found in chemistry. It may be helpful to integrate this work with Athena SWAN departmental task groups. It would also be useful to consider ways in which it can be made easier to combine a career in chemistry with caring responsibilities.[28] The need to disrupt chemistry's associations with masculinity is recognised by organisations such as the Royal Society of Chemistry, whose 2018 report acknowledges the need to change the culture of professional chemistry;

- Support and encourage HE staff and students to adopt anti-sexism practice and access, share and promote resources such as the ASPIRES 'Step Up!' anti-sexism STEM ally resources and/or engage with wider anti-sexism initiatives aimed at tackling the sources of sexism. Chemistry practitioners can reflect and adapt their practice to be more inclusive using tools such as the Equity Compass.[29]

Support more equitable experiences and retention on chemistry degrees, particularly among students from underrepresented communities

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

- Consider giving this issue greater policy consideration and prominence. While it is particularly notable in disciplines such as computing and engineering, it is also an issue within chemistry, 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;

- Explore how support might be directed strategically to ensure it reaches those who could most benefit – not only in terms of supporting students directly, but also ensuring that staff are equipped to recognise the issue and address it through their own practice;

- Support practitioners to engage in critical professional reflection and professional development, with the goal of enhancing their understanding and action to improve retention and belonging among chemistry students.

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

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

- Consider how they can best support young people from underrepresented communities to access key forms of social and cultural capital, to support their chemistry trajectories. It may also be helpful to build awareness and understanding of social inequalities within policy and development teams – reflective tools such as the *Equity Compass* can help inform how to embed an equity perspective within organisational strategy and delivery. 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 chemistry routes for young people from underrepresented communities;
- Support ongoing calls to national policymakers to tackle persistent social class inequalities. Chemistry organisations and funders could provide additional support to students from underserved communities, such as through fully-funded bursaries and bespoke support for first-in-family undergraduates;
- Support educators and practitioners to 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[30] may also provide useful insights.

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

2 Royal Society of Chemistry (RSC). (2022). Written evidence (DIV0032), available at: https://committees.parliament.uk/writtenevidence/42479/pdf/

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

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

5 In this report, chemistry degrees include Chemical, process and energy engineering; Molecular biology, biophysics and biochemistry; and Chemistry degrees.

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12 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.

13 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.

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

15 Using HESA classifications of chemistry degrees as: CAH10-01-09 Chemical, process and energy engineering; CAH03-01-08 Molecular biology, biophysics and biochemistry and CAH07-02-01 Chemistry.

16 This includes those taking combined degrees in which the major subject is chemistry and degrees in which chemistry is a substantial core component, such as chemical engineering, but not degrees in which chemistry is an important element but not clearly core, such as natural science and forensic science.

17 This compares with the 426 who had chosen not to pursue a chemistry degree: Gender: 56% Women, 41% Men, 5% Non-binary or prefer not to say; Ethnicity: 66% White, 18% Asian, 5% Black, 9% Other ethnicities or prefer not to say; IMD: 39% 1st & 2nd quintiles, 22% 3rd quintile, 40% 4th & 5th quintiles.

18 These 50 participants were originally recruited when the children were age 10, by approaching a stratified sample of primary schools, selected on the basis of being broadly representative of schools nationally regarding region and key pupil demographics (gender, ethnicity, eligibility for free school meals), and inviting participation.

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20 Specifically, 59% (27) felt that A levels had prepared them well and 63% (29) said that if they could do it again, they would choose the same subject.

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