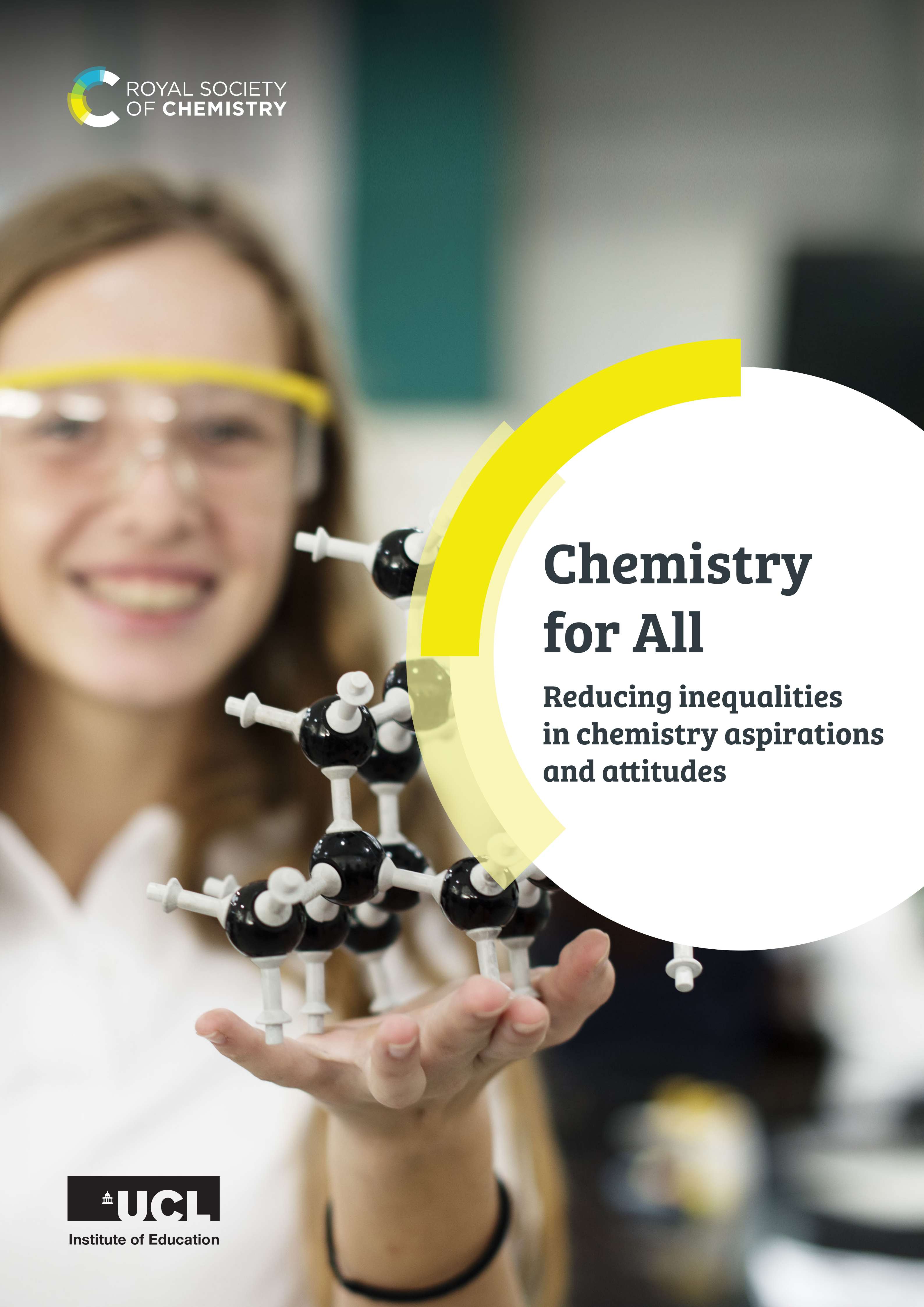

ROYAL SOCIETY OF CHEMISTRY

Chemistry for All

Reducing inequalities in chemistry aspirations and attitudes

UCL Institute of Education

Chemistry for All

Reducing inequalities in chemistry aspirations and attitudes

Findings from the **Chemistry for All** research and evaluation programme

November 2020

Authors

Dr Tamjid Mujtaba

Dr Richard Sheldrake

Professor Michael J. Reiss

UCL Institute of Education, University College London

Acknowledgements

The authors would like to thank the students and staff from across the participating schools.

The authors would also like to thank the Chemistry for All programme delivery teams and members of the programme steering group.

The research was conducted independently by the UCL Institute of Education with funding from the Royal Society of Chemistry.

For further information

For further information on the Chemistry for All project, including requests for related publications or the next phase of the work, please contact Dr Tamjid Mujtaba (**t.mujtaba@ucl.ac.uk**).

CONTENTS

1

Executive summary

1. Executive summary

1.1. Background and context

- Young people are often encouraged towards science-related careers to foster personal and national prosperity, and so that science-related fields can become more accessible, diverse, and inclusive. Nevertheless, science still tends to be seen as less accessible for people from particular backgrounds and/or with particular characteristics.
- Relatively few young people study non-compulsory science subjects at upper-secondary school (Year 12 and above) and at university, including girls, young people from families in less advantaged circumstances, and young people from certain ethnic backgrounds. Within science, more young people tend to study biological sciences than chemistry and physics at upper-secondary school and at university.
- Young people often say that science, including chemistry, is interesting and enjoyable, relevant for careers, and important within school and wider life. However, they also say that chemistry can be difficult and science careers hard to enter, requiring high grades. Boys often express more positive attitudes towards science than girls, and report receiving more support and encouragement.
- Young people's aspirations towards science-related studies and careers have been found to link with their beliefs about science being useful (their perceived utility value of science, which refers to science being valued as facilitating careers, jobs, and future opportunities in general), their interest in science, and their motivational beliefs such as their self-confidence and expected grades, together with numerous other factors including encouragement and support.
- Engaging with extra-curricular activities has been found to link with young people's attitudes and aspirations towards science. Applying formalised programmes of support has been found to achieve variable results but with some successes.
- Overall, existing research highlights the continuing need for, and the potential benefit of, providing further support for young people.

Science-related fields increase prosperity through industry and innovation (EngineeringUK, 2018; Institute of Physics, 2012; Royal Society of Chemistry, 2019). Young people are often encouraged towards science-related careers so that prosperity can continue and so that these careers can become more accessible, regardless of personal background or characteristics, leading to the science-related workforce becoming more diverse and inclusive (EACEA, 2011; Royal Society, 2014; Royal Society of Chemistry, 2014). Nevertheless, relatively few young people in England study non-compulsory science subjects at upper-secondary school and at university; additionally, fewer young people study chemistry and physics than biology (EngineeringUK, 2018; Gatsby, 2018).

Ideally, science-related careers would be a potential avenue for anyone to gain success in life. Students in secondary school in England have often conveyed that science is interesting and enjoyable, relevant for careers, and important within school and wider life (Bennett & Hogarth, 2009; DeWitt, Archer, & Osborne, 2014; Hamlyn, et al., 2020; Hamlyn, Matthews, & Shanahan, 2017; Jenkins & Nelson, 2005; Sheldrake, Mujtaba, & Reiss, 2017a). Many students similarly consider chemistry to be interesting (Bennett & Hogarth, 2009; Cheung, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019), and recognise that chemistry can be necessary or helpful for further careers, especially in medicine, health, and pharmacy (Ogunde, Overton, Thompson, Mewis, & Boniface, 2017; Springate, Harland, Lord, & Wilkin, 2008). However, some students see chemistry as boring, difficult, and challenging; some aspects of chemistry can also be inherently difficult to understand – such as particle structures and imagining how chemical processes work – and are complicated by language and terminology (Rüschenpöhler & Markic, 2020). Generally, boys often express more positive attitudes and beliefs about science and report receiving more support and encouragement than girls, regardless of their attainment (Hamlyn, Matthews, & Shanahan, 2017; Mujtaba & Reiss, 2016; OECD, 2015). Older students generally express lower interest in science and in chemistry than younger students (Bennett & Hogarth, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019). While many students recognise that science careers should be open to anyone regardless of their background, students generally think that science careers are difficult to get into and require high grades, and relatively few students consider that science careers are suitable for 'someone like me' (Hamlyn, Matthews, & Shanahan, 2017).

Problematically, science is often considered less accessible for people from certain backgrounds and/or with certain characteristics (Institute of Physics, 2013, 2014, 2015; Institute of Physics, Royal Astronomical Society, & Royal Society of Chemistry, 2019; Royal Society of Chemistry, 2018; WISE, 2014). Relatively few young women, young people from families with less advantaged circumstances, and young people from some ethnic backgrounds have studied non-compulsory science subjects at upper-secondary school and at university (Elias, Jones, & McWhinnie, 2006; Homer, Ryder, & Banner, 2014; Institute of Physics, 2014; Royal Society, 2008; Royal Society of Chemistry, 2018). The profile of students expressing aspirations towards science-related studies and careers tends to become less diverse as students grow older (Archer, et al., 2013b; Archer, Moote, MacLeod, Francis, & DeWitt, 2020; Sheldrake & Mujtaba, 2019; Sheldrake, 2018).

Many aspects of students' lives, including their family circumstances and educational contexts, can influence their personal beliefs, attitudes, aspirations, and wider identification with science (Archer, et al., 2012; DeWitt, et al., 2011). Students' studying intentions and choices closely associate with their attitudes towards science, including their interest in science, their beliefs about science being useful and valued through facilitating careers, jobs, and future opportunities, and their motivational beliefs such as their self-confidence and expected grades, together with numerous other factors including receiving encouragement and support to follow science-related studies and careers (Bøe & Henriksen, 2015; Mujtaba & Reiss, 2014; Regan & DeWitt, 2015; Sheldrake, 2016; Tripney, et al., 2010).

Providing extra-curricular activities such as science clubs and visits from ambassadors (volunteers from science-related fields who visit schools to give career talks, provide advice, and deliver demonstrations) has been found to result in participating students reporting higher interest in science, interest in studying science further, and aspirations towards science careers, compared to other students (Straw & Macleod, 2015). Further research has also linked engaging with extra-curricular activities with positive attitudes and aspirations towards science (Archer, Moote, MacLeod, Francis, & DeWitt, 2020; Sheldrake, Mujtaba, & Reiss, 2017a). Applying specific programmes of support for students, including those aimed towards fostering interests and/or aspirations towards science, has resulted in variable results but with some successes (Rosenzweig & Wigfield, 2016; van den Hurk, Meelissen, & van Langen, 2019). Earlier programmes that aimed to promote chemical sciences as a beneficial career have achieved benefits to students' interest and career aspirations, although have had the greatest impact for those with existing aspirations towards science (Lord, Straw, Springate, Harland, & Hart, 2008; Lord, Straw, Hart, Springate, & Harland, 2009).

Overall, existing research highlights the continuing need for, and the potential benefit of, providing further support for young people. Within this context, fundamental issues involve ensuring accessibility, inclusion, and equity; some young people may benefit from different forms and/or amounts of support so that studies and careers in chemistry and science can become more accessible and achievable.

1.2. Chemistry for All programme

- The Chemistry for All programme aimed to engage with students from less advantaged backgrounds.
- Seventeen schools received the Chemistry for All programme and six other schools provided a comparison, in order to explore whether the programme achieved any benefits.
- The Chemistry for All schools and comparison schools had higher than average percentages of pupils eligible for free school meals and eligible pupils with special educational needs support, and lower average grades at GCSE (General Certificate of Secondary Education), or equivalent qualifications, than all secondary schools across England.
- Students received the Chemistry for All programme when they were in Year 8, Year 9, Year 10, and Year 11.

In England, secondary school starts at Year 7 (age 11/12) and continues to Year 11 (age 15/16); studying science, including chemistry, is compulsory during this time. General Certificate of Secondary Education (GCSE) or equivalent qualifications are usually studied in Year 10 and Year 11, with examinations in Year 11. Students can then undertake upper-secondary education in Year 12 and Year 13 (ages 16/17 to 17/18), where they can choose all of their subjects. Advanced Level General Certificate of Education (A-Level) or equivalent upper-secondary qualifications are usually studied in Year 12 and Year 13, with examinations in Year 13. Achieving specific grades in particular subjects at A-Level (or equivalent qualifications) is usually necessary for entry to university, depending on the course.

The Chemistry for All programme aimed to engage with students from less advantaged backgrounds, who might not necessarily consider careers within chemistry and/or continue with non-compulsory chemistry studies at upper-secondary school and/or university. The activity providers of the Chemistry for All programme recruited schools within the East Midlands, the North West, and the South East of England. Overall, 17 schools received the Chemistry for All programme and 6 other schools provided a comparison. Comparing the changing views of students across schools that did and did not receive the Chemistry for All programme was then undertaken to reveal whether the programme achieved any benefits.

The Chemistry for All schools and comparison schools had higher than average percentages of pupils eligible for free school meals and eligible pupils with special educational needs support, and lower average grades at GCSE (or equivalent qualifications), than all secondary schools across England.

Students received the Chemistry for All programme when they were in Year 8, Year 9, Year 10, and Year 11; the same students were followed across their secondary education. The programme concurrently engaged with an 'older cohort' of students who were initially in Year 8 in 2014/2015 and a 'younger cohort' of students who were initially in Year 8 in 2015/2016. The programme encompassed diverse activities and events, which aimed to provide enrichment and enhancement to complement the National Curriculum, while fostering students' confidence, motivation, and awareness of (and aspirations for) further studies and careers in chemistry.

1.3. Research and evaluation programme

The research and evaluation programme aimed to reveal the impact of the Chemistry for All programme, and to gain wider insights into students' progression towards science/chemistry, which could inform practices and policies within science/chemistry education. The research and evaluation programme focused on the following areas:

- Revealing the impact (if any) of the Chemistry for All programme on students' attitudes, beliefs, and other views regarding science/chemistry.
- Gaining wider insights into students' aspirations and progressions towards science/chemistry.

The research programme invited students to complete questionnaires each year in order to consider their changing views over time. The questionnaires asked the same core questions each year in order to directly consider changes over time; additional questions were also introduced in later years in order to consider more specific and/or complex views. Across the schools that received the Chemistry for All programme, 6367 students completed a questionnaire on at least one occasion; across the comparison schools, 2181 students completed a questionnaire on at least one occasion. Some students were also interviewed in order to discuss their experiences in more detail.

1.4. Research results and insights

1.4.1. Insights into students' changing attitudes and aspirations

- Students in Chemistry for All schools and students in comparison schools tended to express similar views at Year 8.
- Students' views tended to become less positive over time from Year 8 to Year 11.
- Any changes over time were usually smaller for students within schools that received the Chemistry for All programme.
- Students in schools that received the Chemistry for All programme conveyed more positive views than students within comparison schools at Year 11 for their aspirations toward chemistry studies and careers, chemistry being useful (perceived utility of chemistry), chemistry being interesting/enjoyable, perceptions of their teachers, teaching and learning experiences, and also reported more frequent extra-curricular engagement.
- Students with greater engagement with the Chemistry for All programme showed even smaller changes over time from Year 8 to Year 11, and maintained positive views about chemistry being useful (perceived utility of chemistry), chemistry being interesting/enjoyable, and chemistry being beneficial to society, and also held positive perceptions of their teachers.

Students within Chemistry for All schools and within comparison schools tended to express similar views at the start of the research programme. Initially, at Year 8, students tended to convey positive views for:

- Science/chemistry being perceived as useful and valued for facilitating careers, jobs, and future opportunities in general (referred to as students' perceived utility value of science/chemistry);
- Science/chemistry being thought to improve people's living conditions, help understand the world, and to be generally beneficial and valuable to society (value of science/chemistry to society);
- Liking their teacher and perceiving that their teacher is fair, good at explaining science, and believes that all students can learn (perceptions of teachers);
- Enjoying doing science/chemistry, finding it interesting, and looking forward to lessons (interest/enjoyment in science/chemistry);
- Having opportunities to explain ideas and opinions, experiencing and engaging in a range of practical activities, and feeling that teachers use science to help understand the world outside school (experiences of teaching/learning);
- Perceiving encouragement to continue with science/chemistry from their family;
- Perceiving that their family provides help, wants to talk about science work, and wants them to be successful in science (home support for science/chemistry achievement).

At Year 8, students expressed neutral views for:

- Aspirations toward science/chemistry studying and careers (which encompassed intentions to study science/chemistry at A-Level, at university, and that they would like a job that includes science/chemistry);
- Feeling that they are good at and do well in science/chemistry (self-confidence in science/chemistry).

Considered in more detail, at Year 8, students were relatively neutral regarding their aspirations towards studying science/chemistry at university and towards careers that include science/chemistry, but were more positive about studying science/chemistry at A-Level. At Year 8, 62.4% of students who received the Chemistry for All programme and 63.4% of students in comparison schools agreed or strongly agreed that they intended to continue to study science/chemistry at A-Level or equivalent.

Students' views became less positive over time, from Year 8 to Year 11, but the changes tended to be smaller for students within schools that received the Chemistry for All programme.

At Year 11, students tended to convey positive views for:

- Value of chemistry to society;
- Perceptions of their teachers.

At Year 11, students conveyed neutral views for:

- Perceived utility value of chemistry;
- Interest/enjoyment in chemistry;
- Experiences of teaching/learning.

At Year 11, students conveyed negative views for:

- Self-confidence in chemistry;
- Perceived encouragement to continue with science/chemistry;
- Aspirations toward chemistry studying and careers.

Nevertheless, students in schools that received the Chemistry for All programme were more positive at Year 11 than students within comparison schools for:

- Perceptions of teachers;
- Teaching and learning experiences;
- Aspirations toward chemistry;
- Perceived utility of chemistry;
- Extra-curricular engagement with science/chemistry;
- Interest/enjoyment in chemistry.

In Year 11, 23.2% of students who received the Chemistry for All programme agreed or strongly agreed that they intended to continue to study chemistry at A-Level or equivalent, compared to 18.5% of students in comparison schools.

Changes in views from Year 8 to Year 11 tended to be smaller for students with greater engagement with the Chemistry for All programme (those who were recorded as attending at least one, and/or those who were recorded as attending more than one, optional activity/event). Students with greater engagement with the programme showed slightly declining views but maintained positive perceived utility of chemistry, interest in chemistry, value of chemistry to society, and perceptions of teachers, all as of Year 11. At Year 11, 30.1% of students who were recorded as attending more than one optional activity/event agreed or strongly agreed that they intended to continue to study chemistry at A-Level or equivalent.

Other patterns of changes over time involved gender differences in views (including for science/chemistry aspirations) arising and/or increasing for students in schools that did not experience the Chemistry for All programme (with boys tending to express more positive views than girls), while gender differences were not present or were smaller in magnitude for students in schools that received the Chemistry for All programme. Nevertheless, this was only clearly apparent within the younger cohort of students where, at Year 11, 26.5% of girls and 25.3% of boys within schools that received the Chemistry for All programme agreed or strongly agreed that they intended to continue to study chemistry at A-Level or equivalent, compared to 12.3% of girls and 24.5% of boys within comparison schools.

Students' views becoming less positive over time is not necessarily unusual nor unique to science/chemistry; older students have been found to generally express less positive views than younger students across many academic subjects and other areas of life (Bennett & Hogarth, 2009; Eccles, Wigfield, Harold, & Blumenfeld, 1993; Fredricks & Eccles, 2002; Höft, Bernholt, Blankenburg, & Winberg, 2019; Wang, Chow, Degol, & Eccles, 2017), including for their interest in chemistry (Bennett & Hogarth, 2009; Cheung, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019). Gender differences in aspirations also appear to increase with age: prior research has highlighted that more boys have moved towards science and more girls have moved away from science during secondary school (Sheldrake, Mujtaba, & Reiss, 2017b; Sheldrake, 2018). The findings from the Chemistry for All programme affirm that action to mitigate against such trends can be possible, which may ultimately help increase accessibility and diversity within science and chemistry.

1.4.2. Insights into students' attitudes and views

Likes and dislikes

- Many students liked experimental/practical work in science/chemistry, although highlighting this was less prevalent as students grew older.
- Some students appreciated their teachers, and highlighting this became more prevalent as students grew older.
- Students also liked: learning new things; learning many things and/or a variety of things; and learning about relevant things (including learning about the world and/or how things work).
- Students disliked having to write extensively (including having to write about experimental/practical work), although this was less prevalent as students grew older.
- As students grew older, they increasingly highlighted dislikes following from: material being considered to be difficult, complex, and/or hard to understand; equations, formulae, and symbols; and that teaching/learning involved memorisation.

Many students, across both schools that did and did not receive the Chemistry for All programme, conveyed that they liked experimental/practical work in science/chemistry, but disliked having to write extensively (including having to write about experimental/practical work), although highlighting these likes and dislikes became less prevalent as students grew older. Highlighting that science/chemistry was enjoyable, interesting, and/or fun was generally less prevalent over time, while highlighting boredom, disinterests, and/or perceiving a lack of fun was generally more prevalent over time. Additionally, students increasingly highlighted negative aspects related to self-confidence such as material being considered to be difficult, complex, and/or hard to understand. Students also increasingly disliked equations, formulae, and symbols; and that learning involved memorisation. Many of these areas may intersect and are inherent to teaching and learning about chemistry (such as the equations, formulae, and symbols that are used to represent chemical reactions), which highlight some of the challenges within schools and for wider programmes and initiatives.

Implications of aspects of teaching/learning

Other analysis considered the implications of specific aspects of teaching and learning, accounting for their schools receiving or not receiving the Chemistry for All programme and other factors. Similar patterns of results tended to be seen at different academic years (Year 8, Year 9, Year 10, and Year 11).

Students' reports of their teacher using science/chemistry to help them understand the world outside school, and students' reports of more frequently attending a science/chemistry club, were both important positive predictors of their aspirations towards science/chemistry, their interest/enjoyment in science/chemistry, their perceived utility value of science/chemistry, their self-confidence in science/chemistry, and their perceived value of science/chemistry to society. Students' reports of undertaking practical experiments and having the chance to explain their ideas were also positive predictors of their interest/enjoyment in science/chemistry. Students' reports of being involved in class debate or discussion were other positive predictors of their self-confidence in science/chemistry.

These areas offer potential avenues to help foster students' attitudes and beliefs, regardless of schools applying formalised programmes of activities/events. Additionally, the Chemistry for All programme provided science/chemistry clubs and chances for students to discuss their ideas and views. These findings may also suggest how some programme benefits reach students.

Perceptions of additional activities and events

- Students within schools that received the Chemistry for All programme, compared to students within other schools, had more positive views about the benefits arising from additional activities and events as of Year 11.
- Students who engaged more with the Chemistry for All programme (who experienced at least one optional event or activity) expressed higher perceived benefits.
- In schools that did not receive the Chemistry for All programme, boys tended to express more positive views than girls about perceived benefits; these gender differences were minimal or not present for students who received the Chemistry for All programme.

The Chemistry for All programme involved various additional activities and events for students (such as after-school clubs, careers lectures, visits to industrial companies, activity days at universities, and numerous other activities); students within the comparison schools may have also experienced various activities and events through their own schools.

Students within schools that received the Chemistry for All programme, compared to students within the comparison schools, had more positive views about the (self-perceived and self-reported) benefits arising from additional activities and events as of Year 11. Specifically, more students within schools that received the Chemistry for All programme than comparison schools believed that activities/events increased their science/chemistry self-confidence, interest in science/chemistry, and knowledge about science/chemistry progressions, careers, and their associated benefits. The largest differences involved students in schools that received the Chemistry for All programme expressing higher perceptions that activities/events increased their knowledge about the careers available with a chemistry qualification and made them aware that anyone can be a scientist/chemist. Nevertheless, despite these various differences, most students did not agree that activities/events were beneficial; tendencies towards agreement were more apparent for those students who experienced at least one, or more than one, optional activity/event within the Chemistry for All programme. For the students recorded as attending more than one optional activity/event, more than half agreed or strongly agreed that activities/events were beneficial. More specifically, the following perceived benefits from activities/events were reported.

- Increased confidence in doing science/chemistry: conveyed by 33.5% of all students in comparison schools, 40.9% of all students in Chemistry for All schools, and 63.0% of students in Chemistry for All schools who attended more than one optional activity/event within the Chemistry for All programme.
- Increased interest in science/chemistry: conveyed by 28.8% of students in comparison schools, 34.4% of students in Chemistry for All schools, and 53.1% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge of the different routes available to study non-compulsory science/chemistry: conveyed by 27.2% of students in comparison schools, 37.2% of students in Chemistry for All schools, and 56.1% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge of the benefits of a non-compulsory science/chemistry qualification: conveyed by 24.0% of students in comparison

schools, 34.8% of students in Chemistry for All schools, and 53.5% of students in Chemistry for All schools who attended more than one optional activity/event.

- Increased knowledge of the benefits of a career in science/chemistry: conveyed by 26.1% of students in comparison schools, 37.1% of students in Chemistry for All schools, and 56.0% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge about the careers available with a science/chemistry qualification: conveyed by 24.4% of students in comparison schools, 39.1% of students in Chemistry for All schools, and 59.4% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased understanding of how science/chemistry relates to everyday life: conveyed by 30.0% of students in comparison schools, 42.3% of students in Chemistry for All schools, and 60.8% of students in Chemistry for All schools who attended more than one optional activity/event.
- Made students aware that science/chemistry can be for them: conveyed by 22.0% of students in comparison schools, 33.0% of students in Chemistry for All schools, and 48.1% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased awareness that anyone can be a scientist/chemist: conveyed by 25.3% of students in comparison schools, 39.7% of students in Chemistry for All schools, and 56.5% of students in Chemistry for All schools who attended more than one optional activity/event.
- Inspired students to study science/chemistry after GCSEs: conveyed by 24.6% of students in comparison schools, 33.2% of students in Chemistry for All schools, and 45.7% of students in Chemistry for All schools who attended more than one optional activity/event.

1.4.3. Insights into students' aspirations

In order to gain greater insight, predictive modelling and path analysis revealed the independent associations between various aspects of students' home learning environments, educational contexts, and attitudes and beliefs relating to science/chemistry, as well as their studying and career aspirations for science/chemistry. Many aspects of life such as extra-curricular engagement with science/chemistry were found to associate with students' personal attitudes and beliefs related to science/chemistry (such as their extrinsic motivation in chemistry / perceived utility of chemistry and the personal value of chemistry to their identity), which then associated with their aspirations. Essentially, many aspects of students' lives associate with their aspirations, and in complex ways that can involve direct associations and also indirect associations.

Overall, students' chemistry aspirations at Year 11 most strongly associated with their perceived utility of chemistry (where students are extrinsically motivated to study science/chemistry because they perceive it as being useful and valued for facilitating careers, jobs, and future opportunities in general), personal value of chemistry to their identity (chemistry being a valued and inherent aspect of their identity), expected grades if A-Level chemistry were to be taken, encouragement to continue science/chemistry studying (from friends, teachers, and parents), extra-curricular engagement with science/chemistry, and teaching/learning experiences of practical/experimental work.

The students' perceived utility value of chemistry / extrinsic motivation in chemistry and personal value of chemistry had the strongest direct and independent associations with their aspirations for chemistry studies and careers. Perceived utility value / extrinsic motivation encompasses science/chemistry being valued as inherently supporting particular careers (such as agreeing that 'Making an effort in science/chemistry is worth it because it will help me in the work that I want to do later on' and/or 'I think science/chemistry will help me in the job I want to do in the future') as well as careers and wider benefits in general (such as agreeing that 'Learning science/chemistry is worthwhile for me because it will improve my chance of getting a job', 'I will learn many things in science/chemistry that will help me get a job', and/or 'I think science/chemistry is a useful subject'). Personal value considers science/chemistry as a valued and inherent aspect of someone's identity (such as agreeing that 'Science/chemistry is important to me personally' and/or 'Thinking scientifically is an important part of who I am').

Further cross-sectional analysis between Year 8 and Year 11 revealed numerous insights:

- Cross-sectional analysis indicated that students with increasing perceived utility value / extrinsic motivation of science/chemistry (including increasingly positive views about the benefits of chemistry/science qualifications) between Year 8 and Year 11 were more likely to express positive aspirations at Year 11. Changes in interest/enjoyment and self-confidence did not have the same effect. Fostering utility value / extrinsic motivation may be most effective approach within programmes and initiatives.
- Increasing engagement in extra-curricular activities between Year 8 and Year 11 was not associated with students' aspirations at Year 11. Additionally, engagement with extra-curricular activities as of Year 11 had more impact on aspirations as of Year 11 than engagement with extra-curricular activities as of Year 8. This suggests that continuing to

provide opportunities across secondary school is beneficial.

- Helping students to develop a positive identity with science by ensuring they are confident in their abilities and learning of science (self-confidence beliefs at Year 8 and at Year 11) positively associated with their aspirations at Year 11.
- Receiving the Chemistry for All programme (compared to comparison schools) positively associated with students' chemistry aspirations (but not science aspirations), over and above their attitudes, beliefs, and other aspects of life. This makes sense, as the programme focused on chemistry rather than science.
- Students who reported a positive home learning environment for science/chemistry (perceiving that their family provides help, wants to talk about science/chemistry work, and wants them to be successful in science/chemistry) expressed higher aspirations.
- Students who reported having more family science capital (family members having science-related qualifications, jobs, and/or interest in talking about science) expressed higher aspirations.
- Any impact of socio-economic circumstances was mediated by students' attitudes and beliefs. Essentially, regardless of background, someone with higher perceived utility / extrinsic motivation, interest/enjoyment, and /or self-confidence was much more likely to express positive aspirations.

1.4.4. Insights into students' experiences and lives

Intersectionality between social disadvantage, gender, and ethnic background

There are a range of factors that associate with students' chemistry aspirations and these factors often have inter-related connections. For example, students with families with higher levels of science capital (family members having science-related qualifications, jobs, and/or interest in talking about science) were also more likely to have more advantaged socio-economic circumstances. Both of these measures were found to link with aspirations in various ways. The analysis revealed numerous insights, including the following.

- Students' generally recognised the importance and value of science, but were generally less positive about non-compulsory science/chemistry studying and careers. This disparity was even more prominent across students with different levels of socio-economic circumstances and family science capital.
- Social inequalities linked with differences in aspirations, as well as differences in perceptions and perceived experiences of chemistry/science education. Some students may be more prepared and supported to appreciate and learn about sciences within school, given home learning environments that may broadly support and/or encourage learning for science/chemistry.
- Students from family backgrounds with higher science capital expressed higher science/chemistry aspirations, perceived utility of science/chemistry / extrinsic motivation, self-confidence beliefs, and other attitudes, as well as more positive perceptions of science teaching, and were also more likely to engage in extra-curricular activities.
- Students from family backgrounds with more advantaged socio-economic circumstances expressed higher science/chemistry aspirations, perceived utility / extrinsic motivation in science/chemistry, self-confidence beliefs, interest/enjoyment, and other science attitudes, as well as more positive perceptions of science teaching and were also more likely to engage in extra-curricular science activities.

Chemistry being useful and valued

The qualitative analysis gained insights into some of these complex connections and circumstances. One theme that was prevalent from the students' interview narratives was recognition of the use and utility of chemistry qualifications (as facilitating careers, jobs, and future opportunities in general), essentially with chemistry qualifications being a potential 'door opener'; students were extrinsically motivated to continue with chemistry because of future prospects. The analysis revealed numerous insights, including the following.

- Students from under-represented groups (such as girls, those from ethnic minority backgrounds, and/or those with less advantaged socio-economic circumstances) who had attended Chemistry for All events with a specific focus on careers were able to become more enthused about non-compulsory chemistry courses and make more informed decisions about continuing with chemistry.
- The Chemistry for All programme helped students, especially those from under-represented groups, to become aware of and understand the connection between non-compulsory chemistry qualifications and the careers and courses that subsequently become available.
- The Chemistry for All programme was able to support girls, those from ethnic minority

backgrounds, and/or those with less advantaged socio-economic circumstances to align their future selves with chemistry.

- The quantitative analysis revealed that perceived utility / extrinsic motivation (science/chemistry being useful and valued for facilitating careers, jobs, and future opportunities in general) followed by personal value of chemistry (chemistry being a valued and inherent aspect of identity) were the strongest predictors of aspirations. The qualitative analysis indicated that the two measures could intersect, with implications to students' wider trajectories. Specifically, if students could not easily consider chemistry to be an inherent aspect of their identity but nevertheless recognised the utility value of chemistry, they could consider chemistry A-Level as an avenue towards other professions such as medicine rather than chemistry. Holding a personal value of chemistry may be important for remaining within chemistry.

Natural ability and non-compulsory choices

Another prevalent theme from the students' interview narratives involved 'natural talent and/or cleverness': only students who were perceived to be naturally good at chemistry with little effort were perceived to be the ones who could legitimately remain within chemistry. These beliefs could help reinforce some students' decisions to remain in non-compulsory chemistry education, especially those from families with supportive home-learning environments for science/chemistry, with higher levels of family science capital, and/or with more advantaged socio-economic circumstances. However, the perceptions and discourse around 'natural ability' could discourage some other students from chemistry. The analysis revealed numerous insights, including the following.

- There was a gender-specific construction among young women where chemistry was associated with requiring hard work and/or natural ability, which could lead to some young women deciding not to study non-compulsory chemistry. Essentially, attaining a positive chemistry identity could be difficult for young women if they continued to compare themselves to the notion of being successful in chemistry as meaning being 'naturally clever'.
- Some young women internalised problems with their chemistry learning, linking increasing difficulties and lower confidence with feeling that chemistry required natural ability. Some young men externalised any problems, where increasing difficulties did not necessarily reflect anything about themselves (and/or through identifying with the notion that they held a natural aptitude) and that matters could still be achievable with persistence, which could help protect their chemistry identities.
- Some young women (from under-represented backgrounds) were able to align their future selves with chemistry because of the Chemistry for All programme. Various inspirational and enjoyable experiences were cited, together with their increasing understanding of careers, and through seeing the people who helped to deliver some of the Chemistry for All activities and events (such as university students who were seen as relatable role models). Some young women reported becoming more confident with chemistry because of Chemistry for All activities.
- Young men from families with higher levels of family science capital and/or more advantaged socio-economic circumstances were nevertheless the most confident in their abilities in chemistry, and more likely to make a firm decision about continuing with the sciences at university.

Further programmes and initiatives that help to break down the notion of natural ability in chemistry may help to keep more young women, particularly those from disadvantaged backgrounds, within trajectories towards chemistry.

Confidence in chemistry

Girls and boys with aspirations towards studying A-Level chemistry reported similar views about their expected GCSE and A-Level grades, similar attitudes to chemistry, and similar perceptions of their chemistry education. However, girls with aspirations towards studying A-Level chemistry were less likely to express that they were good at chemistry and were able to do well in chemistry, compared to boys with aspirations towards studying A-Level chemistry. Within their interview narratives, some girls questioned their abilities in chemistry despite having high attainment. Lower confidence in their own abilities, particularly in the context of natural ability discourses, may mean that girls find it harder to align their own identities with chemistry.

Further analysis considered how students' self-confidence beliefs might be supported and/or fostered. Students' self-confidence beliefs positively associated with the following, in addition to boys tending to express higher self-confidence than girls:

- Higher interest/enjoyment in chemistry;
- Higher personal value of chemistry;
- More encouragement to continue studying chemistry after GCSEs;
- More experiences of practical/experimental work and debate/discussion in teaching/learning;
- More engagement with extra-curricular activities;
- Higher levels of family science capital;
- More advantaged socio-economic circumstances (numbers of books at home).

Chemistry identities

The students' interview narratives indicated that the Chemistry for All programme had a positive effect on students' chemistry identities, which, in turn, had a positive impact on their aspirations.

Relevance of chemistry and science to everyday life and society

Beliefs about the value of chemistry to society encompass chemistry being thought to improve people's living conditions, to help understand the world, and to be generally valuable to society.

Students' interview narratives conveyed that they found that the practical elements of the Chemistry for All programme helped them to see the relevance of chemistry to everyday life. This helped to foster their personal value of chemistry and their interest/enjoyment of chemistry.

Students' questionnaire responses revealed that their beliefs about the value of science to society were positively associated with experiencing teaching/learning that conveyed the wider applications and relevance of science, perceived utility of science, participation in extra-curricular activities, perceptions of teachers, interest/enjoyment of chemistry, teachers encouraging students to study chemistry after GCSEs, and students being motivated towards higher achievement through competitiveness. Additionally, boys expressed more positive perceptions about the value of science to society than girls; students with higher levels of family science capital were also more likely to value science for society.

1.5. Implications and recommendations

Much attention has focused on increasing the numbers of students studying science-related subjects at school and university so that they can then follow science-related careers (Royal Society of Chemistry, 2014; Royal Society, 2014). The Chemistry for All programme highlights that benefits to students' views, including to their studying and career aspirations, are achievable through the provision of a diverse and long-lasting programme of activities and events. This broadly affirms the benefit of providing and maintaining support so that studies and careers in chemistry can be considered to be feasible and achievable for all students. Other research in England affirms the benefit of support: some students can and do maintain or even gain connections to science during secondary school, and it remains important to ensure that this can be possible for everyone (Sheldrake & Mujtaba, 2019; Sheldrake, 2018). Nevertheless, students' home and school circumstances, and wider aspects of society, also remain relevant; any one programme such as Chemistry for All cannot feasibly or realistically impact all of these areas. In addition to supporting students, the fields of education and science may also benefit from changes to increase accessibility and so that more pathways into studying and careers become available.

Focusing on students' views and experiences within teaching and learning, the various findings from the research and evaluation programme help highlight and/or affirm specific focus areas in order to support and foster students' aspirations. These include:

- Students' considering science/chemistry to be useful and valued for facilitating careers, jobs, and future opportunities in general (referred to as students' perceived utility value of science/chemistry, which may also reflect an extrinsic motivation towards science/chemistry);
- Students' being interested in science and finding it enjoyable (which may also reflect an intrinsic motivation towards science/chemistry);
- Students' expected grades and confidence in their future performance, which may inherently link with their confidence in their current performance and their general abilities in science/chemistry (their self-confidence);
- Students' considering science/chemistry to be a valued and inherent aspect of their identity (their personal value of science/chemistry).

Utility of chemistry / extrinsic motivation in continuing with chemistry because of the benefits of careers and courses

Perceived utility value encompasses science/chemistry being valued as inherently supporting particular careers, as well as careers and wider benefits in general. Increasing utility value / extrinsic motivation between Year 8 and Year 11 associated with higher aspirations for studying and careers, in chemistry and science in general. Future programmes may benefit from focusing on perceptions of utility and increasing students' extrinsic motivation in chemistry. The students' interview narratives also revealed that raising ethnic minority girls' awareness about the benefits of a non-compulsory qualifications helped to combat some of the issues around their confidence and the dominant discourse of 'natural ability' in chemistry.

Chemistry identities and tackling discourses of natural ability

Personal value considers science/chemistry as a valued and inherent aspect of someone's identity. Becoming a 'science person' may involve reconciling various expectations or beliefs about who someone is and what someone can do against who 'science people' are thought to be and what they are thought to do (Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007). Challenges may arise when someone may not see themselves as good at science, for example, and/or when they are not recognised by others (Calabrese Barton, et al., 2013; Tan, Calabrese Barton, Kang, & O'Neill, 2013). Various social and cultural expectations may also influence what people consider to be appropriate for themselves, and/or 'people like me', which can influence their educational choices (Archer, et al., 2010).

Many perceptions, expectations, and/or stereotypes may be relevant, and may need to be addressed, in order to help create more accessible images and ideals of science and/or the people who do science. For example, it may be beneficial to address assumptions of 'natural ability' being necessary for participation and/or identities. Different students may face different challenges around these areas; the interview narratives revealed how some young men externalised problems or challenges with chemistry learning, for example, while some young women internalised issues and perceived that they were not good enough in chemistry. Discourses of ability, effort, and difficulty could potentially be addressed within school teaching and learning, as well as through wider messages.

Facilitating engagement

Students with greater engagement with the Chemistry for All programme showed the greatest benefits. Nevertheless, students with greater engagement with the Chemistry for All programme may have self-selected themselves, and often (but not always) also tended to express more positive initial views at Year 8 than the comparison students. Students may not have wanted and/or been able to attend optional activities for various reasons.

Previous interventions to promote chemistry resulted in higher interest and career aspirations in students, and had the greatest impact for those with existing aspirations (Lord, Straw, Springate, Harland, & Hart, 2008; Lord, Straw, Hart, Springate, & Harland, 2009). The findings from Chemistry for All were somewhat similar: benefits were observed across all students within the schools that received the Chemistry for All programme compared to comparison students; within the Chemistry for All programme, those who attended more optional activities/events reported the most positive views (they also tended to express positive initial views). This implicitly highlights the continuing need to focus on accessibility and inclusion, even within wider programmes of support.

Integrating programmes of support within regular teaching/learning (and/or applying other actions to mitigate inaccessibly) may help ensure that benefits can reach all students. Teachers may benefit from further support and development to implement any additional activities. Engaging with school leadership may also help facilitate and ensure lasting and holistic changes within schools.

Wider aspects of life and role models

The findings broadly highlighted the relevance of many aspects of life that may be outside of the scope of programmes such as Chemistry for All. For example, encouragement to continue studying chemistry from friends, parents, and teachers each had independent and positive overall associations with students' aspirations (encompassing direct and indirect associations). This highlights the inherent challenge of supporting students, who experience diverse influences across many aspects of life.

Nevertheless, programmes and initiatives can still help mitigate challenges and/or provide benefits. For example, family members, teachers, and/or wider media can provide role models; the students' interview narratives revealed that some young women highlighted that the Chemistry for All delivery teams (including university students who visited schools) helped make chemistry feel more accessible, through providing visible and more relatable people to act as and/or become role models.

Recommendations

Government, awarding bodies, professional organisations, and others involved in determining education policy

- Avoid chemistry being seen as a difficult subject only suitable for 'naturally clever' students.
- Provide examples in curricula of successful people in chemistry who have 'worked hard' rather than rely on 'natural cleverness'.
- Ensure a diversity of people (including across age, ethnicity, gender and other aspects of people's identities, characteristics, and circumstances) are portrayed as contributing to chemistry and working in it and with it.
- Facilitate partnerships between schools and organisations (including universities, professional bodies, and industries) that can complement what schools do for students' learning of and engagement with chemistry.

Schools

- Help students to see the relevance of chemistry, not just to possible careers in medicine but to society more generally.
- Help students to see the relevance of chemistry to themselves, both in terms of possible jobs and in terms of general understanding.
- Ensure students understand the fundamentals of the subject so that they can maintain their confidence in their chemistry ability.
- Keep students engaged with chemistry so that they retain interest and motivation.
- Do not give students the impression that some students are 'naturally good at chemistry' or 'naturally clever'; rather, communicate the benefits of working steadily with persistence and enthusiasm.
- Encourage all students to think about the possibility of continuing with non-compulsory chemistry studies.
- Do not have higher grade requirements for non-compulsory studies in chemistry than for other subjects.

- From early secondary school, provide careers advice and information about the range of courses and qualifications available with chemistry qualifications.
- Ensure girls receive at least as much encouragement as boys.
- Especially among younger students, ensure there is sufficient practical work in chemistry.
- Keep memorisation to a minimum.
- Only get students to write where there is a clear need to do so.
- Where there are optional events or activities, such as out-of-school visits or chemistry/science clubs, ensure that all students are able to access these.
- Give students and their chemistry teachers the opportunity to build good, professional relationships that sometimes last for more than a single year.
- Provide a small number of high-quality extra-curricular engagements with chemistry rather than large numbers of lower-quality ones.
- Provide careers events where knowledgeable people are positive about chemistry, as these can attract students into the subject who might otherwise not continue with it.

University/outreach providers

- Help give students access to high-quality practical work in chemistry and to see the diversity of people who work with and in chemistry.
- Work with teachers in a way that does not require them to miss classes.
- Build up relationships with local schools in ways that do not rely on the enthusiasm of just one or two teachers in a school.
- Take active steps to ensure that your provision is not predominantly taken up by more advantaged students, such as students with families that encourage them to attend optional events, and students who can attend events held off school premises.

Funders

- It is better to target funding on a relatively small number of schools over a period of several to many years than to target a larger number of schools for just one or two years.
- Keep schools engaged, particularly senior management, and reduce the demands made on their time.

Parents

- Be positive about the worth of learning chemistry.
- Encourage your child to value learning about chemistry and participating in extra-curricular chemistry activities.
- Communicate that everyone can succeed at learning chemistry.
- Communicate that chemistry benefits all of society.

Media

- Communicate how chemistry benefits society.
- Promote the view that chemistry is a diverse profession both with regards to what it entails and to who undertakes it.

2

Background and context

2. Background and context

Highlights

- Young people are often encouraged towards science-related careers to foster personal and national prosperity, and so that science-related fields can become more accessible, diverse, and inclusive. Nevertheless, science still tends to be seen as less accessible for people from particular backgrounds and/or with particular characteristics.
- Young people have often felt that science, including chemistry, is interesting and enjoyable, relevant for careers, and important within school and wider life. However, young people have also felt that chemistry can be difficult and science careers can be hard to enter and require high grades. Boys have often expressed more positive attitudes and beliefs about science, and have reported receiving more support and encouragement, than girls. Many young people have thought that science careers are not necessarily for 'someone like me'.
- Relatively few young people have studied non-compulsory science subjects at upper-secondary school and at university, including especially few girls, few young people from families with less advantaged circumstances, and few young people from some ethnic backgrounds. Within science, more young people have tended to study biological sciences than chemistry and physics at upper-secondary school and at university.
- Younger students have often expressed more positive views, including views about science, than older students. It remains less clear how and why students' views change over time. Nevertheless, the profile of students expressing science-related aspirations appears to become less diverse as students grow older.
- Young people's aspirations towards science-related studies and careers have linked with their beliefs about science being useful (perceived utility value of science, which refers to science being valued as facilitating careers, jobs, and future opportunities in general), their interest in science, and their motivational beliefs such as their self-confidence and expected grades, together with numerous other factors including encouragement and support.
- Engaging with extra-curricular activities has linked with young people's views and aspirations towards science. Applying formalised programmes of support has achieved variable results but some successes.

Science-related fields increase prosperity through industry and innovation (EngineeringUK, 2018; Institute of Physics, 2012; Royal Society of Chemistry, 2019). Young people are often encouraged towards science-related careers so that prosperity can continue and so that these careers can become more accessible, regardless of someone's personal background or characteristics, leading to the science-related workforce becoming more diverse and inclusive (EACEA, 2011; Royal Society, 2014; Royal Society of Chemistry, 2014). Studying science is also encouraged because wider benefits such as quantitative skills can be applied in many aspects of life (British Academy, 2015; National Audit Office, 2018).

Ideally, science-related careers would be a potential avenue for anyone to gain success in life. However, science is often considered less accessible by and/or for people from particular backgrounds and/or with particular characteristics (Institute of Physics, 2013, 2014, 2015; Institute of Physics, Royal Astronomical Society, & Royal Society of Chemistry, 2019; Royal Society of Chemistry, 2018; WISE, 2014). Additionally, aspirations and experiences during secondary school may be especially important, as some choices may facilitate or limit career options: a career in science often requires the study of science at university, which usually requires the study of science at upper-secondary school (Royal Society, 2008).

2.1. Students' attitudes towards science

Students in primary school in England have often enjoyed science but have not necessarily seen themselves as becoming scientists (Archer, et al., 2010; Archer, et al., 2013a; Silver & Rushton, 2008; Turner & Ireson, 2010). Science has frequently been perceived to be difficult in primary school, but the challenge has been considered positively; an interest and applying effort were both considered to be important rather than innate ability, although possessing a natural interest in science was considered important in order to be good at science and to be a science person (Archer, et al., 2010). Primary school students could already get a sense of whether or not their peers are 'science people', although students also perceived that the science undertaken in primary school differs from 'real science' in the wider world (Archer, et al., 2010). Students in secondary school in England have often conveyed that science is interesting and enjoyable, relevant for careers, and important within school and wider life (Bennett & Hogarth, 2009; DeWitt, Archer, & Osborne, 2014; Hamlyn, et al., 2020; Hamlyn, Matthews, & Shanahan, 2017; Jenkins & Nelson, 2005; Sheldrake, Mujtaba, & Reiss, 2017a). Students have also often agreed that they learn interesting things in science, that their parents think that it is important to learn science, and that scientists do valuable work (Archer & DeWitt, 2017; Archer, Moote, MacLeod, Francis, & DeWitt, 2020). Aspirations towards science-related studying and careers have not necessarily been uncommon; around a third (29.7%) of a nationally representative sample of students aged 15 across England have expressed science-related career aspirations (Sheldrake, Mujtaba, & Reiss, 2017a).

Nevertheless, fewer secondary school students appear to have explicitly aspired to become scientists (Bennett & Hogarth, 2009; DeWitt, Archer, & Osborne, 2014; Jenkins & Nelson, 2005). The majority of a nationally representative sample of secondary school students across England (aged 14–18) have recognised that science careers make positive contributions to society, and have believed that science careers are open to anyone regardless of their background, but these students also recognised that science careers require high grades and are difficult to enter, and only around a third (36%) considered that science careers are suitable for 'someone like me' (Hamlyn, Matthews, & Shanahan, 2017).

Students' views about different science-related areas and fields have varied, but have often involved preferences towards biology, then chemistry, and then physics (Bennett & Hogarth, 2009; Hamlyn, et al., 2020; Hamlyn, Matthews, & Shanahan, 2017; Regan & Childs, 2003). Many students have found chemistry to be interesting (Bennett & Hogarth, 2009; Cheung, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019), and have recognised that chemistry can be necessary or helpful for further careers (Ogunde, Overton, Thompson, Mewis, & Boniface, 2017) and especially for careers in medicine, health, and pharmacy (Springate, Harland, Lord, & Wilkin, 2008). However, some students have perceived chemistry as boring and difficult, and found it challenging to meet expectations when learning chemistry; some aspects of chemistry could be inherently difficult to understand, such as particle structures and imagining how chemical processes work (Rüschenpöhler & Markic, 2020). The language used within chemistry has also been considered to be difficult by many students, which may present an additional barrier when school chemistry is taught in someone's second language (Rüschenpöhler & Markic, 2020). Students have been aware that chemistry was or was not required or perceived as relevant for various pathways in life, which could be problematic when students felt that their chemistry knowledge and/or existing support might not be sufficient for these pathways (Rüschenpöhler & Markic, 2020). Some students who expressed emotional attachments to chemistry also engaged with chemistry media on television and online, viewing experiments that were perceived as fun, exciting, and dangerous (Rüschenpöhler & Markic, 2020). Students have also conveyed that parents and family members can provide information and support, facilitate activities outside of school, act as a role models, and express excitement and interest in chemistry, which can affirm, maintain, and/or remind the students of their own enjoyment (Rüschenpöhler & Markic, 2020). More generally, secondary school students (and their teachers) have suggested that, in order to make chemistry more meaningful and interesting, more laboratory and practical work, and connecting chemistry education to everyday life situations, may be beneficial (Broman, Ekborg, & Johnels, 2011).

The wider field of science can be perceived in varying ways. Some students have conveyed that the rigorous methods and clarity in science was appealing, and that science could be relevant to everyday life and help solve problems (Holmegaard, Madsen, & Ulriksen, 2014). Some students have also highlighted their motivations and interests towards helping others through science and understanding the world scientifically (Aschbacher, Li, & Roth, 2010; Holmegaard, Madsen, & Ulriksen, 2014). Alternately, some students have perceived the idea of 'being a scientist' as only involving laboratory work (Archer, DeWitt, & Osborne, 2015; Wong, 2015), and/or perceived that learning or undertaking science in general involved rigidly structured and superficial matters (Holmegaard, Madsen, & Ulriksen, 2014). Some students also view science subjects such as physics to be 'masculine' and as inherently requiring 'cleverness' (due to being perceived as being hard subjects), which may entail that science is perceived to be less accessible for girls and for those with less self-confidence in their abilities (Archer, DeWitt, & Osborne, 2015; Archer, Moote, & MacLeod, 2020; Archer, Moote, Francis, DeWitt, & Yeomans, 2017). Aspects of teaching and learning encountered at school may inadvertently convey or reinforce such views, such as teachers warning that physics can be especially difficult and hard to understand (Archer, Moote, & MacLeod, 2020). Compared to girls, boys have often received more support and encouragement towards science from their teachers and families, regardless of their attainment (Mujtaba & Reiss, 2016). Students with more advantaged socio-economic circumstances have also been more likely to receive support and encouragement from teachers (Archer, Moote, MacLeod, Francis, & DeWitt, 2020). Considered generally, boys and girls often have similar science attainment (Department for Education, 2011; OECD, 2015), but boys have often expressed higher science self-confidence and interest, and have perceived science to be more relevant and/or useful to their careers (Bennett & Hogarth, 2009; Hamlyn, Matthews, & Shanahan, 2017; Jenkins & Nelson, 2005).

Students may engage with science within school and outside of school. Over half of a nationally representative sample of secondary school students in England engaged with science-related media outside of school, and expressed interest in hearing from scientists about their research, although only around a third had engaged in science-related extra-curricular activities, events, and/or programmes within school over the last year (Hamlyn, et al., 2020; Hamlyn, Matthews, & Shanahan, 2017). Engaging with science outside of school has often linked with maintaining students' interest in science (Bonnette, Crowley, & Schunn, 2019; Dabney, et al., 2012). Engaging with extra-curricular activities (within and/or outside of school) has associated with students' interest in science, perceived value of science, and self-confidence in science (Sheldrake, Mujtaba, & Reiss, 2017a). Facilitating extra-curricular activities within school can also benefit teachers through affirming professional identities within science and facilitating engagement with scientists and research (Aslam, Adefila, & Bagiya, 2018). Providing science clubs and ambassadors (volunteers from science-related fields who visit schools to give career talks, provide advice, and deliver demonstrations) has resulted in participating students reporting higher interest in science, interest in studying science further, and aspirations towards science careers, compared to other students (Straw & Macleod, 2015). Students who attend science clubs have often expressed positive attitudes and aspirations towards science; additionally, having science clubs within schools has associated with students expressing higher science-related studying aspirations, regardless of whether they attended the clubs (Archer, Moote, MacLeod, Francis, & DeWitt, 2020).

2.2. Students' changing attitudes and aspirations

It remains less clear how children's aspirations and attitudes towards science change during secondary school: some attitudes have appeared to decrease, remain similar, or even increase, although these changes have often been inferred from cross-sectional studies that survey different children of different ages (Bennett & Hogarth, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019; Potvin & Hasni, 2014). For example, older children have generally expressed lower interest in science and in chemistry than younger children (Bennett & Hogarth, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019). However, findings have sometimes varied, for example where children's perceived usefulness of science has appeared to be higher (Potvin & Hasni, 2014) and to be lower (Bennett & Hogarth, 2009) in older children compared to younger children, although the samples and methods have unavoidably varied across different studies.

Considered generally, students' attitudes and beliefs related to their studying and learning, and also for other aspects of life, often appear to be lower in older students. For example, for primary school students, younger children (compared to older children) have expressed more positive views about multiple aspects of their education (Eccles, Wigfield, Harold, & Blumenfeld, 1993; Fredricks & Eccles, 2002; Marsh, 1989), including their interest and enjoyment in science (Murphy & Beggs, 2003). Similarly, for secondary school students, younger children (compared to older students) have often expressed that various academic subjects have been more interesting, enjoyable, and useful (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), including for science (Wang, Chow, Degol, & Eccles, 2017) and for chemistry (Cheung, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019). Younger secondary school students have also often expressed higher self-confidence in many subjects (De Fraine, Van Damme, & Onghena, [see https://www.sciencedirect.com/science/article/abs/pii/S0361476X06000567#!], 2007), higher school engagement (Wang & Eccles, 2012), and higher self-esteem (Rhodes, Roffman, Reddy, & Fredriksen, 2004). There have been indications that different attitudes and beliefs can change in different ways, and/or that changes may vary across different students (Archambault, Eccles, & Vida, 2010; De Fraine, Van Damme, & Onghena, 2007; Fredricks & Eccles, 2002). For example, for three cohorts of secondary school students in the United States, many expressed variable views over time, but around a quarter expressed stable and high self-confidence, interest, and perceived usefulness for science over time (Wang, Chow, Degol, & Eccles, 2017). Overall, generally declining views are not necessarily unique to any particular academic subject or area of life; declining views may not necessarily entail moving from liking to disliking something; general trends may not necessarily apply to everyone.

Some, but relatively few, studies in England have applied longitudinal approaches that survey the same children at different ages. For example, for children in England surveyed at age 10/11 and age 12/13, their aspirations towards science-related careers slightly increased over time while their attitudes towards science (encompassing their interest in science and science being perceived as useful) remained similar (DeWitt, Archer, & Osborne, 2014). Specifically considering physics, for children in England surveyed at age 12/13 and age 14/15, their intentions towards studying non-compulsory physics and their interest in physics decreased over time, while their perceived usefulness of physics increased (Sheldrake, Mujtaba, & Reiss, 2017b). Nevertheless, only around a fifth to a quarter of the children exhibited consistently positive intentions towards studying physics, and there were indications that more girls than boys moved away from such intentions over time (Sheldrake, Mujtaba, & Reiss, 2017b). Considering a nationally-representative cohort of children born in 2000/2001 across England, 20.8% of the children expressed science-related aspirations at age 11 in 2012, which increased to 24.3% of the children at age 14 in 2015 (Sheldrake & Mujtaba, 2019; Sheldrake, 2018). Nevertheless, few children (8.6% of the cohort) expressed science-related career aspirations at age 11 and again at age 14; more children (15.7%) changed from expressing other (non-science) aspirations at age 11 to express science-related aspirations at age 14; other children (12.2%) changed from expressing science-related aspirations at age 11 to expressing other aspirations at age 14; and the remaining majority of children (63.5%) consistently expressed other career aspirations (Sheldrake, 2018). The children who consistently expressed science-related aspirations at age 11 and at age 14 had more advantaged family backgrounds, higher proportions of parents working within science-related fields, higher self-confidence (in science, mathematics, and English), higher school motivation, and higher self-esteem, compared to children who consistently expressed other aspirations (Sheldrake, 2018). Children who changed towards science-related aspirations were more likely to be boys, children from white backgrounds, and children with higher mathematics self-confidence, science self-confidence, school motivation, and self-esteem (Sheldrake, 2018). Children who changed aspirations towards science were characterised by increasing science self-confidence, while those who changed aspirations away from science were characterised by decreasing science self-confidence (Sheldrake, 2018). Essentially, the profile of students expressing science-related aspirations appears to become less diverse as students grow older (Archer, et al., 2013b; Archer, Moote, MacLeod, Francis, & DeWitt, 2020; Sheldrake & Mujtaba, 2019; Sheldrake, 2018).

2.3. Students' aspirations and choices for science studies and careers

Relatively few children in England have studied non-compulsory science subjects at upper-secondary school and at university, including especially few girls, few children from families with less advantaged circumstances, and few children from some ethnic backgrounds (Elias, Jones, & McWhinnie, 2006; Homer, Ryder, & Banner, 2014; Institute of Physics, 2014; Royal Society, 2008; Royal Society of Chemistry, 2018). More students have tended to study biology than chemistry and more have tended to study chemistry than physics in upper-secondary school; somewhat similarly, more students have tended to study biological sciences than physical sciences, including chemistry and physics, at university (EngineeringUK, 2018; Gatsby, 2018). Further differences across fields have also become apparent, for example where girls have been less likely to study engineering, computer sciences, mathematical sciences, and other physical sciences at upper-secondary school and at university, but more likely to study biological sciences, medicine, veterinary science, and other subjects related to medicine (Elias, Jones, & McWhinnie, 2006; EngineeringUK, 2018; Gatsby, 2018; Springate, Harland, Lord, & Wilkin, 2008). Concurrently, those from some minority ethnic backgrounds have been less likely to study physics and more likely to study engineering, chemistry, and subjects related to medicine (EngineeringUK, 2018; Elias, Jones, & McWhinnie, 2006).

Various aspects of students' lives, including their family circumstances and educational contexts, can influence their personal beliefs, attitudes, aspirations, and wider identification with science (Archer, et al., 2012; DeWitt, et al., 2011). Students' attitudes towards science, such as their interest in science and perceived utility of science (science being valued as facilitating future benefits, outcomes, and opportunities, including jobs and careers), and their motivational beliefs, such as their confidence in their own abilities, together with their own attainment, have closely associated with studying intentions and choices (Bøe & Henriksen, 2015; Regan & DeWitt, 2015; Tripney, et al., 2010). For example, for secondary school students across England, intentions to study science across upper-secondary education and into university have associated with their perceived utility of science and their interest in science, and also with other aspects of life including the personal value of science to their identity, their current confidence in their science abilities and attainment, their confidence in their future science attainment (their expected grades), and receiving influence or encouragement from the parents (Mujtaba & Reiss, 2014; Sheldrake, 2016). As another detailed example, across England, secondary school students who were interested in science-related careers have most frequently reported that this followed from their enjoyment in the subjects (endorsed by 66% of the students), the careers are well paid (47%), they are good at the subjects (45%), they can see how the subjects related to the real world (43%), there are a wide range of career options (41%), they want to help others (32%), they know someone working in a related job (17%), their parents advised them (15%), an illness/health condition of someone they know (10%), and/or a teacher advised them (7%) (Hamlyn, Matthews, & Shanahan, 2017). Secondary school students not interested in science-related careers have most frequently reported that this was because they have other career plans (endorsed by 56% of the students), they prefer other subjects (46%), they do not enjoy the subjects (45%), they are not good at the subjects (31%), there is a narrow range of career options (4%), the careers are not well paid (2%), a teacher advised them not to (1%), and/or their parents advised them not to (1%) (Hamlyn, Matthews, & Shanahan, 2017). Similar results (with slightly varying percentages) have been observed with a subsequent sample of secondary school students (Hamlyn, et al., 2020).

Interviews with secondary school and university students have similarly revealed that their intentions and choices have often involved or followed from: interest, enjoyment, and personal meaning and relevance; aspirations towards particular careers; studying subjects that lead towards particular careers and/or facilitate options for many careers; self-confidence; family, teachers, and other role models and influences from others (helping shape expectations as well as informing choices); and wider perceptions of subject appropriateness (including wider social and cultural influences, such as media projections of subjects and careers) (Aschbacher, Li, & Roth, 2010; Blenkinsop, McCrone, Wade, & Morris, 2006; Buschor, Berweger, Frei, & Kappler, 2014; Holmegaard, Madsen, & Ulriksen, 2014; Mellors-Bourne, Connor, & Jackson, 2011; Oliver, Woods-McConney, Maor, & McConney, 2017; Springate, Harland, Lord, & Wilkin, 2008; Wong, 2015). Considered from a wider perspective, students have also conveyed through interviews that decision-making can be complex and difficult, involving balancing diverse interests and the challenge of finding something that might be interesting for the rest of their life (Holmegaard, 2015); having diverse interests could complicate and make decisions harder (Buschor, Berweger, Frei, & Kappler, 2014; Holmegaard, Ulriksen, & Madsen, 2014). Students' interests, intentions, and identities can also vary and evolve, where aspects of life can be considered as elements of a continuous process of development, decision-making, and reflection (Holmegaard, Madsen, & Ulriksen, 2014; Lykkegaard & Ulriksen, 2019). Choices also inherently and/or implicitly involve identity, who someone is, and who they want to become. Someone's choice may reflect their identity and/or be a way to establish who they want to be (Eccles, 2009; Holmegaard, Ulriksen, & Madsen, 2015).

Considered in more detail, young people in England have often conveyed that their decisions to study chemistry at university have followed from their interest in the subject and the possible career prospects;

the majority of students studying chemistry at university were indeed aiming for a career that uses chemistry, and very few were planning for a career that does not use chemistry (Ogunde, Overton, Thompson, Mewis, & Boniface, 2017). Young people from minority ethnic backgrounds in England have conveyed that their decisions to study non-compulsory physics and/or chemistry often followed from: their interest and enjoyment in the subject (which could sometimes link with and/or follow from being good in the subjects); their aspirations towards particular careers; their knowledge of the careers that might be possible with a physics and/or chemistry degree (which could be considered to be few or many, and which could lead some towards more secure medicine/health areas); and whether physics and/or chemistry studies could have real-life applications (Springate, Harland, Lord, & Wilkin, 2008). Additional influences included how the subjects were taught, students' teachers, their perceptions of scientists, and family influences (Springate, Harland, Lord, & Wilkin, 2008). Nevertheless, young people from minority ethnic backgrounds studying chemistry, compared to those studying physics, were more likely to consider chemistry as an avenue towards other science-related careers (Springate, Harland, Lord, & Wilkin, 2008).

From a wider perspective, parents from Chinese, Indian, Pakistani, and some other minority ethnic backgrounds have often viewed science favourably, and conveyed positive views about science and/or science careers to their children. Nevertheless, many of these children have still considered science to be generally associated with 'being male' and 'being white', and hence have still perceived science to be less accessible than other fields (Archer, DeWitt, & Osborne, 2015; Aschbacher, Li, & Roth, 2010; Wong, 2015). Some students from African and Caribbean backgrounds have conveyed that their families warned them of the challenges that might be involved in overcoming exclusion (Springate, Harland, Lord, & Wilkin, 2008). Medicine and health fields within or related to science have often been considered to be more accessible by those from minority ethnic backgrounds, including by Pakistani and Indian students, given the greater visible diversity of the workforce within these areas (Springate, Harland, Lord, & Wilkin, 2008; Wong, 2015). Some students have recognised a sense of uniqueness through being a minority within their science-related field, which could involve feelings of pride and distinction but also risks of challenges to being accepted or belonging (Archer, Moote, Francis, DeWitt, & Yeomans, 2017; Buschor, Berweger, Frei, & Kappler, 2014; Springate, Harland, Lord, & Wilkin, 2008).

2.4. Programmes of support for students

Programmes of support for students, including those aimed towards fostering interests and/or aspirations towards science, have achieved variable results but some successes (Rosenzweig & Wigfield, 2016; van den Hurk, Meelissen, & van Langen, 2019). Emphasising the relevance of science and explaining the experiences and work of scientists has helped to increase students' interest in science (Bernacki, Nokes-Malach, Richey, & Belenky, 2016; Hong & Lin-Siegler, 2012; Hulleman & Harackiewicz, 2009). Similarly, promoting the relevance and utility of science for students and parents has associated with higher science interest and attainment for students, and with students selecting courses in science (Harackiewicz, Rozek, Hulleman, & Hyde, 2012; Rozek, Hyde, Svoboda, Hulleman, & Harackiewicz, 2015). Specific interventions to promote chemical sciences as a beneficial career, to raise students' aspirations, and to promote links between educational and other organisations, have resulted in higher interest and career aspirations in students, but had greatest impact for those with existing aspirations (Lord, Straw, Springate, Harland, & Hart, 2008; Lord, Straw, Hart, Springate, & Harland, 2009).

3

Chemistry for All programme

3. Chemistry for All programme

The Chemistry for All programme aimed to engage with students from less advantaged backgrounds, who might not normally consider and/or continue with chemistry.

The Chemistry for All programme encompassed diverse activities and events, delivered by three providers. The Chemistry for All programme broadly aimed to provide enrichment and enhancement to complement the National Curriculum, while fostering students' confidence, motivation, and awareness of (and aspirations for) further study and careers in chemistry. The programme was devised by the activity providers, drawing from a range of experience, initiatives, and provision of outreach and extra-curricular activities. Some activities/events were provided by partnering organisations.

The programme aimed to encompass (for example) cascaded activities and demonstrations delivered in chemistry lessons in schools, after-school clubs, and careers lectures within schools; online careers and homework resources were provided and/or made available; and visits to schools by ambassadors, visits to industrial companies, and activity days at universities were also provided. The type and/or extent of activities/events could potentially vary over time and across providers. The activities/events were intended to be contextualised to the schools, which broadly encompassed many students with less advantaged socio-economic circumstances, and to the students as they progressed through secondary education. For example, initial activities/events often involved practical experiments, demonstrations, and lectures that aimed to be enjoyable and inspirational, while subsequent events in later years often involved workshops that aimed to support revision and examination attainment. Nevertheless, aims continued to include fostering an awareness of and aspirations for chemistry careers.

3.1. Research and evaluation programme

The research and evaluation programme aimed to reveal the impact (if any) of the Chemistry for All programme, and to gain wider insights into students' progression towards science/chemistry, which could inform practices and policies within science/chemistry education.

The first phase of the programme engaged with students while they were experiencing the Chemistry for All programme during secondary education. The second phase of the programme engaged with students (where possible) completing upper-secondary education, higher education, and/or other circumstances, and considered the students' actual studying choices.

The research and evaluation programme had the following aims:

- Reveal the impact (if any) of the Chemistry for All programme on students' attitudes, beliefs, and other views regarding science/chemistry.
- Gain wider insights into students' aspirations and progressions towards science/chemistry.

4

Methods

4. Methods

Highlights

- The Chemistry for All programme aimed to engage with students from less advantaged backgrounds, who might not consider and/or continue with chemistry.
- The activity providers of the Chemistry for All programme recruited schools within the East Midlands, the North West, and the South East of England.
- Seventeen schools received the Chemistry for All programme and six other schools provided a comparison.
- The Chemistry for All schools and comparison schools had higher percentages of students eligible for free school meals and eligible students with special educational needs support, and lower average grades at GCSE (General Certificate of Secondary Education) or equivalent qualifications, than all secondary schools across England.
- Students received the Chemistry for All programme during Year 8, Year 9, Year 10, and Year 11.
- Students were invited to complete paper or online questionnaires each year to convey their views about their educational experiences, focusing on their views about science/chemistry.
- Across the schools that received the Chemistry for All programme, 6367 students completed a questionnaire on at least one occasion; across the comparison schools, 2181 students completed a questionnaire on at least one occasion.
- Some students were also invited to be interviewed each year, to consider their views about their educational experiences, focusing on their views about science/chemistry, and their experiences of the Chemistry for All programme if they were in schools that received the programme.

4.1. Context

In England, secondary school starts at Year 7 (age 11/12) and continues to Year 11 (age 15/16), and studying science (including chemistry) is compulsory during this time. Students can then undertake upper-secondary education in Year 12 and Year 13 (ages 16/17 to 17/18), where students can choose all of their subjects. GCSE or equivalent qualifications are usually studied in Year 10 and Year 11 (with examinations in Year 11); A-Level or equivalent upper-secondary qualifications are usually studied in Year 12 and Year 13 (with examinations in Year 13).

Aspects of the education system in England can change over time. School performance in England in 2014/2015 was considered through the percentage of students achieving 5 or more GCSE (or equivalent) qualifications at grade A* to C, including in English and in mathematics. A new secondary school accountability system was then introduced in 2016 (Department for Education, 2020c). School performance in England in 2015/2016 and onwards has been considered through the average 'Attainment 8' score for GCSE (or equivalent) qualifications per student, which reflects performance across 8 qualifications including mathematics and English (which receive twice the weighting of other qualifications). Qualification reforms, which occurred from 2017 in stages for different subjects, also entailed that GCSE examination grades are now numerical (from 1 to 9) rather than alphabetical, where numerical and alphabetical grades are not exactly equivalent (Department for Education, 2020c; Ofqual, 2019). Students are also required to undertake a minimum number of practical activities in science at GCSE and at A-Level, and students are assessed on their knowledge, skills, and understanding of practical work in science at GCSE and at A-Level (Ofqual, 2019). A-Level studying is now linear, with examinations at the end of the course, rather than modular, with examinations per module; AS-Level qualifications are now separate and cannot contribute to an A-Level qualification (Ofqual, 2019).

4.2. Sample schools

The Chemistry for All programme aimed to engage with students from less advantaged backgrounds, who might not consider and/or continue with chemistry. The Chemistry for All programme recruited schools within the East Midlands, the North West, and the South East of England. School recruitment was handled by the activity providers. Overall, 17 schools received the Chemistry for All programme and 6 other schools provided a comparison. The comparison schools may have also undertaken various science-related activities and events as part of their teaching and learning provision.

Sample schools and national schools

Information about the schools was sourced from the Department for Education (Department for Education, 2020a, 2020b). One school that received the Chemistry for All programme was for boys, two schools that received the Chemistry for All programme were for girls, and all other schools were mixed. All of the schools had non-selective admissions policies.

The sample schools were compared against all secondary schools across England (schools with phases of education of 'All-through', 'Middle deemed secondary', and 'Secondary'). National statistics for all secondary school across England (including those directly reported by the Department for Education) inherently encompass the schools that received the Chemistry for All programme, the other comparative schools, and all other secondary schools across England, so single-sample tests were used to compare the sample averages against the national averages.

Similar results were also observed when comparing the sample schools against all other secondary schools in England, which involved slightly different averages due to the different approach.) Given the relatively small number of sample schools, however, statistical tests may not necessarily be able to clearly reveal differences.

As of the start of the Chemistry for All programme (the 2014/2015 academic year), the 23 sample schools and all 1941 secondary schools across England had:

- Similar total numbers of students enrolled across all year groups (on average 1127 for the sample, compared to 946 for all secondary schools across England);
- Similar percentages of girls enrolled (47.9% for the sample, compared to 49.1%);
- Similar percentages of students with English as an additional language, where English was not their first or native language (24.1% for the sample, compared to 14.6%; this still reflected a small magnitude of difference, $D = .482$, $p = .054$, although not statistically significant given the $p < .050$ threshold);
- Different percentages of students eligible for free school meals (on average 27.5% for the sample, compared to 15.5% for all secondary schools across England; this entailed a large difference, $D = 1.098$, $p = .001$);
- Different percentages of eligible students with special educational needs support (17.9% for the sample, compared to 13.2%; this entailed a moderate difference, $D = .599$, $p = .016$);
- Similar percentages of special educational needs students with a statement or an Education, Health, and Care (EHC) plan (this reflects students who need more support than is available through special educational needs support; 1.6% for the sample, compared to 1.9%);
- Different percentages of students achieving 5 or more grades at A* to C (or equivalents) at GCSE (46.1% for the sample, compared to 57.5%; this entailed a moderate difference, $D = .657$, $p = .001$).

Chemistry for All programme schools and comparison schools

The sample of 23 schools encompassed 17 schools that received the Chemistry for All programme and 6 other schools that provided a comparison. No school-level differences were revealed across these 17 schools and 6 schools, although statistical tests cannot feasibly reveal school-level differences when considering low numbers of schools.

As of the start of the Chemistry for All programme (the 2014/2015 academic year), the 23 sample schools and all 3359 secondary schools across England had:

- 1161 students enrolled across all year groups (compared to 1032 students for the comparison schools);
- 48.6% girls enrolled (compared to 45.8%);
- 22.7% students with English as an additional language (compared to 28.2%);
- 26.9% of students eligible for free school meals (compared to 29.3%);
- 18.6% of eligible students with special educational needs support (compared to 15.8%);
- 1.6% of special educational needs students with a statement or EHC plan (compared to 1.6%);
- 46.2% students achieving 5 or more grades at A* to C (or equivalents) at GCSE (compared to 45.8%).

4.3. Sample students

Students received the Chemistry for All programme during Year 8, Year 9, Year 10, and Year 11. The Chemistry for All programme started in the academic year of 2014/2015, and initially engaged with an 'older cohort' of students who were in Year 8 in 2014/2015, Year 9 in 2015/2016, Year 10 in 2016/2017, and Year 11 in 2017/2018. The Chemistry for All programme also engaged with a 'younger cohort' of students who were in Year 8 in 2015/2016, Year 9 in 2016/2017, Year 10 in 2017/2018, and Year 11 in 2018/2019; these students were also surveyed and interviewed while they were in Year 7 in 2014/2015 for additional insight.

The research programme invited all Chemistry for All and comparison students to complete questionnaires each year in order to consider their changing views across time. Some students were also invited to interviews in order to discuss their experiences in more detail.

Participation in the research programme was voluntary, students could choose to not participate; students were not obliged to complete any particular questionnaire item. Students may also have been absent and/or otherwise unavailable at the time of surveying. Essentially, it was not necessarily possible to survey every student each year. Additionally, some students did not provide names and/or other identifying information, meaning that some responses could not be matched over time.

Across all schools, from 2014/2015 to 2018/2019, 8548 students completed a questionnaire on at least one occasion (encompassing 4792 students in the younger cohort and 3756 students in the older cohort). Across the schools that received the Chemistry for All programme, 6367 students completed a questionnaire on at least one occasion (encompassing 3463 students in the younger cohort and 2904 students in the older cohort). Across the comparison schools, 2181 students completed a questionnaire on at least one occasion (encompassing 1329 students in the younger cohort and 852 students in the older cohort).

4.4. Questionnaires

Students were invited to complete paper or online questionnaires each year. The questionnaire allowed students to express their characteristics, attitudes and beliefs, and other views about their educational experiences, focusing on science and/or chemistry.

The questionnaire invited students to express their gender identification; equality and inclusion across genders (and other aspects of identity) remains important within education (OECD, 2015) and especially within science education and wider fields of science (Institute of Physics, 2013; Institute of Physics, 2015; Royal Society of Chemistry, 2018; Royal Society, 2014). The questionnaire also invited students to report how many books they had at home ('How many books are in your home (Do not include magazines, newspapers, or your school books)') with response categories of (1) '0-10', (2) '11-25', (3) '26-100', (4) '101-200', (5) '201-500', and (6) '500+'. The number of books at home has often been used as a simple indicator of socio-economic circumstances and/or resources, and has been similarly measured within the international Trends in International Mathematics and Science Study surveys (Martin, Mullis, & Hooper, 2016; Mullis & Martin, 2017) and the Programme for International Student Assessment surveys (OECD, 2017; OECD, 2019).

The questionnaire asked the same core questions each year, in order to directly consider changes over time. Additionally, further questions were introduced in later years in order to consider (for example) more specific or complex views (such as personal identities linked to science and/or chemistry), actual and expected examination grades (as the students came closer to their GCSE examinations), and students' specific experiences of the Chemistry for All programme (and/or any activities and events that were encountered in the comparison schools). Any additional items/areas that were introduced in later academic years were outside of the scope of some longitudinal analytical approaches, but offered additional insight through cross-sectional and other analytical approaches.

Students may initially encounter science as a specific subject (rather than through separate subjects for biology, chemistry, and physics) during primary education and secondary education; separate subjects for biology, chemistry, and physics (and/or increased differentiation between these subjects) may become more prevalent when studying GCSE or equivalent qualifications during Year 10 and Year 11 (Department for Education, 2014). In order to increase accessibility, many items on the questionnaire initially referred to science and then referred to chemistry in Year 10 and Year 11 in order to gain specific insights.

Measuring students' views

For most items on the questionnaire, students expressed their agreement or disagreement against various statements, with response categories of 'Strongly disagree' (scored as 1), 'Disagree' (2), 'Agree' (3), and 'Strongly agree' (4). Other questions invited students to provide written responses.

Questionnaire items were often aggregated to provide single indicators. For example, a single indicator of interest/enjoyment in science/chemistry was formed through aggregating responses to multiple questionnaire items ('I look forward to my science/chemistry lessons', 'I enjoy doing science/chemistry', and 'Science/chemistry is an interesting subject'). This process helped mitigate the impact of missing responses and random variation in responses to any particular questionnaire item(s). Exploratory and confirmatory factor analysis was used, together with considering indicators of reliability, to affirm the formation of the various indicators; this essentially confirmed that the relevant items could indeed be aggregated together. The indicators were then calculated as the average of the underlying items, so that these could be interpreted against the same underlying response scale (from 'Strongly disagree' to 'Strongly agree').

4.4.1. Core questionnaire items

The questionnaire asked the same core questions each year, in order to directly consider changes over time. The core questions focused on students' aspirations and attitudes towards science/chemistry, including their interest, perceived utility, and self-confidence in their own abilities. Such views have often associated with students' intentions and choices (Bøe & Henriksen, 2015; Regan & DeWitt, 2015). Interest in science, perceived utility of science, and self-confidence in doing science are important aspects of the expectancy-value model of educational/career choices within social-cognitive theory (Eccles, 2009; Wigfield & Eccles, 2000). The idea of 'science capital' (somewhat following from sociological ideas of capital) also encompasses students' attitudes and beliefs (together with their contexts and circumstances) through aggregating: self-confidence, thinking that science is useful and relevant for careers (perceived utility value of science), having parents who work in science and/or who find science interesting, engaging in extra-curricular science-related activities, and being encouraged to study science (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; DeWitt, Archer, & Mau, 2016; Godec, King, & Archer, 2017). Essentially, science capital aims to collate dimensions that associate with personal identification with and aspirations towards science, and combines aspects that might otherwise be conceptualised as distinct motivational attitudes or beliefs, and/or as distinct forms of social capital or family capital that reflect aspects of available resources and/or support and encouragement (Archer, Dawson, DeWitt, Seakins, & Wong, 2015).

For increased clarity and potential insight, discrete attitudes and beliefs were considered separately, rather than aggregated into one single measure of 'science/chemistry attitudes' and/or 'science/chemistry capital'. The phrasing of many questionnaire items was informed by established conceptualisations and/or operationalisations in order to maximise comparability and consistency with wider research (Eccles, 2009; Martin, Mullis, & Hooper, 2016; Mullis & Martin, 2017; OECD, 2017, 2019). In order to increase accessibility, the questions initially referred to science and then referred to chemistry in Year 10 and Year 11 in order to gain specific insights.

Aspirations towards science/chemistry

Studying and career aspirations towards science/chemistry were measured across multiple questionnaire items (3 items: 'I intend to continue to study science/chemistry at an A-Level or equivalent'; 'I intend to continue to study science/chemistry at university'; 'I would like a job that includes science/chemistry when I grow up'). Additional questions were also included at Year 10 and Year 11 to still consider aspirations towards science careers ('I would like a job that includes science when I grow up'); the Year 11 questionnaires also asked about science A-Levels for additional insight.

Utility value of science/chemistry/extrinsic motivation

Perceived utility value of science/chemistry was measured across multiple questionnaire items (7 items: 'Making an effort in science/chemistry is worth it because it will help me in the work that I want to do later on'; 'Learning science/chemistry is worthwhile for me because it will improve my chance of getting a job'; 'I think science/chemistry is a useful subject'; 'I think science/chemistry will help me in the job I want to do in the future'; 'I will learn many things in science/chemistry that will help me get a job'; 'Science/chemistry is an important subject for me because I need it for what I want to study later on'; 'People who are good at science/chemistry get well-paid jobs'). Perceived utility value considers science/chemistry being valued as facilitating careers, jobs, and general future opportunities, essentially reflecting extrinsic and/or transferable benefits that may help achieve wider or future goals (Eccles, 2009). When students appreciate the utility of science/chemistry, they are then extrinsically motivated to continue with the subjects post-16.

Interest/enjoyment in science/chemistry

Interest/enjoyment in science/chemistry was measured across multiple questionnaire items (3 items: 'I look forward to my science/chemistry lessons'; 'I enjoy doing science/chemistry'; 'Science/chemistry is an interesting subject'). Interest/enjoyment reflects intrinsic value and/or benefit (Eccles, 2009).

Self-confidence in science/chemistry

Self-confidence in science/chemistry was measured across multiple questionnaire items (7 items: 'I am good at science/chemistry'; 'I do well in science/chemistry tests'; 'I don't need help with science/chemistry'; 'When I am doing science/chemistry, I always know what I am doing'; 'I do better in science/chemistry than most people in my class'; 'I'm certain I can figure out how to do the most difficult science/chemistry tasks in classes'; 'I am able to learn science/chemistry quickly'). This essentially measures someone's subjective interpretations of their current and/or previous abilities and capabilities within science/chemistry; this conceptualisation of self-confidence is sometimes referred to as subject-specific or domain-specific 'self-concept beliefs' (Bong & Skaalvik, 2003). Self-confidence in feeling that someone knows about science is also considered to be an aspect of children's science capital (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; DeWitt, Archer, & Mau, 2016; Godec, King, & Archer, 2017).

Value of science/chemistry to society

Views about the value that science/chemistry offers to society was measured across multiple questionnaire items (4 items: 'Advances in science and technology usually improve people's living conditions'; 'Science is important for helping us to understand the natural world'; 'I will use science in many ways when I am an adult'; 'Science is valuable to society'). Students' perceived value of science to society has been similarly considered within international surveys (OECD, 2007), and has also been considered within national surveys in England that have focused on public attitudes towards science (Castell, et al., 2014) and towards chemistry (TNS BMRB, 2015).

Teaching and learning experiences

The questionnaire also invited students to convey their experiences of teaching and learning at school. Students experiences of teaching and learning at school may associate with their wider attitudes and aspirations; for example, students have often appreciated practical work in science and have believed that this makes science more interesting and easier to understand (National Foundation for Educational Research, 2011). Teaching that conveys the applications and relevance of science has also associated with students' interest in science and their perceived utility value of science (Sheldrake, Mujtaba, & Reiss, 2017a). The phrasing of the various questionnaire items was informed by established surveys, in particular the Programme for International Student Assessment (OECD, 2017).

Teaching and learning experiences of interaction, debate, and/or discussion was measured across multiple questionnaire items (3 items: 'I am given the opportunity to explain my ideas'; 'The lessons involve all students' opinions about the topics'; 'I am involved in class debate or discussion'). Teaching and learning experiences of hands-on practical and/or experimental work was measured across two questionnaire items (2 items: 'I spend time in the lab doing practical experiments'; 'I am allowed to design my own experiments'). Teaching and learning experiences of the relevance and applications of science was measured through one questionnaire item ('The teacher uses science/chemistry to help me understand the world outside school'). All of these questionnaire items were also aggregated to provide an alternate single indicator of teaching and learning experiences for additional ease of interpretation.

Perceptions of teachers

Perceptions of teachers was measured across multiple questionnaire items (5 items: 'I like my science/chemistry teacher'; 'My science/chemistry teacher believes that all students can learn science/chemistry'; 'My science/chemistry teacher is interested in me as a person'; 'My science/chemistry teacher treats all students the same, regardless of how well they can do science'; 'My science/chemistry teacher is good at explaining science').

Encouragement to study science/chemistry (measures an element of the home learning environment)

Encouragement, advice, and/or pressure to study science was measured through one questionnaire item ('Someone in my family thinks that I should continue with science/chemistry after my GCSEs'). In later academic years, additional questions also considered encouragement from teachers and from friends.

Home support for science/chemistry achievement (measures an element of he home learning environment)

Home support for science/chemistry achievement was measured across multiple questionnaire items (3 items: 'Someone in my family wants me to talk to them about my science/chemistry work'; 'Someone in my family wants me to be successful in science/chemistry'; 'Someone in my family helps me with science/chemistry homework/learning at home (via a tutor or personally)'.

Extra-curricular engagement with science/chemistry

Extra-curricular engagement with science/chemistry was considered through engagement frequencies (with response categories of (1) 'Never or hardly ever', (2) 'Sometimes', (3) 'Regularly', and (4) 'Often') and measured across multiple questionnaire items (4 items: 'Put on TV/radio programmes about science/chemistry'; 'Read about science topics in books, science/chemistry magazines, science/chemistry articles in newspapers'; 'Visit websites about science/chemistry topics'; 'Attend a science/chemistry club').

Encouragement and support for extra-curricular science/chemistry

Encouragement and support for extra-curricular science/chemistry engagement was similarly considered through engagement frequencies (with response categories of (1) 'Never or hardly ever', (2) 'Sometimes', (3) 'Regularly, and (4) 'Often') and measured across two questionnaire items (2 items: 'Do you do any of the above with someone from your family?'; 'Are you encouraged to do any of the above by someone from your family?').

4.4.2. Additional questionnaire items

Further questions are introduced in later years (generally Years 10 and/or Year 11) in order to consider more specific or complex views, such as personal identities linked to science and/or chemistry), and actual and expected examination grades as the students came closer to their GCSE examinations. Students were also asked about any activities and events that were encountered within school, specifically focusing on whether these were perceived to be beneficial or not.

Grades

In later academic years, the questionnaire invited students to report their previous and current grades in science ('What overall grade did you get last year for science?' and 'What overall grade have you got so far this year in science?'), and their expected grades for chemistry/science at GCSE ('What grade do you think you will get for chemistry/science GCSE?') and A-Level chemistry ('What grade do you think you would be able to get if you studied chemistry at A-Level?').

Students' expected grades can be conceptualised as a contextualised expression of their self-efficacy, which reflects their perceived capabilities to undertake or accomplish something in the future (Bandura, 1986, 1989, 1997; Bong & Skaalvik, 2003). Students' expected grades for GCSE science have positively associated with their aspirations towards science-related studies and careers (Sheldrake, 2016).

Achievement motivation / ambition in general

In later academic years, students' general orientation or motivation towards achievement was measured across multiple questionnaire items (5 items: 'I want top grades in most or all of my courses'; 'I want to be able to select from among the best opportunities available when I graduate'; 'I want to be the best, whatever I do'; 'I see myself as an ambitious person'; 'I want to be one of the best students in my class'). The phrasing of the questionnaire items was informed by established surveys, in particular the Programme for International Student Assessment (OECD, 2017).

Parents/teachers conveying the relevance of science

In later academic years, the questionnaire measured potential implicit and/or explicit conveyance of interest and/or relevance of science across multiple questionnaire items (4 items: 'Someone in my family believes that chemistry/science is important for my career'; 'One or both of my parents think science is very interesting'; 'One or both of my parents have explained to me that science is useful for my future'; 'My teachers have explained to me that science is useful for my future').

Personal value of science/chemistry

In later academic years, personal value of science/chemistry was also measured across multiple questionnaire items (4 items: 'Science/chemistry is very relevant to me'; 'Science/chemistry is important to me personally'; 'Thinking scientifically is an important part of who I am'; 'Being able to do science/chemistry helps me show other people who I am').

Personal value considers science as a valued and inherent aspect of someone's identity, and forms an important aspect of the expectancy-value model of educational/career choices within social-cognitive theory (Eccles, 2009; Wigfield & Eccles, 2000), although an aspect that has infrequently been measured within research. Nevertheless, previous research has revealed students' personal value of science to be positively associated with their aspirations towards science-related studies and careers (Sheldrake, 2016). Personal value is sometimes referred to as 'attainment value', intending to refer to aspects of life helping people attain and/or affirm aspects of their personal identity (Eccles, 2009). The term 'personal value' is used here in order to avoid any potential confusion, because 'attainment' is usually used to refer to examination attainment/achievement within educational contexts.

Family science context/capital

In later academic years, family science context/capital was also measured across multiple questionnaire items (3 items: 'Someone in my family has a science-related job'; 'Someone in my family has a science-related qualification'; 'Someone in my family likes to talk about scientific facts, theories or news items and how these relate to our lives').

Activities and events

The questionnaire also invited students to convey their views about any chemistry/science activities that they may have experienced, such as talks, events, or any other extra activities outside of chemistry/science lessons, and whether these were perceived to be beneficial. Students who did not experience the Chemistry for All programme may have experienced various events and activities through their own schools. For those who did experience the Chemistry for All programme, these questions were prefaced by a reminder that their school had run additional activities both as whole-year group events and as extra activities outside of science lessons.

Students expressed their agreement/disagreement to various items (such as 'Taking part in extra activities/events has increased my confidence in doing science/chemistry'). Additionally, the questionnaire also invited students to provide written responses ('What do you think about these extra science/chemistry activities and events in general?'), which were transcribed from paper questionnaires or directly entered via online questionnaires.

4.5. Interviews

A selection of students were invited to be interviewed each year. The interview was undertaken within a semi-structured framework, to consider students' views about their educational experiences, science/chemistry, their educational progression, and their experiences of the Chemistry for All programme (if they were in schools that received the programme).

The main interview prompts were as follows, and students were encouraged to elaborate, provide further details and clarification, and/or to highlight other arising matters:

- What do you think about science/chemistry?
- Do you think science/chemistry is important?
- Do you like science/chemistry at school?
- What sort of things do you do in chemistry?
- How do you get on in chemistry?
- Do you find chemistry easy or difficult?
- Do you think chemistry will be a useful subject for you in the future?
- What do you do to succeed in chemistry?
- Do you feel you get on okay in school?
- Does anyone in your family take an interest in science or chemistry?
- Does anyone in your family want you to be successful in science/chemistry?
- Do you ever 'do' science or chemistry to find out about it outside of school?
- Will you carry on doing science/chemistry when you have to choose?
- What do you see yourself doing in 10 years' time?
- Would you be interested in working in science or chemistry?
- Do you imagine you could be a chemist?
- Have you had any additional chemistry events? What were they and what did you think about them?

These areas complemented the questionnaire areas of: interest in science/chemistry; teaching and learning experiences; self-confidence in science/chemistry; perceived utility of science/chemistry; home influences, support, and engagement; studying and career aspirations towards science/chemistry; and aspects of personal value and/or identification with science/chemistry.

4.6. Analytical approaches

The analysis focused on the students' experiences at Year 8, Year 9, Year 10, and Year 11. Analysis considered the younger cohort and the older cohort combined together in order to maximise the numbers of considered students (and therefore increase the statistical power to reveal smaller differences across students) and to enhance potential generalisation. The analysis was also repeated to consider the cohorts separately for further insight and/or to consider similarities and/or differences in trends; where possible/relevant, analysis for the younger cohort also encompassed their views at Year 7 for additional insight. For brevity, the reporting focuses on summarising findings from across the two cohorts combined together.

4.6.1. Students' changing views over time

Students' questionnaire responses were used to quantify means (averages) and frequencies for the various indicators, which could vary across time and across different students, such as students within schools that received the Chemistry for All programme and students within comparison schools.

Differences in students' questionnaire responses across time, and differences in responses across students, were explored through repeated-measures mixed (multi-level) modelling (Snijders & Bosker, 2012). Repeated-measures modelling considers responses from all available students and does not require all students to have responded on every occasion (Hox, Moerbeek, & van de Schoot, 2018). Across both cohorts, 8548 students completed a questionnaire on at least one occasion (6367 students from schools that received the Chemistry for All programme and 2181 students from comparison schools). The repeated-measures modelling accounted for the same students being surveyed on multiple occasions (where students' responses were likely to be somewhat similar instead of being independent, across time) and also accounted for students being clustered within schools (where students' responses were likely to be somewhat similar within schools, instead of being independent due to the shared teaching/learning context and wider environment). The modelling was undertaken with time considered as a factor, which facilitated consideration of differences across any and all particular pairs of time points.

The modelling focused on considering whether patterns of differences across time varied across students who did and did not receive the Chemistry for All programme (which would be revealed through a statistically significant interaction of 'time × programme' within the modelling and illustrated by the students' average responses per year). If students had similar initial views (or even if their views initially differed), an impact of the Chemistry for All programme would be shown through these students having different patterns of changes in their subsequent views, when compared to the comparison students.

Engagement with the Chemistry for All programme

The Chemistry for All programme delivered activities and events to all students from Year 8 to Year 11, such as talks and presentations to entire year groups; however, students were not obligated to attend every additional event. Essentially, every student is likely to have experienced something from the Chemistry for All programme (excepting absences or exceptional circumstances), while some students may have had greater engagement.

Further modelling explored whether increased engagement entailed different changes across time through considering the students who attended optional events or activities, again compared against all of the comparison students. From the students within schools that received the Chemistry for All programme, as of Year 11, 1536 were recorded as having attended at least one Chemistry for All optional event or activity (encompassing 882 students from the younger cohort and 654 students from the older cohort), with 776 recorded as having attended more than one (encompassing 479 students from the younger cohort and 297 students from the older cohort).

Differences across students with different characteristics

Further modelling explored whether any impact of the Chemistry for All programme, considered as patterns of difference across time, might vary across students with different characteristics and/or circumstances.

Further modelling considered whether patterns of differences over time varied across gender with respect to receiving or not receiving the Chemistry for All programme (which would be revealed through a statistically significant interaction of 'time × programme × gender' within the modelling). Across both cohorts and across schools who did and did not receive the Chemistry for All programme, 3938 students (47.8%) identified as girls and 4293 students (52.2%) identified as boys.

Further modelling also considered whether patterns of differences across time varied across those with very low numbers of and those with more books at home for those receiving or not receiving the Chemistry for All programme (which would be revealed through a statistically significant interaction of 'time × programme × books' within the modelling). The number of books at home aimed to reflect socio-economic circumstances and/or capital. Across both cohorts and schools who did and did not receive the Chemistry for All programme, 2705 students (49.6%) reported very low numbers of books at home (0 to 25 books at home) while 2751 students (50.4%) reported more (26 or more books at home).

4.6.2. Associations between students' views

Associations between students' responses were explored through correlations and predictive (multi-level) modelling (Snijders & Bosker, 2012). The predictive modelling accounted for students being clustered within schools, where students' responses were likely to be somewhat similar within schools instead of being independent due to the shared context and environment. The modelling broadly focused on exploring which particular attitudes, beliefs, and/or other indicators predicted the students' aspirations towards studies and careers in science/chemistry.

Associations between students' views and aspects of teaching and learning

Analysis predicted the students' aspirations, interest/enjoyment, perceived utility, self-confidence in science/chemistry, and perceived value of science/chemistry to society. The students' personal characteristics, context (including whether their school received or did not receive the Chemistry for All programme), and their experiences/perceptions of their teaching/learning were used as predictors. Specifically, the analysis included the students' responses to the following questionnaire items:

- 'I am given the chance to explain my ideas';
- 'The lessons involve all students' opinions about the topics';

- ‘I am involved in class debate or discussion’;
- ‘I spend time in the lab doing practical experiments’;
- ‘I am allowed to design my own experiments’;
- ‘The teacher uses science/chemistry to help me understand the world outside school’;
- ‘Attending a science/chemistry club’.

These reflect areas that may be potentially under the control (to some extent) of teachers, and therefore might offer potential avenues to foster students’ attitudes and beliefs in schools in general (regardless of applying formalised programmes of activities/events across multiple years, such as the Chemistry for All programme).

Associations between students’ views and aspirations

Further analysis predicted the students’ aspirations toward science/chemistry studying/careers in more detail, using more extensive arrays of predictors, in order to gain further insights. The analysis encompassed the students’ personal characteristics, context (including whether their school received or did not receive the Chemistry for All programme), and their experiences/perceptions of their teaching/learning, and also their various attitudes and beliefs about science/chemistry.

Associations between students’ views via ath analysis

Further associations between students’ views were revealed through path analysis (structural combinations of predictive models) undertaken through ‘structural equation modelling’ functionality. The analysis predicted the students’ perceived utility value of chemistry, interest/enjoyment in chemistry, self-confidence in chemistry, perceived value of chemistry to society, and their personal value of chemistry, using the various indicators of the students’ school and home contexts and experiences. Concurrently, all of the indicators, including the students’ perceived utility value of chemistry and their other attitudes and beliefs, also predicted the students’ aspirations towards chemistry. The modelling considered students’ reports from Year 11, the last year of secondary education before upper-secondary education or other pathways in life.

This modelling was therefore able to reveal direct associations, indirect associations, and total (overall) associations. For example, the students’ experiences of teaching/learning might predict their perceived utility value, and either or both of these may then predict the students’ aspirations. The students’ experiences of teaching/learning may have direct predictive associations with aspirations, and also indirect associations (through predicting students’ perceived utility value and/or other attitude and beliefs, which then predict aspirations). The total association was the combination of the direct and indirect association.

4.6.3. Interpreting results

The analytical approaches resulted in various indicators of magnitude, such as magnitudes of differences in views between students who received and did not receive the Chemistry for All programme, each with an indicator of statistical significance (p values). Findings were considered to be ‘statistically significant’ when p values were below 0.05.

When considering the average extent of agreement/disagreement, magnitudes of difference were considered through Cohen’s D values. Cohen’s D values are commonly interpreted with values above 0.20 reflecting a small difference, above 0.50 reflecting a moderate/medium difference, and above 0.80 reflecting a large difference (Cohen, 1988).

When considering proportions and percentages (such as per response category), magnitudes of difference were considered through Cramer’s V values. Cramer’s V values are commonly interpreted with values above 0.10 reflecting a small difference, above 0.30 reflecting a moderate/medium difference, and above 0.50 reflecting a large difference (Cohen, 1988).

Associations between indicators were considered through Pearson correlation coefficients (R values). Correlations below 0.10 are commonly interpreted as reflecting minimal associations, from 0.10 to 0.30 as reflecting small associations, from 0.30 to 0.50 as reflecting medium/moderate associations, and above 0.50 as reflecting large/strong associations (Cohen, 1988).

Predictive modelling reveals the independent association between each predictor and an outcome, accounting for all of the other predictors. The standardised predictive coefficients (β values) reflect the number of standard deviations of increase/decrease in the outcome, given one standard deviation increase in the predictor. There are no established standards for interpreting magnitudes of standardised predictive coefficients.

5

Students' changing views over time

5. Students' changing views over time

Highlights and key findings

- Students in schools that did and did not receive the Chemistry for All programme tended to express similar views at Year 8.
- Students' views tended to become less positive over time from Year 8 to Year 11.
- Any changes over time were usually smaller for students within schools that received the Chemistry for All programme.
- Students in schools that received the Chemistry for All programme conveyed higher views than students within comparison schools at Year 11 for their aspirations toward chemistry studies and careers, chemistry being useful (perceived utility of chemistry), chemistry being interesting/enjoyable, perceptions of their teachers, teaching and learning experiences, and also reported more frequent extra-curricular engagement.
- Students with greater engagement with the Chemistry for All programme showed even smaller changes over time from Year 8 to Year 11, and maintained positive views about chemistry being useful (perceived utility of chemistry), chemistry being interesting/ enjoyable, and chemistry being beneficial to society, and also held positive perceptions of their teachers.
- Gender differences in views were often smaller in magnitude for students in schools that received the Chemistry for All programme, although this was only observed in the younger cohort of students.

5.1. Students' views

Initially, at Year 8 (**Table 5-1**), across both cohorts and across schools that received and did not receive the Chemistry for All programme, students often expressed positive views. Students tended to express the highest views for science/chemistry being useful (perceived utility value, which refers to science/ chemistry being valued as facilitating careers, jobs, and future opportunities in general) and science/chemistry being useful and valuable to society (value of science/ chemistry to society, which refers to science/chemistry being thought to improve people's living conditions, help understand the world, and to be generally valuable to society). In more detail, students tended to express positive views at Year 8 for:

- Perceived utility value (science/chemistry being valued as facilitating careers, jobs, and future opportunities in general);
- Value of science/chemistry to society (science/ chemistry being thought to improve people's living conditions, help understand the world, and to be generally valuable to society);
- Perceptions of teachers (liking their teacher and perceiving that their teacher is fair, good at explaining science, and believes that all students can learn);
- Interest/enjoyment in science/chemistry (enjoying doing science/chemistry, finding it interesting, and looking forward to lessons);
- Experiences of teaching/learning (having opportunities to explain ideas and opinions, experiencing and engaging in a range of practical activities, and that teachers use science to help understand the world outside school);
- Encouragement to continue with science/ chemistry from their family;
- Home support for science/chemistry achievement (perceiving that their family provides help, wants to talk about science work, and wants them to be successful in science).

Students tended to express neutral views (around the middle of the disagreement to agreement scale) at Year 8 for:

- Aspirations toward science/chemistry studying/careers (encompassing intentions to study science/chemistry at A-Level, at university, and liking a job that includes science/chemistry);
- Self-confidence in science/chemistry (feeling that they are good at and do well in science/ chemistry).

On average, students conveyed that they 'Sometimes' engaged with extra-curricular science/chemistry (which could occur within and outside of school), and 'Sometimes' received family encouragement to do so.

Considering students' aspirations at Year 8 in more detail, students were relatively neutral regarding their intentions to study science/chemistry at university and that they would like a job that includes science/ chemistry, but more positive about studying science/ chemistry at A-Level. Across both cohorts of students at Year 8: 62.4% of students who received the Chemistry for All programme and 63.4% of students in comparison schools agreed or strongly agreed that they intended to continue to study science/chemistry at an A-Level or equivalent; 46.9% of students who received the Chemistry for All programme and 45.8% of students in comparison schools agreed or strongly agreed that they intended to continue to study science/chemistry at university; 45.8% of students who received the Chemistry for All programme and 48.0% of students in comparison schools agreed or strongly agreed that they would like a job that includes science/chemistry.

5.1.1. Chemistry for All and comparison students

At Year 8 (**Table 5-1**), considering both cohorts combined, the students within schools that received the Chemistry for All programme and the students within comparison schools tended to express similar views. The only differences were that students in schools that received the Chemistry for All programme expressed lower views than those in comparison schools for interest/enjoyment in science/chemistry and teaching/learning experiences related to practical/experimental work.

Engagement with the Chemistry for All programme

Students who would subsequently have greater engagement with the Chemistry for All programme (those who were recorded as attending at least one, and/or those who were recorded as attending more than one, optional activity/event across Year 8, Year 9, Year 10, and Year 11) tended to express more positive initial views at Year 8 than the comparison students (**Table 5-2**).

5.1.2. Students with different characteristics and circumstances

Gender

At Year 8 (**Table 5-3**), considering both cohorts combined, within schools that received the Chemistry for All programme and also within comparison schools, girls and boys tended to express similar aspirations towards science/chemistry, encouragement to study science/chemistry, and home support for science/chemistry achievement.

Considering both cohorts combined, within schools that received the Chemistry for All programme at Year 8, boys tended to express more positive views than girls regarding perceived utility of science/chemistry, interest in science/chemistry, self-confidence in science/chemistry, value of science/chemistry to society, teaching/learning experiences, perceptions of teachers, extra-curricular engagement with science/chemistry, and encouragement / shared extra-curricular engagement. These differences across boys and girls at Year 8 were not seen within the schools that did not receive the Chemistry for All programme; the smaller numbers of students within the comparison schools may have limited the potential to reveal some differences, however.

Books at home

At Year 8 (**Table 5-4**), considering both cohorts combined, within schools that received the Chemistry for All programme, students who reported more books at home tended to express higher views at Year 8 than students who reported very few books at home, for almost all of the measured areas (except for perceptions of teachers, where the students reported similarly). These differences were not seen within the schools that did not receive the Chemistry for All programme, however; the smaller numbers of students within the comparison schools may have limited the potential to reveal some differences.

Socio-economic circumstances are complex, while the number of books at home only offers a simple and single perspective. The overall sample of schools, encompassing the schools that received the Chemistry for All programme and the comparison schools, tended have higher percentages of students eligible for free school meals and eligible students with special educational needs support, and lower average grades at GCSE or equivalent qualifications, than all secondary schools across England. This context may have complicated consideration of within-sample advantage/disadvantage.

Table 5-1: Students' responses at Year 8

Indicator (1–4 scales, unless otherwise shown)	Comparison students		Chemistry for All students		Difference	
	M	SD	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	2.54	.84	2.58	.81	.038	.409
Aspirations towards science/chemistry: A-Level studying	2.71	.91	2.73	.89	.030	.517
Aspirations towards science/chemistry: university studying	2.46	.95	2.50	.91	.045	.329
Aspirations towards science/chemistry: careers	2.46	.95	2.48	.95	.022	.635
Aspirations towards science careers	2.46	.95	2.48	.95	.022	.635
Perceived utility of science/chemistry	2.98	.68	3.00	.62	.020	.656
Interest in science/chemistry	2.91	.77	2.82	.75	**.131**	**.005**
Self-confidence in science/chemistry	2.52	.68	2.51	.65	.018	.697
Value of science/chemistry to society	2.99	.71	3.00	.66	.011	.809
Teaching/learning experiences: interaction/debate/discussion	2.85	.69	2.81	.65	.062	.177
Teaching/learning experiences: practical/experimental	2.46	.80	2.37	.73	**.117**	**.011**
Teaching/learning experiences: relevance/applications	2.86	.89	2.80	.87	.075	.104
Teaching and learning experiences (all)	2.73	.64	2.66	.59	**.104**	**.024**
Perceptions of teachers	3.00	.80	2.96	.71	.055	.232
Encouragement to study science/chemistry	2.71	.99	2.71	.95	.001	.984
Home support for science/chemistry achievement	2.63	.77	2.69	.75	.083	.076
Extra-curricular engagement with science/chemistry	1.62	.65	1.64	.67	.027	.568
Encouragement/shared extra-curricular engagement	1.84	.87	1.83	.87	.007	.876

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups.

Table 5-2: Students' responses at Year 8 by engagement with the Chemistry for All programme

Indicator (1–4 scales, unless otherwise shown)	Comparison students		Chemistry for All students: Attended at least one optional activity/ event		Chemistry for All students: Difference to comparison students		Chemistry for All students: Attended more than one optional activity/ event		Chemistry for All students: Difference to comparison students	
	M	SD	M	SD	D	Sig. (p)	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	2.54	.84	2.66	.80	**.146**	**.007**	2.70	.83	**.180**	**.004**
Aspirations towards science/chemistry: A-Level studying	2.71	.91	2.83	.87	**.140**	**.010**	2.85	.90	**.158**	**.013**
Aspirations towards science/chemistry: university studying	2.46	.95	2.58	.91	**.126**	**.020**	2.61	.93	**.157**	**.014**
Aspirations towards science/chemistry: careers	2.46	.95	2.58	.93	**.130**	**.016**	2.62	.95	**.172**	**.007**
Aspirations towards science careers	2.46	.95	2.58	.93	**.130**	**.016**	2.62	.95	**.172**	**.007**
Perceived utility of science/chemistry	2.98	.68	3.09	.59	**.166**	**.002**	3.13	.58	**.225**	**<.001**
Interest in science/chemistry	2.91	.77	2.96	.70	.064	.231	3.05	.67	**.189**	**.003**
Self-confidence in science/chemistry	2.52	.68	2.58	.63	.087	.109	2.60	.62	**.124**	**.049**
Value of science/chemistry to society	2.99	.71	3.11	.61	**.185**	**.001**	3.15	.59	**.248**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	2.85	.69	2.90	.65	.071	.186	2.94	.67	**.128**	**.042**
Teaching/learning experiences: practical/experimental	2.46	.80	2.44	.73	.023	.663	2.48	.74	.028	.651
Teaching/learning experiences: relevance/applications	2.86	.89	2.88	.88	.018	.736	2.94	.87	.085	.181
Teaching and learning experiences (all)	2.73	.64	2.75	.60	.032	.551	2.79	.62	.098	.120
Perceptions of teachers	3.00	.80	3.08	.68	.096	.075	3.13	.67	**.165**	**.009**
Encouragement to study science/chemistry	2.71	.99	2.79	.93	.083	.134	2.84	.91	**.129**	**.046**
Home support for science/chemistry achievement	2.63	.77	2.75	.72	**.165**	**.003**	2.77	.69	**.188**	**.004**
Extra-curricular engagement with science/chemistry	1.62	.65	1.66	.67	.058	.294	1.70	.68	.117	.072
Encouragement/shared extra-curricular engagement	1.84	.87	1.82	.88	.015	.791	1.83	.87	.003	.961

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups.

Table 5-3: Students' responses at Year 8 by gender

Indicator (1–4 scales, unless otherwise shown)	Comparison students: Girls		Comparison students: Boys		Comparison students: Difference		Chemistry for All students: Boys		Chemistry for All students: Girls		Chemistry for All students: Difference	
	M	SD	M	SD	D	Sig. (p)	M	SD	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	2.56	.87	2.51	.83	.063	.465	2.56	.82	2.59	.81	.033	.385
Aspirations towards science/chemistry: A-Level studying	2.74	.91	2.66	.92	.081	.347	2.74	.89	2.73	.90	.008	.830
Aspirations towards science/chemistry: university studying	2.48	.98	2.43	.93	.047	.587	2.49	.91	2.51	.92	.021	.579
Aspirations towards science/chemistry: careers	2.49	.99	2.43	.92	.061	.482	2.44	.94	2.52	.95	**.084**	**.029**
Aspirations towards science careers	2.49	.99	2.43	.92	.061	.482	2.44	.94	2.52	.95	**.084**	**.029**
Perceived utility of science/chemistry	2.99	.67	2.96	.69	.046	.593	2.97	.61	3.02	.63	**.082**	**.030**
Interest in science/chemistry	2.88	.74	2.95	.81	.079	.354	2.72	.75	2.91	.73	**.262**	**<.001**
Self-confidence in science/chemistry	2.40	.60	2.62	.74	**.325**	**<.001**	2.39	.62	2.63	.65	**.384**	**<.001**
Value of science/chemistry to society	2.98	.63	3.00	.77	.037	.670	2.92	.64	3.08	.67	**.235**	**<.001**
Teaching/learning experiences: interaction/ debate/discussion	2.84	.62	2.86	.77	.027	.753	2.78	.64	2.85	.65	**.102**	**.007**
Teaching/learning experiences: practical/ experimental	2.43	.79	2.47	.82	.044	.610	2.34	.71	2.41	.73	**.099**	**.010**
Teaching/learning experiences: relevance/ applications	2.83	.84	2.89	.95	.065	.452	2.75	.86	2.85	.88	**.112**	**.004**
Teaching and learning experiences (all)	2.70	.59	2.73	.70	.049	.567	2.63	.58	2.70	.60	**.120**	**.002**
Perceptions of teachers	3.03	.81	2.97	.81	.076	.375	2.93	.70	3.00	.73	**.098**	**.010**
Encouragement to study science/chemistry	2.72	.93	2.72	1.04	.006	.943	2.73	.93	2.69	.97	.040	.306
Home support for science/chemistry achievement	2.63	.75	2.62	.81	.013	.886	2.71	.74	2.67	.75	.059	.134
Extra-curricular engagement with science/chemistry	1.48	.51	1.76	.73	**.444**	**<.001**	1.57	.59	1.71	.72	**.213**	**<.001**
Encouragement/shared extra-curricular engagement	1.74	.78	1.92	.94	**.204**	**.022**	1.78	.82	1.88	.92	**.115**	**.004**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups.

Table 5-4: Students' responses at Year 8 by books at home

Indicator (1–4 scales unless otherwise shown)	Comparison students						Chemistry for All students					
	0-25 books at home		26+ books at home		Difference		0-25 books at home		26+ books at home		Difference	
	M	SD	M	SD	D	Sig. (p)	M	SD	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	2.54	.76	2.58	.85	.050	.654	2.52	.80	2.67	.83	**.190**	**<.001**
Aspirations towards science/chemistry: A-Level studying	2.70	.79	2.75	.91	.058	.599	2.67	.89	2.82	.89	**.170**	**<.001**
Aspirations towards science/chemistry: university studying	2.52	.92	2.48	.94	.044	.693	2.45	.91	2.60	.92	**.158**	**<.001**
Aspirations towards science/chemistry: careers	2.42	.93	2.51	.95	.100	.370	2.42	.95	2.59	.93	**.178**	**<.001**
Aspirations towards science careers	2.42	.93	2.51	.95	.100	.370	2.42	.95	2.59	.93	**.178**	**<.001**
Perceived utility of science/chemistry	2.99	.63	3.03	.67	.067	.541	2.96	.61	3.06	.62	**.172**	**<.001**
Interest in science/chemistry	2.96	.70	3.00	.73	.063	.567	2.76	.75	2.93	.72	**.219**	**<.001**
Self-confidence in science/chemistry	2.48	.67	2.55	.67	.101	.361	2.44	.65	2.62	.63	**.271**	**<.001**
Value of science/chemistry to society	2.89	.65	3.11	.68	**.336**	**.003**	2.96	.65	3.07	.64	**.166**	**<.001**
Teaching/learning experiences: interaction/ debate/discussion	2.91	.73	2.86	.67	.080	.467	2.81	.62	2.89	.66	**.122**	**.003**
Teaching/learning experiences: practical/ experimental	2.48	.80	2.48	.81	.005	.963	2.34	.72	2.46	.72	**.163**	**<.001**
Teaching/learning experiences: relevance/ applications	2.90	.87	2.90	.89	.007	.947	2.78	.88	2.87	.83	.100	.017
Teaching and learning experiences (all)	2.77	.63	2.74	.65	.046	.678	2.65	.57	2.74	.59	**.160**	**<.001**
Perceptions of teachers	3.13	.73	3.01	.83	.147	.182	2.99	.70	3.03	.71	.059	.156
Encouragement to study science/chemistry	2.61	.96	2.85	.98	**.252**	**.028**	2.62	.92	2.84	.96	**.238**	**<.001**
Home support for science/chemistry achievement	2.52	.73	2.69	.77	.216	.055	2.64	.73	2.79	.73	**.204**	**<.001**
Extra-curricular engagement with science/chemistry	1.57	.57	1.61	.63	.073	.523	1.60	.66	1.68	.66	**.114**	**.009**
Encouragement/shared extra-curricular engagement	1.71	.75	1.88	.90	.206	.073	1.76	.83	1.90	.89	**.152**	**<.001**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups.

5.2. Changes in students' views across time

Changes in students' views across time and any different patterns of changes across different students were considered through repeated-measures modelling (**Table 5-5**). This accounted for the same students being surveyed on multiple occasions (where students' responses were likely to be somewhat similar instead of being independent across time) and also accounted for students being clustered within schools (where students' responses were likely to be somewhat similar within schools instead of being independent due to the shared teaching/learning context and wider environment). Comprehensive details of students' changing views per year and per cohort are available as Supplemental Material.

The modelling revealed changes occurring over time for every outcome (**Table 5-5**). As an overview, generalising across both cohorts and across schools that received and did not receive the Chemistry for All programme, at Year 11, students tended to convey (**Table 5-6**):

- Positive views regarding the value of chemistry to society and perceptions of their teachers;
- Neutral views regarding utility value of chemistry, interest/enjoyment in chemistry, and experiences of teaching/learning;
- Negative views regarding their self-confidence in chemistry, encouragement to continue with science/chemistry, home support for chemistry achievement, and aspirations toward chemistry studying and careers.

Essentially, students' views tended to become less positive over time from Year 8 (**Table 5-1**) to Year 11 (**Table 5-6**). The clearest exceptions were that the students still tended to report that they 'Sometimes' engaged in extra-curricular engagement with science/chemistry (which could occur within and outside of school) and that they still 'Sometimes' had family encouragement/shared extra-curricular engagement. For these two areas, various changes occurred from year to year (but with no clear pattern); comparison students showed no differences when comparing their Year 8 and Year 11 views (via additional tests undertaken as part of the repeated-measures modelling), while the Chemistry for All students reported slightly higher at Year 11 than Year 8.

5.2.1. Chemistry for All and comparison students

Considering both cohorts combined (**Table 5-5**), the repeated-measures modelling revealed different patterns of change over time for the students who received the Chemistry for All programme compared to the comparison students for:

- Aspirations towards science/chemistry overall (and for specific aspirations towards A-Level studying, university studying, and careers, when considered separately);
- Perceived utility of science/chemistry;
- Interest/enjoyment in science/chemistry;
- Self-confidence in science/chemistry;

- Teaching and learning experiences overall (and for the specific indicators of having opportunities to explain ideas and opinions, experiencing and engaging in a range of practical activities, and that teachers use science to help understand the world outside school, when considered separately);
- Perceptions of teachers;
- Extra-curricular engagement with science/chemistry.

These differences were characterised by changes over time being smaller for students within schools that received the Chemistry for All programme. Students tended to express similar views at Year 8 (**Table 5-1**); subsequently, students in schools that received the Chemistry for All programme tended to convey slightly higher views at Year 11 than students within comparison schools who did not receive the programme (**Table 5-6**).

Specifically, at Year 11 (**Table 5-6**), students within schools that received the Chemistry for All programme expressed more positive views than the comparison students for (in order of largest to smallest differences): perceptions of teachers, teaching and learning experiences, aspirations toward chemistry, perceived utility of chemistry, extra-curricular engagement with science/chemistry, and interest/enjoyment in chemistry. Self-confidence was an exception, however: students who did and did not receive the Chemistry for All programme had similar views at Year 8, then had different patterns of change over time, and then their views were again similar at Year 11.

Considering students' aspirations in more detail, across both cohorts of students at Year 11: 23.2% of students who received the Chemistry for All programme agreed or strongly agreed that they intended to continue to study chemistry at an A-Level or equivalent, compared to 18.5% of students in comparison schools; 15.6% of students who received the Chemistry for All programme agreed or strongly agreed that they intended to continue to study chemistry at university, compared to 9.1% of students in comparison schools; 22.3% of students who received the Chemistry for All programme agreed or strongly agreed that they would like a job that includes chemistry, compared to 13.6% of students in comparison schools.

No overall differences in patterns/trends over time (across students within schools that did and did not received the Chemistry for All programme) were revealed for:

- Specific aspirations towards science careers;
- Value of science/chemistry to society;
- Encouragement to study science/chemistry;
- Home support for science/chemistry achievement;
- Encouragement / shared extra-curricular engagement.

For these areas, students who did and did not receive the Chemistry for All programme reported similar views at Year 8 and also reported similar views at Year 11. Across both cohorts of students at Year 11: 41.3% of students who received the Chemistry for All programme and 44.3% of students in comparison schools agreed or strongly agreed that they would like a job that includes science.

Engagement with the Chemistry for All programme

Considering both cohorts combined, additional repeated-measures modelling revealed different patterns of change over time for the comparison students when compared to students with greater engagement with the Chemistry for All programme (those who were recorded as attending at least one, and/or those who were recorded as attending more than one, optional activity/event) for:

- Aspirations towards science/chemistry overall (and for specific aspirations towards A-Level studying, university studying, and careers, when considered separately);
- Perceived utility of science/chemistry;
- Interest/enjoyment in science/chemistry;
- Self-confidence in science/chemistry;
- Teaching and learning experiences overall (and for the specific indicators of having opportunities to explain ideas and opinions, experiencing and engaging in a range of practical activities, and that teachers use science to help understand the world outside school, when considered separately);
- Perceptions of teachers;
- Extra-curricular engagement with science/chemistry.

Changes over time tended to be smaller for students with greater engagement with the Chemistry for All programme. Across both cohorts combined (**Table 5-7**), students with greater engagement with the Chemistry for All programme showed slightly declining views but maintained positive perceived utility of science/chemistry, interest in science/chemistry, value of science/chemistry to society, and perceptions of teachers. Nevertheless, students with greater engagement with the Chemistry for All programme may have selected themselves, and often (but not always) also tended to express more positive initial views at Year 8 than the comparison students.

Students' wider views

Some other views were only measured in later academic years, so patterns of change over time could not be considered through repeated-measures modelling. Nevertheless, the students' wider views at Year 11, towards the end of the Chemistry for All programme, provide additional insights (**Table 5-6**).

Across both cohorts and across schools that received and did not receive the Chemistry for All programme, at Year

11 students tended to convey positive views regarding their general achievement motivation (aiming for top grades and the best opportunities), slightly negative views for their personal value of chemistry (chemistry being a valued and inherent aspect of their identity), and slightly negative views for their family science capital/ connection (their perceptions of their family members having science-related qualifications, jobs, and/or interest in talking about science). Additionally, again at Year 11, students tended to convey current science grades and expected GCSE chemistry/science grades between 4 and 5 (on the 0–9 numeric grade scale, with 9 reflecting the highest grade and 0 reflecting grade U); students tended to expect that they would achieve around grade C if they were to take A-Level chemistry (on a scale with A* reflecting the highest grade and U reflecting the lowest).

At Year 11, students within schools that received the Chemistry for All programme expressed more positive views than the comparison students for their personal value of chemistry, similar levels of family science capital/ connection, and less positive views for their general achievement motivation. Additionally, again at Year 11, students within schools that received the Chemistry for All programme expressed lower current science grades and lower expected GCSE science/chemistry grades, but expressed similar expected grades if A-Level chemistry were to be taken.

5.2.2. Students with different characteristics and circumstances

Additional repeated-measures modelling considered whether students with different characteristics/ circumstances had different patterns of changing views over time, in order to essentially reveal whether the Chemistry for All programme had different impacts on different students. Nevertheless, differences are generally harder to reveal across smaller groups of students, and considering specific characteristics (such as gender) in isolation cannot account for the full complexities of life, where characteristics and circumstances may intersect to entail particular experiences or challenges.

Gender

Across both cohorts combined, different patterns of changing views over time across gender and programmes (being within a school that received the Chemistry for All programme or being within a comparison school) were revealed for:

- Specific aspirations towards science/ chemistry careers;
- Specific aspirations towards science careers;
- Value of science/chemistry to society.

These changes tended to involve gender differences (with boys tending to express higher views than girls) arising and/or increasing for students in schools that did not receive the Chemistry for All programme, while gender differences were not present or were smaller in magnitude for students in schools that received the Chemistry for All programme (**Table 5-8**).

Differences were more apparent within the younger cohort of students considered alone, where different patterns of change across gender and programmes were revealed for:

- Aspirations towards science/chemistry overall (and for specific aspirations towards science/chemistry A-Level studying, and towards science/chemistry careers, when considered separately);
- Specific aspirations towards science careers;
- Perceived utility of science/chemistry;
- Interest/enjoyment in science/chemistry;
- Value of science/chemistry to society;
- Teaching and learning experiences overall (and for having opportunities to explain ideas and opinions, and perceiving that teachers use science to help students understand the world outside school, when considered separately);
- Perceptions of teachers.

These changes also tended to involve gender differences (with boys tending to express higher views than girls) arising and/or increasing for students in schools that did not experience the Chemistry for All programme, while gender differences were not present or were smaller in magnitude for students in schools that received the Chemistry for All programme.

Considering students' aspirations in detail, within the younger cohort of students, girls within schools that received the Chemistry for All programme and girls within comparison schools tended to express similar views at Year 8 but different views at Year 11. For example, in the younger cohort of students at Year 8, 63.1% of girls within schools that received the Chemistry for All programme and 65.1% of girls within comparison schools agreed or strongly agreed that they intended to continue to study science/chemistry at an A-Level or equivalent; 62.6% of boys within schools that received the Chemistry for All programme and 64.2% of boys within comparison schools agreed or strongly agreed that they intended to continue to study science/ chemistry at an A-Level or equivalent. At Year 11, 26.5% of girls within schools that received the Chemistry for All programme and 12.3% of girls within comparison schools agreed or strongly agreed that they intended to continue to study chemistry at an A-Level or equivalent; 25.3% of boys within schools that received the Chemistry for All programme and 24.5% of boys within comparison schools agreed or strongly agreed that they intended to continue to study chemistry at an A-Level or equivalent.

Essentially, it is possible to infer that the Chemistry for All programme particularly helped to support girls in some areas, and/or mitigated implicit or explicit barriers or challenges that might arise in other schools. Nevertheless, variability across the two cohorts suggests that further programmes may need to consider features of their cohorts and/or delivery in order to best deliver support.

Books at home

There were no differences in patterns of changing views over time across those with very low books at home and those with more books at home across receiving or not receiving the Chemistry for All programme. Essentially, it is possible to infer that the Chemistry for All programme had a similar influence on students with very low books at home and students with more books at home. Nevertheless, socio-economic circumstances are complex, and considering the number of books at home in this way only offers one particular and simplified perspective.

At Year 11 **(Table 5-9)**, considering both cohorts combined, within schools that received the Chemistry for All programme, students who reported more books at home tended to express higher views than students who reported very few books at home. This highlights the continuing need to address inequity and inequality, within and/or regardless of programmes of support.

Table 5-5: Patterns of change across time across Chemistry for All and comparison students

Indicators	Time	Time x programme
Aspirations towards science/chemistry (all)	**<.001**	**<.001**
Aspirations towards science/chemistry: A-Level studying	**<.001**	**.004**
Aspirations towards science/chemistry: university studying	**<.001**	**.001**
Aspirations towards science/chemistry: careers	**<.001**	**<.001**
Aspirations towards science careers	**<.001**	.347
Perceived utility of science/chemistry	**<.001**	**<.001**
Interest in science/chemistry	**<.001**	**.002**
Self-confidence in science/chemistry	**<.001**	**<.001**
Value of science/chemistry to society	**<.001**	.057
Teaching/learning experiences: interaction/debate/discussion	**<.001**	**<.001**
Teaching/learning experiences: practical/experimental	**<.001**	**<.001**
Teaching/learning experiences: relevance/applications	**<.001**	**.002**
Teaching and learning experiences (all)	**<.001**	**<.001**
Perceptions of teachers	**<.001**	**<.001**
Encouragement to study science/chemistry	**<.001**	.246
Home support for science/chemistry achievement	**<.001**	.572
Extra-curricular engagement with science/chemistry	**<.001**	**<.001**
Encouragement/shared extra-curricular engagement	**<.001**	.942

Notes: Results from both cohorts combined. The table shows the significance (p-values) of the 'time' and 'time × programme' elements from repeated measures modelling. Significant values for 'time' reflect patterns of change occurring over time. Significant values for 'time × programme' reflect different patterns of change occurring over time across Chemistry for All and comparison students (expressed more simply, Chemistry for All students can be inferred to have one pattern of change over time while comparison students can be inferred to have a different pattern of change over time).

Indicator (1–4 scales, unless otherwise shown)	Comparison students		Chemistry for All students		Difference	
	M	SD	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	1.67	.79	1.87	.84	**.232**	**<.001**
Aspirations towards science/chemistry: A-Level studying	1.77	.99	1.92	.97	**.150**	**.007**
Aspirations towards science/chemistry: university studying	1.55	.76	1.76	.82	**.250**	**<.001**
Aspirations towards science/chemistry: careers	1.69	.81	1.91	.89	**.240**	**<.001**
Aspirations towards science careers	2.26	1.07	2.25	1.03	.016	.768
Perceived utility of science/chemistry	2.39	.69	2.51	.69	**.163**	**.003**
Interest in science/chemistry	2.41	.78	2.53	.77	**.146**	**.009**
Self-confidence in science/chemistry	2.12	.69	2.18	.70	.080	.168
Value of science/chemistry to society	2.72	.72	2.75	.72	.035	.555
Teaching/learning experiences: interaction/debate/discussion	2.43	.70	2.64	.67	**.308**	**<.001**
Teaching/learning experiences: practical/experimental	2.02	.67	2.20	.71	**.263**	**<.001**
Teaching/learning experiences: relevance/applications	2.46	.87	2.65	.84	**.224**	**<.001**
Teaching and learning experiences (all)	2.30	.59	2.50	.61	**.325**	**<.001**
Perceptions of teachers	2.72	.75	2.98	.70	**.359**	**<.001**
Encouragement to study science/chemistry	2.29	1.00	2.33	.99	.038	.510
Home support for science/chemistry achievement	2.31	.79	2.34	.80	.037	.522
Extra-curricular engagement with science/chemistry	1.62	.65	1.73	.71	**.148**	**.012**
Encouragement/shared extra-curricular engagement	2.01	.91	1.96	.87	.061	.306
Personal value of science/chemistry	2.04	.74	2.14	.76	**.142**	**.010**
Achievement motivation / ambition in general	3.35	.52	3.29	.58	**.119**	**.029**
Family science capital/connection	2.31	.88	2.33	.87	.022	.706
Parents/teachers conveying the value of science/chemistry	2.42	.82	2.43	.80	.006	.914
Grades: Science grade this year (0-9)	4.74	1.95	4.20	1.79	**.297**	**<.001**
Grades: Expected GCSE science/chemistry grade (0-9)	5.13	1.83	4.59	1.78	**.302**	**<.001**
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	3.79	1.72	3.86	1.69	.041	.458

Table 5-6: Students' responses at Year 11

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups. Current and GCSE grades are shown on a 0-9 scale (0=U, 1=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9); expected A-Level grades are shown on a 1-7 scale (1=U, 2=E, 3=D, 4=C, 5=B, 6=A, 7=A*).

Table 5-7: Students' responses at Year 11 by engagement with the Chemistry for All programme

Indicator (1–4 scales unless otherwise shown)	Comparison students		Chemistry for All students				Chemistry for All students			
			Attended at least one optional activity/ event		Difference to comparison students		Attended more than one optional activity/ event		Difference to comparison students	
	M	SD	M	SD	D	Sig. (p)	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	1.67	.79	1.99	.88	**.372**	**<.001**	2.04	.88	**.440**	**<.001**
Aspirations towards science/chemistry: A-Level studying	1.77	.99	2.06	1.02	**.280**	**<.001**	2.10	1.03	**.328**	**<.001**
Aspirations towards science/chemistry: university studying	1.55	.76	1.86	.85	**.373**	**<.001**	1.91	.86	**.443**	**<.001**
Aspirations towards science/chemistry: careers	1.69	.81	2.04	.94	**.386**	**<.001**	2.08	.94	**.448**	**<.001**
Aspirations towards science careers	2.26	1.07	2.44	1.06	**.169**	**.009**	2.50	1.06	**.223**	**.003**
Perceived utility of science/chemistry	2.39	.69	2.67	.68	**.404**	**<.001**	2.71	.68	**.468**	**<.001**
Interest in science/chemistry	2.41	.78	2.72	.70	**.412**	**<.001**	2.77	.66	**.481**	**<.001**
Self-confidence in science/chemistry	2.12	.69	2.28	.70	**.230**	**.001**	2.30	.68	**.263**	**.001**
Value of science/chemistry to society	2.72	.72	2.89	.68	**.237**	**<.001**	2.97	.65	**.354**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	2.43	.70	2.72	.64	**.435**	**<.001**	2.78	.62	**.518**	**<.001**
Teaching/learning experiences: practical/experimental	2.02	.67	2.33	.73	**.438**	**<.001**	2.43	.71	**.593**	**<.001**
Teaching/learning experiences: relevance/applications	2.46	.87	2.77	.80	**.377**	**<.001**	2.82	.79	**.431**	**<.001**
Teaching and learning experiences (all)	2.30	.59	2.60	.59	**.507**	**<.001**	2.67	.58	**.633**	**<.001**
Perceptions of teachers	2.72	.75	3.08	.68	**.499**	**<.001**	3.12	.66	**.561**	**<.001**
Encouragement to study science/chemistry	2.29	1.00	2.50	.98	**.214**	**.002**	2.51	.97	**.222**	**.005**
Home support for science/chemistry achievement	2.31	.79	2.46	.80	**.178**	**.008**	2.48	.80	**.208**	**.008**
Extra-curricular engagement with science/chemistry	1.62	.65	1.84	.74	**.313**	**<.001**	1.83	.71	**.301**	**<.001**
Encouragement/shared extra-curricular engagement	2.01	.91	2.03	.89	.014	.842	2.05	.86	.037	.640
Personal value of science/chemistry	2.04	.74	2.31	.78	**.359**	**<.001**	2.34	.78	**.399**	**<.001**
Achievement motivation / ambition in general	3.35	.52	3.39	.56	.060	.339	3.41	.57	.111	.134
Family science capital/connection	2.31	.88	2.40	.87	.100	.140	2.41	.88	.112	.157
Parents/teachers conveying the value of science/chemistry	2.42	.82	2.55	.77	**.168**	**.012**	2.57	.77	**.180**	**.022**
Grades: Science grade this year (0-9)	4.74	1.95	4.68	1.69	.029	.654	4.82	1.70	.046	.539
Grades: Expected GCSE science/chemistry grade (0-9)	5.13	1.83	5.10	1.69	.013	.839	5.20	1.66	.041	.583
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	3.79	1.72	4.22	1.62	**.259**	**<.001**	4.24	1.63	**.269**	**<.001**

Notes: Results from both cohorts combined. The table shows the significance (p-values) of the 'time' and 'time × programme' elements from repeated measures modelling. Significant values for 'time' reflect patterns of change occurring over time. Significant values for 'time × programme' reflect different patterns of change occurring over time across Chemistry for All and comparison students (expressed more simply, Chemistry for All students can be inferred to have one pattern of change over time while comparison students can be inferred to have a different pattern of change over time).

Table 5-8: Students' responses at Year 11 by gender

Indicator (1–4 scales unless otherwise shown)	Comparison students						Chemistry for All students					
	Girls		Boys		Difference		Boys		Girls		Difference	
	M	SD	M	SD	D	Sig. (p)	M	SD	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	1.56	.73	1.77	.83	**.268**	**.009**	1.88	.84	1.85	.84	.038	.390
Aspirations towards science/chemistry: A-Level studying	1.65	.93	1.88	1.03	**.229**	**.025**	1.94	.97	1.90	.97	.041	.362
Aspirations towards science/chemistry: university studying	1.46	.66	1.63	.83	**.226**	**.028**	1.77	.80	1.75	.84	.026	.565
Aspirations towards science/chemistry: careers	1.55	.74	1.81	.85	**.327**	**.002**	1.92	.89	1.89	.89	.036	.413
Aspirations towards science careers	2.11	1.09	2.39	1.03	**.264**	**.011**	2.27	1.03	2.23	1.02	.037	.407
Perceived utility of science/chemistry	2.29	.65	2.48	.70	**.279**	**.006**	2.50	.70	2.52	.68	.021	.629
Interest in science/chemistry	2.31	.76	2.51	.80	**.255**	**.014**	2.52	.76	2.55	.77	.043	.341
Self-confidence in science/chemistry	1.96	.60	2.27	.73	**.459**	**<.001**	2.09	.67	2.28	.71	**.280**	**<.001**
Value of science/chemistry to society	2.62	.69	2.81	.73	**.266**	**.014**	2.72	.71	2.78	.73	.088	.065
Teaching/learning experiences: interaction/debate/discussion	2.38	.66	2.48	.73	.153	.140	2.63	.66	2.66	.68	.039	.384
Teaching/learning experiences: practical/experimental	1.97	.59	2.06	.73	.131	.208	2.21	.69	2.20	.73	.025	.582
Teaching/learning experiences: relevance/applications	2.39	.83	2.51	.91	.139	.187	2.62	.83	2.68	.84	.067	.139
Teaching and learning experiences (all)	2.24	.52	2.35	.65	.173	.096	2.49	.59	2.51	.62	.022	.622
Perceptions of teachers	2.74	.75	2.71	.76	.033	.755	2.96	.70	3.00	.69	.059	.194
Encouragement to study science/chemistry	2.20	.97	2.36	1.02	.160	.137	2.38	.98	2.27	.98	**.113**	**.016**
Home support for science/chemistry achievement	2.23	.79	2.39	.79	.210	.050	2.39	.79	2.30	.81	**.107**	**.024**
Extra-curricular engagement with science/chemistry	1.46	.50	1.76	.74	**.463**	**<.001**	1.71	.69	1.75	.73	.053	.272
Encouragement/shared extra-curricular engagement	2.03	.88	2.01	.93	.021	.843	1.98	.86	1.93	.89	.056	.245
Personal value of chemistry/science	1.92	.67	2.14	.78	**.308**	**.003**	2.12	.75	2.18	.78	.068	.127
Family science (science-related job, qualifications, talks science)	2.25	.90	2.37	.85	.127	.239	2.37	.88	2.30	.86	.075	.115
Achievement motivation	3.31	.50	3.39	.53	.170	.091	3.27	.57	3.31	.58	.082	.061
Parents/teachers conveying the value of science/chemistry	2.34	.84	2.50	.80	.196	.068	2.45	.78	2.40	.81	.053	.264
Grades: Science grade this year (0-9)	4.61	1.64	4.84	2.18	.122	.232	4.13	1.73	4.28	1.82	.086	.059
Grades: Expected GCSE science/chemistry grade (0-9)	4.91	1.72	5.31	1.90	**.218**	**.032**	4.47	1.74	4.71	1.79	**.134**	**.003**
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	3.48	1.67	4.06	1.72	**.339**	**.001**	3.68	1.66	4.06	1.68	**.226**	**<.001**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups. Current and GCSE grades are shown on a 0-9 scale (0=U, 1=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9); expected A-Level grades are shown on a 1-7 scale (1=U, 2=E, 3=D, 4=C, 5=B, 6=A, 7=A*).

Table 5-9: Students' responses at Year 11 by books at home

Indicator (1–4 scales unless otherwise shown)	Comparison students						Chemistry for All students					
	0-25 books at home		26+ books at home		Difference		0-25 books at home		26+ books at home		Difference	
	M	SD	M	SD	D	Sig. (p)	M	SD	M	SD	D	Sig. (p)
Aspirations towards science/chemistry (all)	1.62	.74	1.70	.81	.095	.371	1.81	.78	1.94	.90	**.150**	**.001**
Aspirations towards science/chemistry: A-Level studying	1.68	.87	1.83	1.05	.148	.162	1.86	.90	2.00	1.05	**.142**	**.001**
Aspirations towards science/chemistry: university studying	1.55	.71	1.55	.78	.003	.977	1.72	.77	1.82	.87	**.119**	**.008**
Aspirations towards science/chemistry: careers	1.64	.78	1.72	.82	.097	.363	1.85	.83	1.98	.95	**.156**	**.001**
Aspirations towards science careers	2.20	1.07	2.30	1.06	.088	.410	2.16	.98	2.36	1.07	**.191**	**<.001**
Perceived utility of science/chemistry	2.33	.68	2.42	.69	.138	.189	2.46	.66	2.57	.71	**.149**	**.001**
Interest in science/chemistry	2.34	.80	2.45	.77	.143	.186	2.48	.76	2.59	.77	**.143**	**.002**
Self-confidence in science/chemistry	2.06	.65	2.15	.70	.134	.222	2.14	.67	2.23	.71	**.128**	**.006**
Value of science/chemistry to society	2.58	.67	2.80	.73	**.311**	**.006**	2.64	.70	2.89	.71	**.354**	**<.001**
Teaching/learning experiences: interaction/ debate/discussion	2.40	.70	2.46	.69	.084	.437	2.66	.65	2.64	.69	.037	.417
Teaching/learning experiences: practical/ experimental	2.02	.63	2.02	.67	.010	.927	2.18	.70	2.24	.71	.078	.084
Teaching/learning experiences: relevance/ applications	2.40	.89	2.49	.87	.105	.337	2.61	.84	2.70	.82	**.114**	**.012**
Teaching and learning experiences (all)	2.27	.59	2.32	.59	.100	.354	2.49	.59	2.51	.62	.036	.425
Perceptions of teachers	2.73	.73	2.72	.76	.008	.943	2.97	.68	3.00	.71	.047	.307
Encouragement to study science/chemistry	2.16	.93	2.35	1.02	.197	.077	2.22	.93	2.45	1.03	**.234**	**<.001**
Home support for science/chemistry achievement	2.16	.75	2.41	.80	**.325**	**.004**	2.27	.77	2.44	.81	**.218**	**<.001**
Extra-curricular engagement with science/chemistry	1.66	.67	1.60	.65	.085	.451	1.63	.67	1.84	.74	**.307**	**<.001**
Encouragement/shared extra-curricular engagement	1.77	.82	2.16	.93	**.431**	**<.001**	1.83	.83	2.12	.89	**.338**	**<.001**
Personal value of chemistry/science	1.96	.74	2.07	.73	.162	.125	2.09	.73	2.22	.78	**.173**	**<.001**
Family science (science-related job, qualifications, talks science)	2.05	.80	2.47	.89	**.486**	**<.001**	2.23	.85	2.47	.88	**.282**	**<.001**
Achievement motivation	3.26	.56	3.41	.48	**.293**	**.005**	3.25	.56	3.34	.58	**.166**	**<.001**
Parents/teachers conveying the value of science/chemistry	2.23	.80	2.53	.81	**.377**	**.001**	2.33	.79	2.55	.78	**.270**	**<.001**
Grades: Science grade this year (0-9)	4.08	1.86	5.09	1.91	**.531**	**<.001**	3.79	1.65	4.68	1.80	**.520**	**<.001**
Grades: Expected GCSE science/chemistry grade (0-9)	4.54	1.78	5.44	1.77	**.503**	**<.001**	4.19	1.65	5.07	1.79	**.510**	**<.001**
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	3.39	1.56	4.02	1.77	**.368**	**.001**	3.67	1.63	4.09	1.72	**.252**	**<.001**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups. Current and GCSE grades are shown on a 0-9 scale (0=U, 1=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9); expected A-Level grades are shown on a 1-7 scale (1=U, 2=E, 3=D, 4=C, 5=B, 6=A, 7=A*).

5.3. Summary

Overall, the students' views and other experiences tended to become less positive over time; however, any changes over time were often smaller for students within schools that received the Chemistry for All programme compared to students within comparison schools. Specifically, the students tended to express similar initial views at Year 8; subsequently, at Year 11, students within schools that received the Chemistry for All programme tended to express higher views than the comparison students for their perceptions of teachers, teaching and learning experiences, aspirations toward chemistry, perceived utility of chemistry, extra-curricular engagement with science/chemistry, and interest/enjoyment in chemistry.

At Year 11, the differences in views across students within schools that received the Chemistry for All programme and students within comparison schools were largest for their perceptions of teachers and teaching/learning experiences (which encompassed having opportunities to explain ideas and opinions, experiencing and engaging in a range of practical activities, and that teachers use science to help students understand the world outside school). The Chemistry for All programme involved practical demonstrations, talks and events, and various other activities; these were intended to be fun and enjoyable, and to also convey the benefits of science/chemistry studying and careers.

Students may have perceived some programme activities to be part of their overall school science teaching/learning environment, which might encompass opportunities to explain ideas and using science/chemistry to help understand the world outside school (whether as part of Chemistry for All and/or as part of other lessons). The programme may also have been directly instructive and/or inspirational, and accordingly reflected in the students' aspirations toward chemistry, perceived utility of chemistry, and interest/enjoyment in chemistry.

No differences in patterns of changing views were observed across students within schools that received the Chemistry for All programme and students within comparison schools for the students' beliefs about the value of science/chemistry to society and for their home/family support and encouragement to study science/chemistry. It is possible that the Chemistry for All programme focused on conveying the personal benefits of science/chemistry careers (given that the programme aimed to inspire students to study chemistry in the future), more so than conveying the wider benefits of science/chemistry to society such as via industry and innovation in general terms. From a wider perspective, programmes within schools are less likely to change home/family matters; different students may face different challenges and further support may still be beneficial, whether from schools, universities, industry, and/or through other avenues.

6

Students' likes and dislikes about science/chemistry

6. Students' likes and dislikes about science/chemistry

Highlights and key findings

- Many students liked experimental/practical work in science/chemistry, although highlighting this became less prevalent as students grew older.
- Some students appreciated their teachers, and highlighting this became more prevalent as students grew older.
- Students also liked: learning new things; learning many things and/or a variety of things; and learning about relevant things (including learning about the world and/or how things work).
- Students disliked having to write extensively (including have to write about experimental/ practical work), although highlighting this was less prevalent as students grew older.
- As students grew older, they increasingly highlighted dislikes following from: material being considered to be difficult, complex, and/ or hard to understand; equations, formulae, and symbols; and that teaching/learning involved memorisation and/or having to otherwise remember information.

6.1. What things do you like about science/chemistry at your school?

The questionnaires invited students to explain what they liked and disliked about science at school ('What things do you like about science at your school?' and 'What things do you not like about science at your school?'). From Year 10 onwards, the questions were orientated towards chemistry ('What things do you like about chemistry at your school?' and 'What things do you not like about chemistry at your school?'). Students provided written responses, which were transcribed from paper questionnaires or directly entered via online questionnaires. Iterative content analysis was applied to form and refine categories from the students' responses, in order to develop a classification structure that was quantifiable, interpretable, and consistent across the multiple waves of surveying (given that some categories might be more or less prevalent and/or present at different times). One response (from one student) could cover one or more thematic categories, for example where multiple aspects of teaching and learning could be mentioned. Across both cohorts of students, 3269 students provided responses about what they liked about science/chemistry at Year 8, 3756 at Year 9, 3349 at Year 10, and 2008 at Year 11 (12382 responses overall); 3117 students provided responses about what they disliked about science/chemistry at Year 8, 3498 at Year 9, 3019 at Year 10, and 1759 at Year 11 (11393 responses overall).

Similar findings were revealed across the two cohorts when considered separately and when combined; detailed results are available as Supplemental Material. Considering both cohorts of students combined across Year 8, Year 9, Year 10, and Year 11, and encompassing students within schools that received the Chemistry for All programme and the comparison students within other schools, the most prevalent themes for 'What things do you like about science/chemistry at your school?' were the following:

- Experimental and/or practical work (7684 instances across Year 8, Year 9, Year 10, and Year 11; 62.1% of all responses).
- Mentioning particular science topics (across all science subjects; 1709 instances; 13.8%).
- Fun, enjoyment, and/or interest (1680 instances; 13.6%).
- Teachers being good, beneficial, and/or positively perceived (across all aspects linked with teachers, including teachers facilitating understanding and enjoyment; 1066 instances; 8.6%).
- Learning new things (611 instances; 4.9%).
- Learning many things and/or a variety of things (312 instances; 2.5%).
- Learning about relevant things (278 instances; 2.2%). This category included learning about the world and/or how things work.
- Everything and/or that science/chemistry was generally perceived positively without further detail being provided (243 instances; 2.0%). This category encompassed students literally expressing 'everything', that science/chemistry was 'good', and other equivalent views.
- Groupwork within teaching/learning (195 instances; 1.5%).
- Usefulness or utility of science/chemistry and any wider benefits from learning/careers (189 instances; 1.5%).

However, some students highlighted (via this question) that nothing was liked and/or that science/chemistry was perceived negatively (1211 instances across Year 8, Year 9, Year 10, and Year 11; 9.8% of all responses).

Experimental and/or practical work was the most frequent category overall (7684 instances across Year 8, Year 9, Year 10, and Year 11; 62.1% of all responses). Considered in more detail, some responses involved highlighting that practical activities facilitated fun, enjoyment, and/or interest (494 instances; 4.0%); some responses involved highlighting explosions, fire, and/or danger linked with practical activities (316 instances; 2.6%); and some responses involved highlighting that practical activities facilitated understanding (202 instances; 1.6%).

Mentioning particular science topics was another prevalent theme. Considered in more detail, many students explicitly mentioned chemistry topics (1019 instances across Year 8, Year 9, Year 10, and Year 11; 8.2% of all responses), biology topics (560 instances; 4.5%), and physics topics (335 instances; 2.7%). The prevalence of these different subjects cannot be compared, however, given that the question was explicitly orientated towards chemistry from Year 10 onwards.

The prevalence of some categories varied across time (**Table 6-1** and **Table 6-2**); repeated-measures modelling was used to concurrently consider changes across time and students who received and did not receive the Chemistry for All programme. Nevertheless, the smaller numbers of responses for some categories may have limited the potential of any analysis to definitively consider differences. For both cohorts considered together at Year 8, Year 9, Year 10, and Year 11, repeated-measures modelling revealed the following (where patterns across time were similar across students who did and did not receive the Chemistry for All programme, unless otherwise mentioned):

- Experimental and/or practical work: changes occurred over time (with a lesser extent of change for those who received the Chemistry for All programme), which could be characterised as less frequent mentioning over time.
- Mentioning particular science topics: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Fun, enjoyment, and/or interest: changes occurred over time (with a lesser extent of change for those who received the Chemistry for All programme), which could be characterised as less frequent mentioning over time.
- Teachers being good, beneficial, and/or positively perceived: changes occurred over time (with a lesser extent of change for those who received the Chemistry for All programme), which could be characterised as more frequent mentioning over time.
- Learning new things: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Learning many things and/or a variety of things: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Learning about relevant things: no clear changes were revealed over time.
- Everything and/or that science/chemistry was generally perceived positively without further detail being provided: changes occurred over time, but with no characteristic pattern.
- Groupwork within teaching/learning: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Usefulness or utility of science/chemistry and any wider benefits from learning/careers: changes occurred over time, but with no characteristic pattern.

Considering the overall instances of categories can provide an illustrative overview of students likes/dislikes; few differences were apparent across students who received and did not receive the Chemistry for All programme. Nevertheless, given students' potentially limited time and/or any other contextual factors that might have influenced their responses, the changing prevalence of mentioning different categories over time may not necessarily reflect that any earlier aspects became less important, but might reflect that highlighting other aspects may have taken precedence at later times. Essentially, students often provided relatively short answers, within the context of a longer questionnaire; with limited time, students may have briefly highlighted their favoured area or areas (such as experimental/practical work) and then moved onto the next question.

6.1.1. Examples of responses

Experimental and/or practical work:

- "I enjoy doing anything practical";
- "All the practicals and experiments";
- "The practical work is interesting and a fun experience";
- "The practicals in chemistry are quite fun";
- "Blowing up stuff";
- "Teachers make it more fun by doing practicals. Which helps to learn easier";
- "I like learning about the bonds and atoms but I really like practical's because they are really exciting and fun";
- "I like it when we do practices that are more interesting that putting magnesium in Ethanoic acid";
- "I like the fact that we get to do lots of practices and that there is a lot of theory work as well. It's also really fun learning about all the acids and alkalis";
- "I can't exaggerate how much I love seeing reactions take place. I love scientific explanations for my surroundings";
- "I like the practical part of chemistry because you get to discover how the chemicals interact with one another, which means that I have the experience of seeing what will happen in that specific type of reaction";
- "The things that I like about chemistry is the topics that I get to learn and the experiments that I do to further support my learning";

- "I love doing the practices and the topics in the second paper of chemistry. I love talking about abiotic and biotic fuels and factor that affect the global temperature, the atmosphere along side with talking about the metals and the fuels that surround the world".

Mentioning particular science topics:

- "I like to learn about how atoms and all kinds of bonding work";
- "Ions, bonds, periodic table";
- "Atoms";
- "Electrolysis";
- "At the moment, I like learning about resources and the atmosphere";
- "Global warming, pollution, crude oil";
- "I like learning about organic chemistry";
- "Learning about the atmosphere";
- "Learning about the human body";
- "Learning about the elements";
- "Protons electrons and neutrons".

Fun, enjoyment, and/or interest:

- "That it is interesting";
- "It's fun";
- "The lessons are exciting and fun to learn";
- "I enjoy the experiments and I find it very interesting";
- "Interesting topics";
- "I like that it keeps me interested in science";
- "The interesting nature of the subjects we do";
- "I just like chemistry";
- "I think chemistry is fun especially when we do practicals";
- "It's fun doing experiments".

Teachers being good, beneficial, and/or positively perceived:

- "The teacher is nice";
- "I like my teacher";
- "We do lots of practicals and teachers make it easy";
- "My teacher is good at teaching it";
- "I like that topics are taught well and we are frequently tested";
- "It's extremely interesting my teacher helps me lots";
- "Experiments and the way I am being taught";
- "Guided through the subject";
- "Good teachers, good equipment";
- "It is amazing because our teacher teaches it very well";
- "Teacher is interactive and helpful";
- "Teacher knows everything about the subject";
- "It is good and the teachers are passionate about their jobs";
- "It is good as the teachers help when you don't understand a topic";
- "The guidance and support provided";
- "The teacher gives you confidence you will achieve well in your GCSE's and the content is interesting";
- "The teacher makes sure we understand a certain topic before moving on. We learn a variety of things";
- "Teacher makes subject enjoyable";
- "The teachers are very fun and make lessons interesting";
- "I find it the easiest out of all the sciences. I like my teacher which makes it more enjoyable".

Learning new things:

- "Practicals and learning new things";
- "Learning new things";
- "Learning things I didn't know, practical";
- "The unusual things that take place in experiments and learning about new and interesting things";
- "We're always learning new things".

Learning many things and/or a variety of things:

- "I enjoy the wide range of subjects we study as a part of chemistry";
- "I like learning about the different topics and how they intertwine";
- "I enjoy the wide range of subjects we study as a part of chemistry";
- "I like learning about different things";
- "The diversity in topics".

Learning about relevant things:

- "Know more about the world";
- "Learning about how the materials in the world work";
- "Learning about your body";
- "Learning how the world works. Theory work";
- "Learning how things work";
- "The subject can be engaging and helps in understanding situations across the world";
- "Interesting and helps us understand the way things work";
- "I like how it links to everyday life. I like learning new things";
- "It covers a wide range of subjects it gives a better understanding of the world";
- "We get to do interesting practicals which help us in day to day life and help us to expand our knowledge";
- "The practicals and being taught how it is relevant to everyday life".

Everything and/or that science/chemistry was generally perceived positively without further detail being provided:

- "Everything";
- "All of it";
- "Everything is just fine";
- "Everything it is very interesting and sometimes challenging";
- "Most if not all".

Groupwork within teaching/learning:

- "Having class discussions working in small groups";
- "Group work";
- "The practical work and working in pairs/groups";
- "Practical work and group work";
- "Practicals, experiments. Working in groups to complete class work".

Utility of science/chemistry and any wider benefits from learning/careers:

- "We learn something new everyday and I understand science/chemistry is an important GCSE needed";
- "Practicals and how relevant it is in the future";
- "When we learn something that could help us in the future";
- "I enjoy the lessons and learning about topics that will help me in my future career";
- "It's fun and I understand it and I also need it to do engineering";
- "It gets me a job for the future if I do well. It is hard but I have a good teacher to understand it more".

Category/theme	Year 8	Year 9	Year 10	Year 11
Experimental and/or practical work	70.2%	62.4%	58.9%	53.4%
Mentioning particular science topics	16.2%	15.6%	11.4%	10.7%
Fun, enjoyment, and/or interest	14.7%	15.2%	11.7%	11.8%
Teachers	6.4%	7.4%	10.1%	12.1%
Learning new things	5.1%	7.0%	3.7%	2.8%
Learning many things	3.6%	3.1%	1.5%	1.2%
Learning about relevant things	2.3%	2.6%	1.6%	2.5%
Everything	2.4%	1.3%	1.9%	2.7%
Groupwork within teaching/learning	2.2%	2.3%	.9%	.3%
Utility of science/chemistry	1.9%	1.8%	1.2%	1.0%

Notes: Results from both cohorts combined (and combining Chemistry for All and comparison students). The table shows the percentage of provided responses per category/theme. One or more categories may have applied to one response, so the reported percentages may sum to more than 100% per year.

Table 6-1: What things do you like about science/chemistry at your school?

Category/theme	Year 8				Year 11			
	Comparison students	Chemistry for All students	Difference		Comparison students	Chemistry for All students	Difference	
	Percentage	Percentage	V	Sig. (p)	Percentage	Percentage	V	Sig. (p)
Experimental and/or practical work	67.1%	70.9%	.031	.077	50.5%	54.0%	.026	.238
Mentioning particular science topics	14.9%	16.4%	.016	.374	8.0%	11.2%	.039	.083
Fun, enjoyment, and/or interest	18.7%	13.9%	**.051**	**.003**	11.0%	12.0%	.011	.627
Teachers	9.6%	5.7%	**.060**	**.001**	15.6%	11.4%	**.048**	**.031**
Learning new things	4.7%	5.2%	.008	.631	3.1%	2.7%	.007	.747
Learning many things	3.8%	3.6%	.004	.807	1.5%	1.1%	.014	.544
Learning about relevant things	2.4%	2.3%	.001	.947	2.4%	2.5%	.001	.956
Everything	2.4%	2.4%	.000	.989	1.5%	3.0%	.033	.143
Groupwork within teaching/learning	2.5%	2.1%	.011	.548	.3%	.4%	.003	.886
Utility of science/chemistry	1.1%	2.0%	.026	.141	.6%	1.1%	.017	.444
Nothing (or negative views)	4.0%	4.7%	.013	.469	16.5%	15.1%	.014	.519

Notes: Results from both cohorts combined. The table shows the percentage of provided responses per category/theme. One or more categories may have applied to one response, so the reported percentages may sum to more than 100% per year.

Table 6-2: What things do you like about science/chemistry at your school? Year 8 and Year 11 comparisons

6.2. What things do you not like about science/chemistry at your school?

Similar findings were revealed across the two cohorts when considered separately and when combined. Considering both cohorts of students combined across Year 8, Year 9, Year 10, and Year 11, encompassing students within schools that received the Chemistry for All programme and students within other schools, the most prevalent themes for 'What things do you not like about science/chemistry at your school?' were the following:

- Writing within teaching/learning (1398 instances across Year 8, Year 9, Year 10, and Year 11; 12.3% of all responses). This included writing about practical/experimental work and writing in general.
- Self-confidence related aspects (across any/all aspects; 1183 instances; 10.4%). This category encompassed students mainly conveying that science/chemistry was hard, difficult, complex, confusing, and/or hard to understand.
- Boredom, no enjoyment, and/or disinterest (1119 instances; 9.8%).
- Everything and/or that science/chemistry was generally perceived negatively without further detail being provided (1025 instances; 9.0%). This category encompassed students literally expressing 'everything', that science/chemistry was 'not good', and other equivalent views.
- Mentioning particular science topics (across all science subjects; 961 instances; 8.4%). This category was formed from students mentioning particular topics and/or areas within science.
- Teachers being perceived negatively (across any/all aspects related to teachers; 946 instances; 8.3%). This category encompassed perceptions of teachers and/or their teaching in general, teachers being perceived as not providing support, teachers being perceived as not facilitating understanding and/or enjoyment, instances of supply teachers and/or many changes of teacher, and teachers (not) controlling class behaviour.
- Not doing more experimental and/or practical work (937 instances; 8.2%).
- Tests, quizzes, and examinations within teaching/learning (787 instances; 6.9%).
- Equations, formulae, and symbols (553 instances; 4.9%).
- Volume of work within teaching/learning (551 instances; 4.8%).
- Peers being problematic often through disruptive behaviour (474 instances; 4.2%).
- Doing experimental and/or practical work (419 instances; 3.7%).
- Textbooks within teaching/learning (370 instances; 3.2%).
- Learning having to involve memorisation/remembering (247 instances; 2.2%).

However, some students highlighted (within this question) that nothing was disliked and/or that science/chemistry was perceived positively (880 instances across Year 8, Year 9, Year 10; 7.7% of all responses).

The prevalence of some categories varied across time (**Table 6-3** and **Table 6-4**). For both cohorts considered together at Year 8, Year 9, Year 10, and Year 11, repeated-measures modelling revealed the following (where patterns across time were similar across students who did and did not receive the Chemistry for All programme, unless otherwise mentioned):

- Writing: changes occurred over time (with a greater extent of change for those who received the Chemistry for All programme), which could be characterised as less frequent mentioning over time.
- Self-confidence related aspects: changes occurred over time (with a lesser extent of change for those who received the Chemistry for All programme), which could be characterised as more frequent mentioning over time.
- Boredom, not fun, disinterest: no clear changes were revealed over time.
- Everything: changes occurred over time, which could be characterised as more frequent mentioning over time.
- Mentioning particular science topics: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Teachers: changes occurred over time, but with no characteristic pattern.
- Not doing more practical work: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Tests, quizzes, and examinations: changes occurred over time, which could be characterised as less frequent mentioning over time.
- Equations, formulae, and symbols: changes occurred over time, which could be characterised as more frequent mentioning over time.
- Volume of work: changes occurred over time (but to a lesser extent for those who received the Chemistry for All programme), but with no characteristic pattern.
- Peers being disruptive: changes occurred over time (but to a lesser extent for those who received the Chemistry for All programme),

which could be characterised as less frequent mentioning over time.

- Doing practical work: no clear changes were revealed over time.
- Textbooks: changes occurred over time (with a lesser extent of change for those who received the Chemistry for All programme), which could be characterised as less frequent mentioning over time.
- Memorisation/remembering: changes occurred over time, which could be characterised as more frequent mentioning over time.

6.2.1. Examples of responses

Writing within teaching/learning:

- "The written work";
- "When we have to write a lot";
- "Loads of writing";
- "Lots of writing and explanations";
- "Long writing tasks";
- "The lessons writing out loads";
- "The writing can get boring".

Self-confidence related aspects:

- "Difficult";
- "It's very difficult";
- "It's extremely difficult";
- "How hard it comes across";
- "I just find it hard in general";
- "That it takes a long time to do and is very hard to do";
- "I don't understand it";
- "It's confusing";
- "It's complicated to understand sometimes";
- "The concepts are really difficult and very confusing at first";
- "It is quite hard in some areas. No matter how much effort I put into it I still do not perform as well as I should".

Boredom, no enjoyment, and/or disinterest:

- "Boring";
- "It's boring at times";
- "Boring then not doing practicals";
- "Don't find it fun";
- "Everything to hard and boring";
- "I don't really enjoy the topic at all";
- "I personally just don't like the subject";
- "I just don't like science";
- "I don't like chemistry".

Everything and/or that science/chemistry was generally perceived negatively without further detail being provided:

- "Everything";
- "I like nothing about it";
- "Almost everything";
- "All of it";
- "Most things";
- "The subject in general";
- "Everything but the practicals";
- "Everything else but experiments".

Mentioning particular science topics:

- "The compounds and elements";
- "Ionic compounds, structure, equations";
- "Bonding";
- "Bonds and chemical formula";
- "Moles";
- "Titrations";
- "Periodic table";
- "Anything to do with the periodic table";
- "Electrons – why do we need to know";
- "I do not like the electrolysis topic as it is very confusing to me and in my opinion I don't see any point in learning about electrolysis".

Teachers being perceived negatively:

- "The teachers";
- "Some teachers";
- "The way the lessons are taught";
- "The way the teacher teaching us";
- "The teacher and work is boring";
- "It's boring and the teacher I have is particularly lazy";
- "That its hard and that the teacher doesn't explain it well enough";
- "Teacher doesn't help me much";
- "Don't have a proper teacher. It has been 6 months";
- "Haven't had a proper teacher for around 3 months";
- "Not having a teacher, studying the same things over and over due to the lack of a teacher";
- "The amount of teachers I've had for the subject in one year";

- "We've had 5 chemistry teachers in the past 2 years".
- Not doing more experimental and/or practical work:
- "Not enough practicals";
- "We don't do a lot of practicals";
- "Hardly any practicals";
- "That we hardly do experiments";
- "Lack of experiments, lack of chemistry lessons";
- "Lack of focus on practicals, only on memory-testing exams";
- "We have no teacher, we learn the same things, not enough practicals";
- "I don't, there are barely any practicals teachers are moody and I am not taught to understand";
- "Too much content to get through and learn in 2 years, some textbook q's and a's quickly put together so answers are wrong, although there are practicals there need to be more";
- "Chemistry doesn't have a lot of experiments that makes it boring in my school so they might have to work on and do more experiments for students to understand more about the topic".

Tests, quizzes, and examinations within teaching/learning:

- "Exams";
- "Tests";
- "The many tests that we have";
- "Having to be tested on it";
- "Pressure of tests";
- "Can be a bit hard sometimes, exams are too hard";
- "Can be hard to understand tests are difficult";
- "Memory tests and too much writing that doesn't help you remember the information".

Equations, formulae, and symbols:

- "Equations";
- "Word equations";
- "Balancing out equations";
- "Equations, formulas";
- "All the equations and what sort of substances join together";
- "There are many equations to learn";
- "The amount of equations and maths work relative to everything else";
- "Bonds and chemical formula".

Volume of work within teaching/learning:

- "The large amount of content";
- "Learning too much and things I don't like";
- "There is too much to learn in one subject in one day";
- "How much work there is";
- "The amount information needed to take in";
- "The amount of things that a certain topic might have remembering triangle equations (all of them). Amount of required practicals you have to remember";
- "All the extra content and practicals and equations and the constant revision needed just to get a 5".

Peers being problematic often through disruptive behaviour:

- "People distracting me";
- "My class is disruptive";
- "The behaviour of the class";
- "People messing about";
- "The lack of enthusiasm in the students";
- "The noisy people who ruin the lesson";
- "The things that I don't quite like about chemistry is the distractions and silly behaviours whilst doing practicals";
- "I don't really like the class I am in because there's a lot of people who distract me in chemistry by talking and keeping the class from carrying on by wasting time";
- "The things that I don't like about chemistry are that some of the students in there are just damn right disrespectful to the teacher and to the students that actually want to learn and get their GCSEs".

Doing experimental and/or practical work:

- "Practicals all the time";
- "The practicals sometimes";
- "Experiments are boring, it's incredibly confusing";
- "When we have to write lots and do practical";
- "The practicals could be more applicable to real life scenarios";
- "It feels repetitive and the practicals don't help me understand what I should";
- "Practicals involving potentially dangerous substances".

Textbooks within teaching/learning:

- "Have to do a lot of textbook work";
- "Copying out of textbooks";
- "Working from books/doing tests";
- "Working from textbooks";
- "Book work in the sense that we just read off the textbook and write it down".

Learning having to involve memorisation/remembering:

- "Learning the periodic table by heart";
- "Memorising periodic table";
- "Having to remember formulas";
- "It's a lot to remember + moles!";
- "Remembering everything";
- "Too many equations that are too much for me to remember";
- "Equations, remembering all of the things I need to in order to do well";
- "Tests are on memory recall not applying the chemistry".

Category/theme	Year 8	Year 9	Year 10	Year 11
Writing	22.1%	12.4%	6.9%	3.9%
Self-confidence related aspects	5.5%	9.1%	14.5%	14.4%
Boredom, not fun, disinterest	9.3%	10.3%	10.5%	8.6%
Everything	5.8%	7.3%	11.7%	13.3%
Mentioning particular science topics	12.9%	8.0%	4.8%	7.6%
Teachers	7.6%	10.8%	7.5%	5.9%
Not doing more practical work	8.7%	11.0%	6.4%	5.1%
Tests, quizzes, and examinations	8.7%	7.4%	5.3%	5.5%
Equations, formulae, and symbols	.6%	2.8%	8.6%	10.0%
Volume of work	5.1%	5.3%	3.6%	5.5%
Peers being disruptive	5.2%	4.5%	3.6%	2.4%
Doing practical work	3.7%	3.9%	3.0%	4.3%
Textbooks	5.5%	3.9%	1.8%	.5%
Memorisation/remembering	.9%	1.7%	3.3%	3.5%

Notes: Results from both cohorts combined (and combining Chemistry for All and comparison students). The table shows the percentage of provided responses per category/theme. One or more categories may have applied to one response, so the reported percentages may sum to more than 100% per year.

Table 6-3: What things do you not like about science/ chemistry at your school?

Category/theme	Year 8				Year 11			
	Comparison students	Chemistry for All students	Difference		Comparison students	Chemistry for All students	Difference	
	Percentage	Percentage	V	Sig. (p)	Percentage	Percentage	V	Sig. (p)
Writing	14.1%	23.6%	**.085**	**<.001**	4.1%	3.9%	.005	.847
Self-confidence related aspects	5.7%	5.5%	.003	.856	17.4%	13.8%	.039	.098
Boredom, not fun, disinterest	7.6%	9.6%	.025	.159	9.8%	8.4%	.019	.414
Everything	4.9%	6.0%	.017	.339	10.4%	13.9%	.039	.098
Mentioning particular science topics	12.0%	13.1%	.013	.476	7.0%	7.7%	.011	.657
Teachers	9.4%	7.3%	.030	.099	12.0%	4.5%	**.123**	**<.001**
Not doing more practical work	8.4%	8.7%	.004	.818	4.7%	5.1%	.007	.779
Tests, quizzes, and examinations	7.6%	8.9%	.016	.373	5.1%	5.6%	.009	.698
Equations, formulae, and symbols	1.4%	.5%	**.040**	**.024**	6.6%	10.7%	**.052**	**.028**
Volume of work	3.1%	5.5%	**.040**	**.026**	7.9%	5.0%	**.049**	**.039**
Peers being disruptive	9.4%	4.4%	**.083**	**<.001**	2.2%	2.5%	.007	.771
Doing practical work	3.7%	3.6%	.002	.929	2.8%	4.6%	.034	.155
Textbooks	10.8%	4.4%	**.104**	**<.001**	.9%	.4%	.029	.229
Memorisation/remembering	1.0%	.9%	.004	.830	2.2%	3.7%	.032	.179

Notes: Results from both cohorts combined. The table shows the percentage of provided responses per category/theme. One or more categories may have applied to one response, so the reported percentages may sum to more than 100% per year

Table 6-4: What things do you not like about science/ chemistry at your school? Year 8 and Year 11 comparisons

6.3. Summary

The findings affirm that many students like experimental/practical work in science/chemistry, but some students dislike having to write extensively (including having to write about experimental/practical work), although highlighting these likes and dislikes became less prevalent as students grew older. Some students appreciated their teachers, and highlighting this became more prevalent as students grew older. Highlighting that science/chemistry was fun, enjoyable, and/or interesting was generally less prevalent over time, while highlighting boredom, lack of fun, and/or disinterest was generally more prevalent over time. Additionally, students increasingly highlighted negative aspects related to self-confidence such as material being considered to be difficult, complex, and/or hard to understand. Students also increasingly disliked: equations, formulae, and symbols; and that teaching/learning involved memorisation/remembering. Many of these areas may intersect and also inherently involve chemistry, which may present challenges within teaching/learning and for wider programmes and initiative.

These findings affirm and also extend prior research from the Science Education Tracker (which surveyed students in Year 7 to Year 13, rather than surveying the same students over time), where students reported that they were encouraged to study science primarily because they liked practical work, they found science interesting, they had good teachers, science is relevant to real life, science aligns with their studying and career plans, and for various other reasons (Hamlyn, et al., 2020). In the Science Education Tracker, students also highlighted that they were discouraged primarily due to: science being difficult, the volume of work, being disinterested in science, teachers, science not aligning with studying and career plans, and various other reasons (Hamlyn, et al., 2020). The results presented here followed from categorising the students' freely written responses, which provides an important affirmation of the earlier findings from the Science Education Tracker, which followed from students ranking reasons from a list of provided categories (Hamlyn, et al., 2020). The Chemistry for All and comparison students also conveyed likes and dislikes that were absent from the Science Education Tracker's list of already-defined categories; for example, the findings presented here highlighted that many students also liked learning new things, many things and/or a variety of things, and learning about relevant things (including learning about the world and/or how things work).

Students have often expressed their appreciation for experimental/practical work (Hamlyn, et al., 2020; Hamlyn, Matthews, & Shanahan, 2017; National Foundation for Educational Research, 2011). Practical work is often favoured and/or applied within science education because it is assumed to reflect the empirical nature of science, to help foster and support interest and enjoyment, and to improve students' understanding. The findings presented here help affirm some intuitions or assumptions behind the wider approaches for the Chemistry for All programme, which often involved practical experiments, demonstrations, and lectures that aimed to be enjoyable and inspirational for younger students, while events for older students often had other foci or approaches (such as helping with revision and understanding for examinations).

From a wider perspective, it may be challenging to ensure that curriculum content, pedagogies, and further aspects of teaching and learning can be refined, optimised, and/or otherwise balanced to best support students' learning and progression within science. For example, qualification reforms require that students in England undertake a minimum number of practical activities in science at GCSE and at A-Level, and students are assessed on their knowledge, skills, and understanding of practical work in science at GCSE and at A-Level (Department for Education, 2020c; Ofqual, 2019). The findings presented here highlighted that although many students liked experimental/practical activities, highlighting this became less prevalent as students grew older; concurrently, students increasingly found science/chemistry to be difficult, complex, and/or hard to understand. Compulsory assessment of practical activities may present particular challenges for complex areas of science and/or chemistry. It may be beneficial to consult and engage with students regarding potential changes to educational policies.

The findings highlighted, to some extent, other challenges that may intersect with equality and accessibility. Some students highlighted problematic and/or frequent changes in teachers (as a subsidiary category when teachers were perceived negatively; 110 instances across Year 8, Year 9, Year 10, and Year 11; 1.0% of all responses). The recruitment and retention of (specialist) science/chemistry teachers has often received focus within educational aims and policies (Gatsby, 2018; Royal Society of Chemistry, 2014; Royal Society, 2008, 2010, 2014). Nevertheless, it remains unclear whether some schools face particular challenges for recruitment and/or retention, and whether (and/or to what extent) this intersects with socio-economic profiles of students, schools, and/or geographic regions, and (ultimately) what impact this has on students. The findings presented here also highlighted that some students found their peers to be problematic, often through their disruptive behaviour (474 instances across Year 8, Year 9, Year 10, and Year 11; 4.2% of all responses). Existing research has highlighted that peers and also teachers have been important influences on students' senses of school belonging and engagement, which have then associated with students' well-being and academic outcomes (Allen, Kern, Vella-Brodrick, Hattie, & Waters, 2018; Fredricks, Blumenfeld, & Paris, 2004; Upadyaya & Salmela-Aro, 2013). Engagement with science/chemistry (and/or any other subject) may assume and/or rely on general engagement and belonging. It remains unclear whether some schools may face particular challenges linking with behaviour and/or engagement, and this may risk assumptions and/or stereotyping around socio-economic profiles. Nevertheless, from the perspective of accessibility and inclusion, some students and/or schools may face more challenging circumstances than others.

7

Students' perceptions of activities and events

7. Students' perceptions of activities and events

Highlights and key findings

- Students within schools that received the Chemistry for All programme, compared to students within other schools, had more positive views about the benefits of additional (extra-curricular) activities and events as of Year 11.
- Students with more engagement with the Chemistry for All programme (who experienced at least one, or more than one, optional event or activity) expressed higher perceived benefits.
- In schools that did not receive the Chemistry for All programme, boys tended to express more positive views than girls about perceived benefits; these gender differences were minimal or not present for students who received the Chemistry for All programme.

7.1. Perceived benefits of extra-curricular activities and events

7.1.1. Questionnaire responses

The questionnaire invited students to convey their views about chemistry/science activities that they may have experienced, such as talks, events, or any other extra activities outside of chemistry/science lessons. For those who did experience the Chemistry for All programme, the questions were prefaced by a reminder that their school had run additional activities both as whole year group events and as extra activities outside of science lessons. Students who did not experience the Chemistry for All programme may have experienced various events and activities through their own schools. The analysis focused on the students' responses from Year 11 in order to consider the students' self-reflective experiences towards the end of secondary education, which was also towards the end of the Chemistry for All programme for some students.

Students within schools that received the Chemistry for All programme, on average, compared to students within other schools, had more positive views about the benefits arising from additional activities and events (**Table 7-1** and **Table 7-2**). On average, the students did not necessarily agree that events/activities were beneficial, however; tendencies towards agreement were more apparent for those students who experienced at least one, or more than one, optional event or activity. For the students recorded as attending more than one optional event/activity, more than half agreed or strongly agreed that events/activities were beneficial. Essentially, perceived benefits of events/activities were higher with more engagement with the Chemistry for All programme. More specifically, across both cohorts of the students, the following was reported:

- Increased confidence in doing science/chemistry: conveyed by 33.5% of all students in comparison schools, 40.9% of all students in Chemistry for All schools, and 63.0% of students in Chemistry for All schools who attended more than one optional activity/event within the Chemistry for All programme.
- Increased interest in science/chemistry: conveyed by 28.8% of students in comparison schools, 34.4% of students in Chemistry for All schools, and 53.1% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge of the different routes available to study non-compulsory science/chemistry: conveyed by 27.2% of students in comparison schools, 37.2% of students in Chemistry for All schools, and 56.1% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge of the benefits of a non-compulsory science/chemistry qualification: conveyed by 24.0% of students in comparison schools, 34.8% of students in Chemistry for All schools, and 53.5% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge of the benefits of a career in science/chemistry: conveyed by 26.1% of students in comparison schools, 37.1% of students in Chemistry for All schools, and 56.0% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased knowledge about the careers available with a science/chemistry qualification: conveyed by 24.4% of students in comparison schools, 39.1% of students in Chemistry for All schools, and 59.4% of students in Chemistry for All schools who attended more than one optional activity/event.
- Increased understanding of how science/chemistry relates to everyday life: conveyed by 30.0% of students in comparison schools, 42.3% of students in Chemistry for All schools, and 60.8% of students in Chemistry for All schools who attended more than one optional activity/event.
- Students were made aware that science/chemistry can be for them: conveyed by 22.0% of students in comparison schools, 33.0% of students in Chemistry for All schools, and 48.1% of students in Chemistry for All schools who attended more than one optional activity/event.
- Students were made aware that anyone can be a scientist/chemist: conveyed by 25.3% of students in comparison schools, 39.7% of students in Chemistry for All schools, and

56.5% of students in Chemistry for All schools who attended more than one optional activity/event.

- Students were inspired to study science/chemistry after GCSEs: conveyed by 24.6% of students in comparison schools, 33.2% of students in Chemistry for All schools, and 45.7% of students in Chemistry for All schools who attended more than one optional activity/event.

The largest differences involved perceptions that extra activities/events increased the students' knowledge about the careers available with a chemistry qualification and made students aware that anyone can be a scientist/chemist. At Year 11, across both cohorts of the students: 39.1% of students within schools that received the Chemistry for All programme agreed or strongly agreed that additional activities/events increased their knowledge about the careers available with a chemistry qualification (59.4% of students who were recorded as attending more than one optional activity/event within the Chemistry for All programme agreed or strongly agreed); in comparison, 24.4% of student in comparison schools agreed or strongly agreed. Again, at Year 11, across both cohorts of the students: 39.7% of students within schools that received the Chemistry for All programme agreed or strongly agreed that additional activities/events had made them aware that anyone can be a scientist/chemist (56.5% of students who were recorded as attending more than one optional activity/event within the Chemistry for All programme agreed or strongly agreed); in comparison, 25.3% of students in comparison schools agreed or strongly agreed.

Additionally, for students within comparison schools (that did not receive the Chemistry for All programme), boys tended to express more positive views than girls (**Table 7-3**). Conversely, for students within schools that received the Chemistry for All programme, differences across boys and girls were not present (when considering averages) or were minimal (when considering cross-tabulations, where boys tended towards more positive views) (**Table 7-4**). Essentially, experiencing the Chemistry for All programme can be inferred to have reduced or eliminated a potential gender difference.

Table 7-1: Overview of perceived benefits from extra-curricular activities and events at Year 11

Category/theme	Comparison students	Chemistry For All students		
		All students	Attended at least one optional event	Attended more than one optional event
Increased confidence in doing science/chemistry	33.5%	40.9%	54.6%	63.0%
Increased interest in science/chemistry	28.8%	34.4%	47.9%	53.1%
Increased knowledge of the different routes available to study science/chemistry post-16	27.2%	37.2%	49.7%	56.1%
Increased knowledge of the benefits of a career in science/chemistry	26.1%	37.1%	49.7%	56.0%
Helped give a better understanding of how science/chemistry relates to everyday life	30.0%	42.3%	55.5%	60.8%
Increased knowledge of the benefits of a post-16 science/chemistry qualification	24.0%	34.8%	47.7%	53.5%
Increased my knowledge about the careers available with a chemistry qualification	24.4%	39.1%	51.6%	59.4%
Increased my belief that science/chemistry can be for me	22.0%	33.0%	43.2%	48.1%
Made me aware that anyone can be a scientist/chemist	25.3%	39.7%	49.6%	56.5%
Inspired me to study science/chemistry after GCSEs	24.6%	33.2%	44.0%	45.7%

Notes: Results from both cohorts combined. The table shows the percentage of students agreeing or strongly agreeing per question.

Table 7-2: Perceived benefits from extra-curricular activities and events at Year 11

Questionnaire item	Category of students	Responses				Difference to comparison students	
		Strongly Disagree	Disagree	Agree	Strongly Agree	V	Sig. (p)
Taking part in extra activities/events has increased my confidence in doing science/chemistry	Comparison students	31.9%	34.6%	28.0%	5.5%	-	-
	Chemistry for All students	20.7%	38.5%	32.7%	8.2%	**.101**	**<.001**
	- attended at least one optional event	13.5%	31.9%	42.9%	11.7%	**.250**	**<.001**
	- attended more than one optional event	10.3%	26.6%	49.5%	13.5%	**.325**	**<.001**
Taking part in extra activities/events has increased my interest in science/chemistry	Comparison students	34.4%	36.9%	24.3%	4.5%	-	-
	Chemistry for All students	22.7%	42.9%	27.0%	7.4%	**.103**	**<.001**
	- attended at least one optional event	15.0%	37.1%	37.5%	10.4%	**.248**	**<.001**
	- attended more than one optional event	11.1%	35.9%	42.9%	10.2%	**.308**	**<.001**
Taking part in extra activities/events has increased my knowledge of the different routes available to study science/chemistry post-16	Comparison students	34.7%	38.1%	23.9%	3.3%	-	-
	Chemistry for All students	22.3%	40.6%	30.5%	6.7%	**.115**	**<.001**
	- attended at least one optional event	15.5%	34.8%	40.0%	9.7%	**.263**	**<.001**
	- attended more than one optional event	12.7%	31.2%	44.6%	11.5%	**.328**	**<.001**
Taking part in extra activities/events has increased my knowledge of the benefits of a career in science/chemistry	Comparison students	34.0%	39.9%	21.6%	4.5%	-	-
	Chemistry for All students	22.1%	40.9%	30.3%	6.8%	**.112**	**<.001**
	- attended at least one optional event	15.5%	34.9%	39.9%	9.8%	**.263**	**<.001**
	- attended more than one optional event	11.8%	32.2%	45.2%	10.8%	**.335**	**<.001**
Taking part in extra activities/events has helped give me a better understanding of how science/chemistry relates to everyday life	Comparison students	31.5%	38.5%	27.2%	2.8%	-	-
	Chemistry for All students	21.4%	36.3%	35.9%	6.4%	**.110**	**<.001**
	- attended at least one optional event	13.7%	30.8%	46.1%	9.4%	**.276**	**<.001**
	- attended more than one optional event	9.9%	29.3%	50.3%	10.5%	**.344**	**<.001**
Taking part in extra activities/events has increased my knowledge of the benefits of a post-16 science/chemistry qualification	Comparison students	35.5%	40.5%	21.2%	2.8%	-	-
	Chemistry for All students	23.5%	41.7%	28.9%	5.9%	**.114**	**<.001**
	- attended at least one optional event	17.0%	35.3%	38.4%	9.3%	**.266**	**<.001**
	- attended more than one optional event	13.1%	33.4%	43.3%	10.2%	**.337**	**<.001**
Taking part in extra activities/events has increased my knowledge about the careers available with a chemistry qualification	Comparison students	35.6%	40.1%	21.3%	3.1%	-	-
	Chemistry for All students	22.2%	38.7%	32.4%	6.7%	**.136**	**<.001**
	- attended at least one optional event	16.0%	32.5%	41.8%	9.8%	**.292**	**<.001**
	- attended more than one optional event	11.8%	28.8%	48.9%	10.5%	**.378**	**<.001**
Taking part in extra activities/events has increased my belief that science/chemistry can be for me	Comparison students	37.0%	41.0%	18.6%	3.4%	-	-
	Chemistry for All students	25.1%	41.9%	27.0%	6.0%	**.111**	**<.001**
	- attended at least one optional event	19.6%	37.3%	34.0%	9.2%	**.241**	**<.001**
	- attended more than one optional event	17.3%	34.6%	36.9%	11.2%	**.299**	**<.001**
Taking part in extra activities/events has made me aware that anyone can be a scientist/chemist	Comparison students	34.6%	40.2%	22.8%	2.5%	-	-
	Chemistry for All students	22.0%	38.4%	34.3%	5.4%	**.130**	**<.001**
	- attended at least one optional event	16.6%	33.8%	42.3%	7.3%	**.264**	**<.001**
	- attended more than one optional event	13.7%	29.7%	49.2%	7.3%	**.336**	**<.001**
Taking part in extra activities/events has inspired me to study science/chemistry after GCSEs	Comparison students	34.6%	40.8%	20.4%	4.2%	-	-
	Chemistry for All students	25.8%	41.0%	25.4%	7.8%	**.088**	**.001**
	- attended at least one optional event	20.7%	35.2%	32.6%	11.4%	**.214**	**<.001**
	- attended more than one optional event	18.7%	35.6%	33.0%	12.7%	**.249**	**<.001**

Notes: Results from both cohorts combined. The table shows the percentage per response category per questionnaire item. The magnitude ('V'; Cramer's V) and significance ('Sig. (p)'; p-values) of the differences between the comparison students and the Chemistry for All students are also shown.

Questionnaire item	Gender	Responses				Gender difference	
		Strongly Disagree	Disagree	Agree	Strongly Agree	V	Sig. (p)
Taking part in extra activities/events has increased my confidence in doing science/chemistry	Girls	32.7%	42.7%	21.6%	2.9%	**.201**	**.002**
	Boys	31.1%	27.5%	33.7%	7.8%	**.201**	**.002**
Taking part in extra activities/events has increased my interest in science/chemistry	Girls	35.1%	44.6%	17.9%	2.4%	**.196**	**.003**
	Boys	33.7%	30.0%	30.0%	6.3%	**.196**	**.003**
Taking part in extra activities/events has increased my knowledge of the different routes available to study science/chemistry post-16	Girls	36.7%	43.8%	17.8%	1.8%	**.170**	**.015**
	Boys	33.0%	33.0%	29.3%	4.7%	**.170**	**.015**
Taking part in extra activities/events has increased my knowledge of the benefits of a career in science/chemistry	Girls	36.9%	44.0%	16.1%	3.0%	**.153**	**.039**
	Boys	31.4%	36.2%	26.6%	5.9%	**.153**	**.039**
Taking part in extra activities/events has helped give me a better understanding of how science/chemistry relates to everyday life	Girls	32.3%	44.9%	22.2%	.6%	**.183**	**.008**
	Boys	30.7%	32.8%	31.7%	4.8%	**.183**	**.008**
Taking part in extra activities/events has increased my knowledge of the benefits of a post-16 science/chemistry qualification	Girls	38.3%	47.9%	12.6%	1.2%	**.229**	**<.001**
	Boys	33.0%	34.0%	28.8%	4.2%	**.229**	**<.001**
Taking part in extra activities/events has increased my knowledge about the careers available with a chemistry qualification	Girls	38.0%	45.2%	14.5%	2.4%	**.166**	**.021**
	Boys	33.5%	35.6%	27.2%	3.7%	**.166**	**.021**
Taking part in extra activities/events has increased my belief that science/chemistry can be for me	Girls	40.4%	45.8%	12.7%	1.2%	**.193**	**.004**
	Boys	34.0%	36.7%	23.9%	5.3%	**.193**	**.004**
Taking part in extra activities/events has made me aware that anyone can be a scientist/chemist	Girls	35.2%	47.3%	17.6%	.0%	**.207**	**.002**
	Boys	34.0%	34.0%	27.2%	4.7%	**.207**	**.002**
Taking part in extra activities/events has inspired me to study science/chemistry after GCSEs	Girls	38.1%	45.2%	14.3%	2.4%	**.174**	**.012**
	Boys	31.6%	36.8%	25.8%	5.8%	**.174**	**.012**

Notes: Results from both cohorts combined. The table shows the percentage per response category per questionnaire item. The magnitude ('V'; Cramer's V) and significance ('Sig. (p)'; p-values) of the differences between girls and boys are also shown.

Table 7-3: Perceived benefits from extra-curricular activities and events at Year 11 by gender: students in comparison schools

Questionnaire item	Gender	Responses				Gender difference	
		Strongly Disagree	Disagree	Agree	Strongly Agree	V	Sig. (p)
Taking part in extra activities/events has increased my confidence in doing science/chemistry	Girls	18.4%	42.9%	31.8%	6.9%	**.100**	**<.001**
	Boys	22.9%	33.9%	33.7%	9.5%	**.100**	**<.001**
Taking part in extra activities/events has increased my interest in science/chemistry	Girls	20.3%	47.1%	26.4%	6.2%	**.095**	**.001**
	Boys	25.1%	38.5%	27.7%	8.7%	**.095**	**.001**
Taking part in extra activities/events has increased my knowledge of the different routes available to study science/chemistry post-16	Girls	19.6%	44.2%	29.6%	6.6%	**.084**	**.004**
	Boys	24.9%	36.6%	31.6%	6.8%	**.084**	**.004**
Taking part in extra activities/events has increased my knowledge of the benefits of a career in science/chemistry	Girls	19.0%	44.7%	29.7%	6.6%	**.089**	**.002**
	Boys	25.0%	36.9%	31.1%	7.1%	**.089**	**.002**
Taking part in extra activities/events has helped give me a better understanding of how science/chemistry relates to everyday life	Girls	18.5%	38.8%	37.3%	5.4%	**.089**	**.002**
	Boys	24.2%	33.8%	34.5%	7.5%	**.089**	**.002**
Taking part in extra activities/events has increased my knowledge of the benefits of a post-16 science/chemistry qualification	Girls	20.7%	46.2%	27.5%	5.6%	**.095**	**.001**
	Boys	26.2%	37.1%	30.7%	6.0%	**.095**	**.001**
Taking part in extra activities/events has increased my knowledge about the careers available with a chemistry qualification	Girls	19.7%	42.3%	32.0%	6.0%	**.084**	**.005**
	Boys	24.6%	34.9%	33.1%	7.4%	**.084**	**.005**
Taking part in extra activities/events has increased my belief that science/chemistry can be for me	Girls	23.4%	45.2%	25.3%	6.0%	**.071**	**.026**
	Boys	26.6%	38.4%	29.0%	5.9%	**.071**	**.026**
Taking part in extra activities/events has made me aware that anyone can be a scientist/chemist	Girls	19.9%	42.2%	33.4%	4.5%	**.089**	**.002**
	Boys	23.9%	34.2%	35.4%	6.4%	**.089**	**.002**
Taking part in extra activities/events has inspired me to study science/chemistry after GCSEs	Girls	22.8%	44.1%	25.3%	7.7%	**.076**	**.014**
	Boys	28.6%	37.7%	25.9%	7.8%	**.076**	**.014**

Notes: Results from both cohorts combined. The table shows the percentage per response category per questionnaire item. The magnitude ('V'; Cramer's V) and significance ('Sig. (p)'; p-values) of the differences between girls and boys are also shown.

Table 7-4: Perceived benefits from extra-curricular activities and events at Year 11 by gender: students in Chemistry for All schools

7.1.2. Written responses

The questionnaire also invited students to provide written responses ('What do you think about these extra science/chemistry activities and events in general?'), which were transcribed from paper questionnaires or directly entered via online questionnaires. Iterative content analysis was applied to develop and refine categories from the students' responses, in order to develop a classification structure that was quantifiable, interpretable, and consistent across the multiple waves of surveying (given that some categories might be more or less prevalent and/or present at different times). One response could have one or more applicable categories.

Given students' potentially limited time when completing a questionnaire, the prevalence of different categories may not necessarily reflect their importance. Instead, these written responses may provide affirmation and/or additional information to contextualise the students' responses to other areas of the questionnaire, and may suggest areas to be explored and/or considered further with students. For example, if all students were presented with questionnaire items asking about a particular issue, more students might agree (or disagree) compared to the percentages of students who write about an issue (who might have focused on conveying other issues, given limited space and/or time).

At Year 11, 1461 students provided responses to 'What do you think about these extra science/chemistry activities and events in general?' (encompassing 1206 students from schools that received the Chemistry for All programme and 255 students from comparison schools), covering 810 students from the younger cohort (606 students from schools that received the Chemistry for All programme and 204 students from comparison schools) and 651 students from the older cohort (600 students from schools that received the Chemistry for All programme and 51 students from comparison schools).

Considering responses from all students at Year 11, across both cohorts, more students provided positive written views about activities and events within schools that received the Chemistry for All programme (**Table 7-5**). Across both cohorts, positive views about activities and events were conveyed through 64.6% of responses from students within schools that received the Chemistry for All programme compared to 54.1% of responses from students within comparison schools ($V = .082$, $p = .002$). Similar results were found for the younger and older cohorts considered separately: in the younger cohort, 65.5% of responses were positive from students within schools that received the Chemistry for All programme compared to 56.4% of responses from students within comparison schools ($V = .082$, $p = .019$); in the older cohort, 63.7% of responses from students within schools that received the Chemistry for All programme were positive compared to 45.1% of responses from students within comparison schools ($V = .103$, $p = .009$).

Aside from generally positive views (such as 'good' or 'great'), activities and events were most frequently considered to be beneficial through helping learning, studying, and understanding, and through being fun, interesting, and enjoyable. This may potentially reflect and/or link with the provision of revision sessions through the Chemistry for All programme in later academic years. Positive Year 11 examples are as follows:

- "Interesting and fun";
- "I enjoy them, learn from them";
- "Great, really interesting, love the new insight on chemistry";
- "I think it's awesome";
- "They are very interactive and fun, while also helpful to my studies";
- "They're very useful";
- "They help students get more information out of class";
- "Good as they expand your knowledge on chemistry";
- "Helpful to improve learning";
- "Full of information";
- "Good for studying/revising";
- "They are good as you recap what you do in lessons";
- "They're a great way to catch up or to actually do something after school that's useful";
- "Interesting. Helped me understand how science is used in the everyday life";
- "They were highly educational, and greatly inspiring";
- "Helpful, gives you an idea about science and career path ways";
- "They are very useful - give an idea of what science is like outside of class (very helpful in making decisions about pursuing science)";
- "I think they are good because learning outside of the school environment can be beneficial. It gives students the chance to see how chemistry/science relates to everyday life. Also they usually help students to decide whether they would like to continue science/chemistry after year 11";
- "I think they're a good thing as a lot of people have an interest in science and with these extra curricular activities and events going on, it helps boost their interest and boost their confidence in their GCSE's".

Across both cohorts at Year 11, negative written views about activities and events were conveyed through 15.9% of responses from students within schools that received the Chemistry for All programme and 15.3% of responses from students within comparison schools. Similar results were found for the younger cohort alone (where negative views about activities and events were conveyed through

15.0% of responses from students within schools that received the Chemistry for All programme and 17.6% of responses from students within comparison schools). For the older cohort of students alone, more students conveyed negative views within schools that received the Chemistry for All programme (16.8%) compared to students in comparison schools (5.9%) (V = .080, p = .040).

Aside from generally negative views (such as 'bad'), activities and events were most frequently considered to be negative through being boring or uninteresting. Negative Year 11 examples are as follows:

- "Bad";
- "Not good";
- "They're not interesting";
- "Boring!";
- "I don't like science, so I think they seem boring";
- "Irrelevant";
- "Personally I don't think they're useful";
- "They don't help";
- "They are not very informative";
- "They can be very repetitive";
- "Pointless unless they are revision sessions";
- "I think that a lot of the events are run by people who don't make it fun. So when it's not fun I don't have an interest in it".

Students could also convey both positive and negative views. Overlapping positive and negative Year 11 examples are as follows:

- "They are good but sometimes very boring and long";
- "Boring but knowledge packed";
- "They are alright, bit boring but can deal with it";
- "They can vary from helpful to boring and unhelpful";
- "Can be helpful + a waste of time";
- "They're not too helpful but it motivates for my GCSE exams".

The students also conveyed various other views and observations regarding activities/events. Some students expressed an awareness that benefits were or would be likely to be for people who were (already) interested and/or science people. This was conveyed through 5.1% of responses from students within schools that received the Chemistry for All programme and 5.1% of responses from students within comparison schools (at Year 11, across both cohorts). Examples are as follows:

- "It's good if you enjoy chemistry or science";
- "They are interesting if you like the subject";
- "They are very useful, but only for people with an interest in science";
- "Good for people who enjoy chemistry";
- "I think they're useful for students considering choosing science but pointless for everyone else";
- "I think they can be fun/helpful to people who have an interest in science, for me, however, they are completely useless";
- "They are pointless for nearly everyone other than a very small group of people".

Some students, somewhat similarly, were aware and/or perceived that science/chemistry was not necessarily for them. This was conveyed through 3.5% of responses from students within schools that received the Chemistry for All programme and 4.7% of responses from students within comparison schools (at Year 11, across both cohorts). Examples are as follows:

- "They appear to be fun but I find them irrelevant to my future career";
- "Since I don't find myself doing chemistry in the future I find it irrelevant";
- "They were interesting, but I'm afraid that Chemistry is not for me!";
- "Good for those that enjoy it but not me";
- "They are entertaining and informative, I gained a deeper understanding, however chemistry isn't for me";
- "I think they are useful for those who need it and enjoy it but personally I don't enjoy it or learn from it";
- "I personally have never been to any because science isn't really in my interest in studying further on in life, however it obviously benefits the people who want to learn extra stuff about science".

Some students highlighted that activities and events were not available and/or were few in number, although to a lesser extent within schools that received the Chemistry for All programme. At Year 11, across both cohorts, this was conveyed through 2.7% of responses from students in schools that received Chemistry for All programme, compared to 10.2% of responses from students within comparison schools across both cohorts (V = .144, p < .001). Examples are as follows:

- "Are there any?" [Chemistry for All school];
- "I wasn't aware that they happened" [Chemistry for All school];
- "We don't have them" [Chemistry for All school];
- "They were non-existent" [comparison school];
- "Don't think they exist" [comparison school];
- "We don't have many extra activities in chemistry and I don't get involved" [comparison school];
- "School run events are very rare or very unpromoted. Only one I can remember in school was fairly boring not inspiring. Outside events like museums, online videos etc make it seem interesting" [comparison school].

Some students highlighted that participation could be potentially limited within schools and/or that particular students might be chosen (which suggests that others were not). At Year 11, across both cohorts, this was only conveyed through 1.2% of responses from students within schools that received the Chemistry for All programme and 1.6% of responses from students within comparison schools. Nevertheless, this may be a wider issue to consider when maximising inclusion and accessibility to extra-curricular activities/events. Examples are as follows:

- "The same people get chosen every time so I wouldn't know" [Chemistry for All school];
- "They are good but not many people go because we don't know about them and only certain people can go" [Chemistry for All school];
- "I have never been invited to them just some of my class mate[s]. I think that they are [a] great idea but should be open to more people" [Chemistry for All school];
- "I think they are good, but the same people are offered these extra-curricular activities; they don't really ask others to participate" [Chemistry for All school];
- "Not widely available but the concept is good, would be better if it was executed fairly and evenly distributed" [comparison school];
- "There are no extra science lessons which take place except for triple set" [comparison school].

Table 7-5: Perceived benefits from extra-curricular activities and events at Year 11 (written responses)

Indicator (1–4 scales, unless otherwise shown)	Comparison students	Chemistry for All students	Difference	
			D	Sig. (p)
Other/unclassifiable	1.6%	1.2%	.011	.677
Negative responses (all)	15.3%	15.9%	.007	.803
- Negative: boring, not interesting	5.1%	4.9%	.004	.890
- Negative: waste of time	1.2%	1.1%	.004	.891
- Negative: not seeing the point and/or relevance	.8%	1.8%	.031	.235
- Negative: not helping learning and/or studying	.4%	.7%	.016	.533
Do not know / ambivalent	9.0%	6.9%	.031	.232
Not participated and/or would not like to participate	16.5%	12.0%	.051	.053
Not available and/or very few events	10.2%	2.7%	**.144**	**<.001**
Not told about events and/or would need more information	.8%	.6%	.010	.705
Activities/events not considered necessary	.4%	.6%	.010	.711
Not interested / not for me	4.7%	3.5%	.025	.347
Participation and/or focus is limited	1.6%	1.2%	.011	.677
Benefits are likely for science people and/or already interested people	5.1%	5.1%	.001	.977
Benefits are likely for others	.4%	.6%	.010	.711
Participation requires time and/or time is limited	1.2%	.5%	.033	.208
Participation should be optional	.8%	.0%	**.081**	**.002**
Benefits would depend on activities/events and/or topics	1.2%	.1%	**.079**	**.002**
Activities/events could be better and/or improved	.0%	.0%	-	-
Would like to attend (or attend more) and/or have more activities/events	2.0%	1.2%	.027	.306
Positive responses (all)	54.1%	64.6%	**.082**	**.002**
- Positive: helping learning, studying, understanding	18.8%	18.4%	.004	.877
- Positive: general knowledge, relevant to general life	1.6%	1.0%	.021	.424
- Positive: general future careers	1.2%	1.3%	.005	.847
- Positive: studying and/or working within science	1.2%	2.4%	.032	.223
- Positive: fun, interesting, enjoyable	6.7%	11.9%	**.063**	**.016**
- Positive: helping confidence	.0%	.8%	.038	.145

Notes: Results from both cohorts combined. The table shows the percentage of provided responses per category/theme. One or more categories may have applied to one response, so the reported percentages may sum to more than 100%. The magnitude ('V'; Cramer's V) and significance ('Sig. (p)'; p-values) of the differences between the comparison students and the Chemistry for All students are also shown.

8

Associations between students' views and aspects of teaching and learning

8. Associations between students' views and aspects of teaching and learning

Highlights and key findings

- Students' reports of their teacher using science/chemistry to help them understand the world outside school positively predicted their aspirations, interest/enjoyment, perceived utility value, self-confidence, and perceived value of science/chemistry to society.
- Attending a science/chemistry club was also an important positive predictor of students' views.
- Doing practical experiments and having the chance to explain ideas were also important positive predictors of interest/enjoyment of science/chemistry.
- Involvement in class debate/discussion was another positive predictor of self-confidence in science/chemistry.

8.1. Associations between students' views

The analysis predicted the students' aspirations, interest/enjoyment, perceived utility, and self-confidence for science/chemistry, and perceived value of science/chemistry to society, at Year 8 (**Table 8-1**), Year 9 (**Table 8-2**), Year 10 (**Table 8-3**), and Year 11 (**Table 8-4**).

The analysis considered the students' personal characteristics, context (including whether their school received or did not receive the Chemistry for All programme), and their experiences/perceptions of their teaching/learning. Specifically, the analysis considered the students' responses to the following questionnaire items as predictors:

- 'I am given the chance to explain my ideas';
- 'The lessons involve all students' opinions about the topics';
- 'I am involved in class debate or discussion';
- 'I spend time in the lab doing practical experiments';
- 'I am allowed to design my own experiments';
- 'The teacher uses science/chemistry to help me understand the world outside school';
- 'Attending a science/chemistry club'.

These reflect areas that may be under the control (to some extent) of teachers. These areas may offer potential avenues to foster students' attitudes and beliefs in schools that may not necessarily be able to apply a formalised programme of activities/events across multiple years.

Aspirations towards science/chemistry

Considering both cohorts together, the students' aspirations towards science/chemistry (A-Level, university, and careers) were most strongly and positively predicted by:

- 'The teacher uses science/chemistry to help me understand the world outside school';
- 'Attending a science/chemistry club'.

These results were consistently seen across Year 8, Year 9, Year 10, and Year 11. The next highest positive predictors of students' aspirations varied across different academic years, and were:

- 'I am given the chance to explain my ideas' at Year 8;
- 'I am involved in class debate or discussion' and 'I am given the chance to explain my ideas' at Year 9;
- 'I am allowed to design my own experiments' at Year 10 and Year 11.

Perceived utility of science/chemistry

Considering both cohorts together, the students' perceived utility of science/chemistry was most strongly and positively predicted by 'The teacher uses science/chemistry to help me understand the world outside school'. This was consistently seen across Year 8, Year 9, Year 10, and Year 11. The next highest positive predictors of students' perceived utility varied across different academic years, and were:

- 'I spend time in the lab doing practical experiments', 'I am given the chance to explain my ideas', and 'I am involved in class debate or discussion' at Year 8 and Year 9;
- 'Attending a science/chemistry club' and 'I am allowed to design my own experiments' at Year 10 and Year 11.

Interest and enjoyment of science/chemistry

Considering both cohorts together, the students' interest and enjoyment of science/chemistry was most strongly and positively predicted by:

- 'The teacher uses science/chemistry to help me understand the world outside school';
- 'I spend time in the lab doing practical experiments';
- 'I am given the chance to explain my ideas'.

These results were consistently seen across Year 8, Year 9, Year 10, and Year 11.

Self-confidence for science/chemistry

The strongest positive predictors of students' self-confidence included (in varying orders across different academic years) the students' gender, being involved in class debate/discussion, attending a science/chemistry club, and their teacher using science/chemistry to help them understand the world.

Considering both cohorts together, at Year 8 the students' self-confidence for science/chemistry was most strongly and positively predicted by:

- Their gender (where boys were predicted to express higher than girls);
- 'I am involved in class debate or discussion';
- 'Attending a science/chemistry club';
- 'The teacher uses science/chemistry to help me understand the world outside school'.

At Year 9, the students' self-confidence for science/chemistry was most strongly and positively predicted by:

- Their gender (where boys were predicted to express higher than girls);
- 'The teacher uses science/chemistry to help me understand the world outside school';
- 'Attending a science/chemistry club';
- 'I am involved in class debate or discussion'.

At Year 10, the students' self-confidence for science/chemistry was most strongly and positively predicted by:

- 'The teacher uses science/chemistry to help me understand the world outside school';
- Their gender (where boys were predicted to express higher than girls);
- 'Attending a science/chemistry club';
- 'I am involved in class debate or discussion'.

At Year 11, the students' self-confidence for science/chemistry was most strongly and positively predicted by:

- 'The teacher uses science/chemistry to help me understand the world outside school';
- Their gender (where boys were predicted to express higher than girls);
- 'I am allowed to design my own experiments';
- 'Attending a science/chemistry club';
- 'I am involved in class debate or discussion'.

Value of science/chemistry to society

Considering both cohorts together, the students' perceived valued of science/chemistry to society was most strongly and positively predicted by 'The teacher uses science/chemistry to help me understand the world outside school', which was consistently seen across Year 8, Year 9, Year 10, and Year 11. The order of the other predictors then varied across the different academic years.

Other insights

Boys were predicted to express higher than girls for their interest/enjoyment of science/chemistry, self-confidence for science/chemistry, and their perceived value of science/chemistry to society, when accounting for their perceptions/experiences of their teaching and learning. There are numerous other potential influences on students' attitudes and beliefs that would need to be considered in order to explain such gender differences.

Table 8-1: Associations between students' views and aspects of teaching and learning at Year 8

Predictors	Aspirations		Utility		Interest		Self-confidence		Value to society	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept / constant	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	.003	.930	.003	.948	-.026	.250	.027	.424	.018	.436
Cohort (Younger=0, Older=1)	.020	.298	.001	.971	-.010	.512	.007	.682	**-.057**	**.001**
School: Total number of pupils	-.015	.636	-.016	.635	-.077	.001	.014	.624	-.021	.249
School: Percentage of girls	-.012	.701	-.045	.190	-.023	.257	.018	.526	-.006	.783
School: Percentage of EAL	**.083**	**.028**	**.082**	**.036**	**.061**	**.007**	.061	.059	**.086**	**.001**
School: Percentage of FSM	-.001	.984	-.037	.380	-.037	.110	-.033	.354	-.042	.088
School: Percentage of SEN	-.024	.477	-.020	.547	.006	.776	-.015	.625	.013	.551
Gender (Girls=0, Boys=1)	-.016	.387	-.010	.552	**.077**	**<.001**	**.160**	**<.001**	**.063**	**<.001**
I am given the chance to explain my ideas	**.094**	**<.001**	**.091**	**<.001**	**.172**	**<.001**	**.099**	**<.001**	**.078**	**<.001**
The lessons involve all students' opinions about the topics	**.055**	**.017**	**.081**	**<.001**	**.121**	**<.001**	.022	.315	**.090**	**<.001**
I am involved in class debate or discussion	**.066**	**.002**	**.084**	**<.001**	**.090**	**<.001**	**.159**	**<.001**	**.101**	**<.001**
I spend time in the lab doing practical experiments	**.079**	**<.001**	**.106**	**<.001**	**.171**	**<.001**	**.110**	**<.001**	**.094**	**<.001**
I am allowed to design my own experiments	.032	.110	.002	.912	.024	.148	**.039**	**.040**	.005	.789
The teacher uses science to help me understand the world outside school	**.216**	**<.001**	**.263**	**<.001**	**.267**	**<.001**	**.130**	**<.001**	**.301**	**<.001**
Attending a science club	**.136**	**<.001**	**.087**	**<.001**	**.076**	**<.001**	**.144**	**<.001**	**.105**	**<.001**
Explained variance	19.3%		24.7%		43.5%		23.9%		31.2%	
Unexplained variance (residual)	79.6%		73.9%		56.3%		75.2%		68.8%	
Unexplained variance (school)	1.2%		1.4%		.1%		.9%		.1%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 8-2: Associations between students' views and aspects of teaching and learning at Year 9

Predictors	Aspirations		Utility		Interest		Self-confidence		Value to society	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept / constant	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	-.027	.436	-.045	.290	-.020	.538	**-.078**	**.036**	-.033	.306
Cohort (Younger=0, Older=1)	-.021	.189	.008	.604	**-.035**	**.012**	-.010	.521	-.012	.413
School: Total number of pupils	.005	.875	-.020	.641	.009	.774	.025	.468	-.010	.750
School: Percentage of girls	.056	.110	.046	.274	.059	.079	.055	.119	.024	.430
School: Percentage of EAL	**.075**	**.041**	**.096**	**.034**	.066	.056	**.080**	**.032**	**.111**	**.003**
School: Percentage of FSM	.070	.110	.015	.764	-.005	.905	.048	.260	-.048	.220
School: Percentage of SEN	-.045	.214	.006	.878	.003	.933	-.036	.309	-.019	.559
Gender (Girls=0, Boys=1)	.016	.341	.025	.109	**.078**	**<.001**	**.191**	**<.001**	**.059**	**<.001**
I am given the chance to explain my ideas	**.080**	**<.001**	**.083**	**<.001**	**.149**	**<.001**	**.111**	**<.001**	**.134**	**<.001**
The lessons involve all students' opinions about the topics	.009	.650	.028	.149	**.073**	**<.001**	-.031	.097	-.011	.543
I am involved in class debate or discussion	**.093**	**<.001**	**.083**	**<.001**	**.077**	**<.001**	**.131**	**<.001**	**.046**	**.011**
I spend time in the lab doing practical experiments	**.071**	**<.001**	**.073**	**<.001**	**.106**	**<.001**	**.108**	**<.001**	**.074**	**<.001**
I am allowed to design my own experiments	**.062**	**.001**	.028	.110	**.044**	**.004**	**.096**	**<.001**	-.006	.700
The teacher uses science to help me understand the world outside school	**.184**	**<.001**	**.262**	**<.001**	**.320**	**<.001**	**.154**	**<.001**	**.363**	**<.001**
Attending a science club	**.128**	**<.001**	**.068**	**<.001**	**.095**	**<.001**	**.144**	**<.001**	**.074**	**<.001**
Explained variance	18.5%		21.2%		40.3%		28.4%		29.4%	
Unexplained variance (residual)	79.8%		75.7%		58.0%		69.7%		69.2%	
Unexplained variance (school)	1.7%		3.1%		1.7%		1.9%		1.4%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 8-3: Associations between students' views and aspects of teaching and learning at Year 10

Predictors	Aspirations		Utility		Interest		Self-confidence		Value to society	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept / constant	**N/A**	**.019**	**N/A**	**<.001**	N/A	.355	**N/A**	**<.001**	**N/A**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	.003	.930	.005	.880	.027	.411	.022	.519	.004	.876
Cohort (Younger=0, Older=1)	**.047**	**.004**	-.023	.148	-.004	.795	-.008	.619	.005	.733
School: Total number of pupils	.023	.484	.037	.219	.044	.132	.025	.417	-.008	.731
School: Percentage of girls	.026	.472	.026	.437	.046	.170	.023	.498	-.004	.886
School: Percentage of EAL	**.097**	**.015**	.061	.080	.047	.164	**.072**	**.048**	**.071**	**.016**
School: Percentage of FSM	.055	.171	**.079**	**.037**	.033	.343	-.001	.986	.020	.495
School: Percentage of SEN	.029	.355	.012	.687	.023	.404	.058	.053	.017	.495
Gender (Girls=0, Boys=1)	-.001	.928	.009	.579	**.051**	**<.001**	**.168**	**<.001**	**.052**	**.001**
I am given the chance to explain my ideas	**.054**	**.012**	**.057**	**.006**	**.134**	**<.001**	**.094**	**<.001**	**.072**	**<.001**
The lessons involve all students' opinions about the topics	-.019	.375	.016	.466	**.089**	**<.001**	-.014	.503	.011	.588
I am involved in class debate or discussion	**.056**	**.004**	**.061**	**.001**	**.096**	**<.001**	**.124**	**<.001**	**.048**	**.010**
I spend time in the lab doing practical experiments	**.048**	**.012**	**.090**	**<.001**	**.154**	**<.001**	**.090**	**<.001**	**.138**	**<.001**
I am allowed to design my own experiments	**.117**	**<.001**	**.107**	**<.001**	**.053**	**.001**	**.115**	**<.001**	.007	.670
The teacher uses science to help me understand the world outside school	**.240**	**<.001**	**.279**	**<.001**	**.308**	**<.001**	**.206**	**<.001**	**.376**	**<.001**
Attending a science club	**.175**	**<.001**	**.113**	**<.001**	**.074**	**<.001**	**.151**	**<.001**	**.076**	**<.001**
Explained variance	22.6%		26.5%		44.2%		31.2%		31.5%	
Unexplained variance (residual)	75.4%		71.9%		54.1%		67.0%		67.8%	
Unexplained variance (school)	2.0%		1.6%		1.7%		1.8%		.7%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Predictors	Aspirations		Utility		Interest		Self-confidence		Value to society	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept / constant	N/A	.333	**N/A**	**<.001**	N/A	.324	**N/A**	**.005**	**N/A**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	.088	.082	.016	.726	.006	.891	.027	.533	-.015	.681
Cohort (Younger=0, Older=1)	**-.075**	**.001**	-.029	.198	-.004	.839	-.029	.175	-.017	.424
School: Total number of pupils	.062	.185	.027	.538	.015	.709	-.023	.558	.036	.298
School: Percentage of girls	.046	.276	.078	.071	.053	.160	.032	.394	**.070**	**.044**
School: Percentage of EAL	**.127**	**.011**	.023	.600	.052	.190	**.087**	**.040**	.027	.428
School: Percentage of FSM	-.018	.723	-.002	.975	-.030	.500	-.065	.159	-.027	.484
School: Percentage of SEN	**.114**	**.044**	.047	.378	.077	.110	.082	.101	.053	.221
Gender (Girls=0, Boys=1)	.026	.231	**.043**	**.038**	**.038**	**.030**	**.154**	**<.001**	**.064**	**.001**
I am given the chance to explain my ideas	.022	.443	**.067**	**.014**	**.143**	**<.001**	**.102**	**<.001**	**.083**	**.001**
The lessons involve all students' opinions about the topics	**-.063**	**.029**	**-.057**	**.042**	-.019	.436	**-.063**	**.019**	**-.111**	**<.001**
I am involved in class debate or discussion	**.070**	**.007**	**.082**	**.001**	**.101**	**<.001**	**.131**	**<.001**	**.089**	**<.001**
I spend time in the lab doing practical experiments	**.104**	**<.001**	**.083**	**.001**	**.152**	**<.001**	**.114**	**<.001**	**.116**	**<.001**
I am allowed to design my own experiments	**.170**	**<.001**	**.116**	**<.001**	**.080**	**<.001**	**.151**	**<.001**	.035	.117
The teacher uses science to help me understand the world outside school	**.198**	**<.001**	**.290**	**<.001**	**.351**	**<.001**	**.192**	**<.001**	**.430**	**<.001**
Attending a science club	**.174**	**<.001**	**.187**	**<.001**	**.113**	**<.001**	**.144**	**<.001**	**.111**	**<.001**
Explained variance	24.0%		28.2%		45.4%		31.1%		34.6%	
Unexplained variance (residual)	73.8%		69.6%		52.7%		67.2%		64.3%	
Unexplained variance (school)	2.2%		2.2%		1.9%		1.7%		1.0%	

Table 8-4: Associations between students' views and aspects of teaching and learning at Year 11

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

8.2. Summary

Students' reports of their teacher using science/chemistry to help them understand the world outside school positively predicted their aspirations towards science/chemistry, their interest/enjoyment in science/chemistry, their perceived utility value of science/chemistry, their self-confidence in science/chemistry, and their perceived value of science/chemistry to society. Students reports of more frequently attending a science/chemistry club was also an important positive predictor of their views. Doing practical experiments and having the chance to explain ideas were also important positive predictors of interest/enjoyment of science/chemistry.

These findings follow from generalising across both cohorts of students and accounting for their schools receiving or not receiving the Chemistry for All programme and other factors. Accordingly, these areas offer potential avenues to help foster students' attitudes and beliefs, regardless of schools applying formalised programmes of activities/events. Additionally, the Chemistry for All programme applied science/chemistry clubs and likely involved (to some extent) debates, discussions, and chances for students to explain their ideas and views (whether formally or informally as part of the various activities/events). These findings may suggest how some programme benefits reach students. Nevertheless, many aspects of programmes such as Chemistry for All cannot easily be isolated and/or revealed through quantitative modelling; many other aspects of programmes and/or students' lives are likely to associate with their attitudes and beliefs.

The presented findings, considering students in schools that did and did not receive the Chemistry for All programme, help affirm associations between various aspects of teaching and learning, including practical work, and students' interest and enjoyment (Hamlyn, Matthews, & Shanahan, 2017; National Foundation for Educational Research, 2011; Straw & Macleod, 2015). Practical and/or experimental work is generally valued within science education, and assumed to reflect the empirical nature of science, although other justifications and contrasting views are possible (Abrahams & Reiss, 2012; Hodson, 1993; Millar, 1998). Secondary school students have often reported preferences towards practical work, and have believed that this made science more interesting and easier to understand (National Foundation for Educational Research, 2011); many students have also conveyed that they wanted to undertake more practical work (Hamlyn, Matthews, & Shanahan, 2017). Teachers have often tended to value practical work as being motivational for their pupils, rather than value the use of practical work to foster the underlying principles of scientific enquiry, specific practical skills, and/or the acquisition of conceptual knowledge (Gatsby Charitable Foundation, 2017), and teachers have also conveyed the challenges of devising and delivering meaningful practical activities (National Foundation for Educational Research, 2011).

Additionally, it is important to consider that undertaking practical experiments cannot cover all aspects of science education. The findings presented here highlight that while students' reports of undertaking practical experiments associated with many outcomes, undertaking practical experiments was not one of the strongest predictors of self-confidence or perceived value of science to society.

The presented findings highlighted that students' reports of more frequently attending a science/chemistry club positively associated with their aspirations, interest/enjoyment, perceived utility value, self-confidence, and perceived value of science/chemistry to society. This helps affirm prior research, which has shown that providing science clubs and ambassadors (volunteers from science-related fields who visit schools to give career talks, provide advice, and deliver demonstrations) has resulted in students reporting higher interest in science, interest in studying science further, and aspirations towards science careers, compared to other students (Straw & Macleod, 2015). Further research across England has revealed that students who attend science clubs have often expressed positive attitudes and aspirations towards science; additionally, having science clubs within schools has associated with students expressing higher science-related studying aspirations, regardless of whether they attended the clubs (Archer, Moote, MacLeod, Francis, & DeWitt, 2020).

The presented findings highlighted that students having the chance to explain their ideas positively associated with their interest and enjoyment in science/chemistry. Class debate or discussion had positive associations with students' self-confidence in science/chemistry. Debate, discussion, and processes of argumentation are also often assumed to reflect some aspects of scientific practice and/or reasoning (which may involve theories being challenged and/or adapted following critique and/or new findings), although wider benefits remain less clear (Cavagnetto, 2010; Erduran & Jiménez-Aleixandre, 2007). It is possible that benefits might arise through discussions facilitating engagement and inclusion, and which may help students to discuss, convey, and/or affirm their ideas and understanding. A challenge may involve ensuring inclusion: the celebration or expectation of confident displays of scientific knowledge (especially within debate and/or discussion) within school may entail that some girls and also some boys are excluded (Archer, et al., 2019).

The findings also affirm potential benefits arising from teachers conveying the wider value and relevance of science, such as through helping understand the world outside school (Sheldrake, Mujtaba, & Reiss, 2017a). This could be undertaken in addition to other teaching and learning approaches, through conveying and highlighting information. This could also be undertaken through context-based/problem-based learning, which uses applied contexts and/or applications of science as a means to learn and/or apply scientific ideas and understanding (rather than starting from ideas and concepts that may or may not be given a context or application). Context-based learning has often been found to associate with positive attitudes to science while being broadly equivalent to other learning approaches in developing students' understanding (Bennett, Lubben, & Hogarth, 2007), and including linking with students' interest in chemistry (Vaino, Holbrook, & Rannikmäe, 2012). Nevertheless, context-based learning can require complex thinking and problem-solving (there may not be only one correct answer), and so can be inherently challenging to students (Broman & Parchmann, 2014).

From a wider perspective, many aspects of teaching and learning are often considered in the context of attainment and achievement. In contrast, the presented findings focus on students' views. Many teaching and learning approaches may help to foster students' attainment and achievement. For example, enquiry-based/inquiry/based, context-based, computer-based, and collaborative learning approaches, and applying questioning/prompting to ensure and affirm understanding, have all positively associated with students' attainment (Bennett, Lubben, & Hogarth, 2007; Furtak, Seidel, Iverson, & Briggs, 2012; Minner, Levy, & Century, 2010; Rahman & Lewis, 2019; Savelsbergh, et al., 2016; Schroeder, Scott, Tolson, Huang, & Lee, 2007).

9

Factors associated with aspirations: the impact of social inequalities, perceived utility of chemistry (extrinsic motivation), and personal value of chemistry

9. Factors associated with aspirations: the impact of social inequalities, perceived utility of chemistry (extrinsic motivation), and personal value of chemistry

Highlights and key findings

This section starts with quantitative analysis and weaves in findings from qualitative case studies.

- Predictive modelling considered four outcomes, as expressed by students during Year 11: overall aspirations towards chemistry (across A-Level studying, university studying, and careers); specific aspirations towards studying chemistry at A-Level; specific aspirations towards studying chemistry at university; and specific aspirations towards chemistry careers.
- Broadly similar findings were revealed when considering students' overall aspirations towards chemistry (across A-Level studying, university studying, and careers) and when considering students' specific aspirations towards A-Level studying, university studying, and careers, in turn.
- Social inequalities such as socio-economic circumstances, gender, family science capital/context, and home learning environments had initial associations with aspirations.
- Students in schools that received the Chemistry for All programme (compared to students in comparison schools) were predicted to express higher aspirations, over and above influences following from other predictors. This effect disappeared in the final model looking at A-Level aspirations (suggesting that the programme may have impact shown via other predictors within the model) but remained for the models measuring university and career aspirations.
- The effect of family science capital (encompassing someone in the family having a science-related job, a science-related qualification, and/or interest in talking about science) lost significance when accounting for other predictors, including the students' perceived utility value of chemistry and/or encouragement to continue studying. This suggested that students' views and/or the provision of support or encouragement may be more important than the potential for support (someone's access to capital/context).
- Higher school-level percentages of students where English was not their first language predicted students expressing higher aspirations.
- Students' participation in science extra-curricular activities was positively associated with their aspirations.
- The qualitative results indicate that Year 11 students reported that they had been influenced to select A-Level chemistry because of the Chemistry for All programme at Year 11.
- Year 11 interviews indicate that students who had more exposure to the Chemistry for All programme, where they were able to participate in hands-on activities, selected A-Level Chemistry at the end of Year 11.
- Encouragement to continue studying science/chemistry from teachers predicted higher aspirations for all four chemistry outcomes.
- Encouragement to continue studying science/chemistry from parents predicted higher aspirations for all four chemistry outcomes.
- Personal value of chemistry (chemistry being a valued and inherent aspect of students' identities) predicted higher aspirations for all four chemistry outcomes.
- Competitiveness/achievement motivation (aiming for top grades and the best opportunities in general) predicted higher aspirations in chemistry for all four chemistry outcomes, although this lost significance when accounting for the students' attitudes towards chemistry.
- The largest predictor of Year 11 students' aspirations in chemistry was their perceived utility value in chemistry (chemistry being valued as facilitating careers, jobs, and future opportunities in general), followed by their personal value of chemistry (chemistry being a valued and inherent aspect of their identity), for all four chemistry outcomes.
- Interest/enjoyment (intrinsic value/motivation) of chemistry was positively associated with A-Level chemistry aspirations and chemistry career aspirations.
- Students' self-confidence in their own chemistry abilities was significantly associated with their overall aspirations towards chemistry (across A-Level studying, university studying, and careers). Students' expected grades, if A-Level chemistry were to be undertaken, were associated with their overall aspirations towards chemistry and their specific aspirations towards A-Level studying and careers.
- Boys were predicted to express higher aspirations than girls for all four chemistry outcomes.

- The students' interview narratives from Year 11 affirmed that they felt that they had been positively influenced to select A-Level chemistry because of the Chemistry for All programme.
- The students' interview narratives from Year 11 also highlighted that students who had more exposure to the Chemistry for All programme, especially where they were able to participate in hands-on activities, reported that they were selecting A-Level chemistry at the end of Year 11.
- Year 11 interviews indicate that students who had more exposure to the Chemistry for All programme, where they were able to participate in hands-on activities, selected A-Level Chemistry at the end of Year 11.

Students who were from less advantaged socio-economic backgrounds were predicted to express the lowest aspirations in chemistry (when controlling for gender and the percentage of students in their school where English was not their first language). However, the magnitude of socio-economic disadvantage was reduced at Year 11 when controlling for engagement in extra-curricular science activities. This suggests how benefits from the Chemistry for All programme, which involved various extra-curricular activities/events, might reach and/or impact students.

9.1. Predictive modelling

Predictive modelling revealed the independent associations between aspects of students' home life, educational contexts, and attitudes and beliefs relating to science/chemistry, and their studying and career aspirations for science/chemistry. The analysis focused on students' views at Year 11, when students study GCSE or equivalent qualifications, immediately prior to studying A-Level or equivalent qualifications (or embarking on other studies and/or work). The predictive (multi-level) modelling accounted for students being clustered within schools, where students' responses are likely to be somewhat similar within schools instead of being independent due to the shared context and environment (Snijders & Bosker, 2012).

The modelling predicted the students' overall aspirations towards studying and careers (encompassing 'I intend to continue to study chemistry at an A-Level or equivalent', 'I intend to continue to study chemistry at university', and 'I would like a job that includes chemistry when I grow up'). Further detail and insights were also gained through predicting the separate items reflecting aspirations for A-Level studying, university studying, and careers, in turn.

For potential insight, the various predictors were added in sequential steps. This can help explore whether any initially observed associations are explained by the introduction of further indicators. For example, gender might initially associate with students' aspirations; subsequently, also modelling students' interest might reveal that interest predictively associates with aspirations, while gender might no longer be predictive. That pattern of changes would suggest that the initial association between gender and aspirations can be explained by different genders tending to express different levels of interest, which then associates with aspirations.

The findings were contextualised by students' interview narratives, which broadly conveyed (for example) that, at Year 11, extra-curricular engagement through the Chemistry for All programme helped with fostering aspirations.

9.2. Results for chemistry as of Year 11

9.2.1. Insights from interviews

The qualitative interviews indicated that for those students' who selected Chemistry at Year 11 their attitudes towards Chemistry and their perceptions (and attendance) of the Chemistry for All programme experiences tended to increase particularly by Year 11. By the end of Year 11 these students indicated they had an increase in the following attitudes and areas of Chemistry directly because of the Chemistry for All programme, which mapped on to what the quantitative models indicated were predictors of Chemistry aspirations:

- Increased aspirations towards science/chemistry;
- Perceived utility of science/chemistry;
- Interest in science/chemistry;
- Self-confidence in science/chemistry;
- Value of science/chemistry to society;
- Teaching and learning experiences;
- Perceptions of teachers.

Few longitudinal intervention programmes have been undertaken on this scale, which allows the findings to affirm and extend existing research. For example, research on physics aspirations has demonstrated that extrinsic motivation was an important predictor of students' aspirations (Mujtaba & Reiss, 2013, 2014; Sheldrake, Mujtaba, & Reiss, 2017a). At Year 11, some students who intended to continue to study chemistry highlighted the influence of Chemistry for All on their decision-making, conveying positive benefits in a number of areas.

9.2.2. Correlations

The analysis considered students in schools that did and did not receive the Chemistry for All programme in order to gain generalisable insights. The questionnaire covered students' subjective attitudes and beliefs, including those likely to associate with science aspirations from prior research (Bøe, Henriksen, Lyons, & Schreiner, 2011; Mujtaba, Sheldrake, Reiss, & Simon, 2018):

- Students' perceived utility of science/chemistry (science/chemistry being valued as facilitating careers, jobs, and future opportunities in general), which can also reflect an extrinsic motivation towards science/chemistry;

- Students' interest/enjoyment in science/chemistry, which can also reflect an intrinsic motivation towards science/chemistry;
- Students' self-confidence beliefs, reflecting their confidence in their own abilities in science/chemistry.

Correlation analysis (**Table 9-1**) affirmed that these indicators associated with the students' aspirations towards chemistry, and that the magnitudes were similar for students who did and did not receive the Chemistry for All programme. At Year 11, for students who received the Chemistry for All programme (across both cohorts), the students' overall aspirations for chemistry (encompassing aspirations for A-Level, university, and careers) strongly correlated with their perceived utility value of chemistry (R = .734, p < .001), followed by their interest/enjoyment in chemistry (R = .548, p < .001) and then their self-confidence beliefs (R = .515, p < .001). Similarly, at Year 11, for students in comparison schools (across both cohorts), the students' overall aspirations for chemistry (encompassing aspirations for A-Level, university, and careers) strongly correlated with their perceived utility value of chemistry (R = .741, p < .001) followed by their interest/enjoyment in chemistry (R = .555, p <.001), and then their self-confidence beliefs (R = .559, p < .001). In addition, the students' aspirations towards chemistry at Year 11 also had notably large correlations with their reported personal value of chemistry to their identity (for the comparison students, R = .690, p < .001; for the Chemistry for All students, R = .714, p < .001).

Table 9-1: Correlations between aspirations and students' views at Year 11

Indicator	Correlation with overall aspirations towards chemistry studying/careers					
	All students		Comparison students		Chemistry for All students	
	R	Sig. (p)	R	Sig. (p)	R	Sig. (p)
Perceived utility of chemistry	**.736**	**<.001**	**.741**	**<.001**	**.734**	**<.001**
Interest in chemistry	**.551**	**<.001**	**.555**	**<.001**	**.548**	**<.001**
Self-confidence in chemistry	**.522**	**<.001**	**.559**	**<.001**	**.515**	**<.001**
Value of chemistry to society	**.447**	**<.001**	**.431**	**<.001**	**.450**	**<.001**
Personal value of chemistry	**.711**	**<.001**	**.690**	**<.001**	**.714**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.084**	**<.001**	-	-	-	-
Cohort (Younger=0, Older=1)	**-.062**	**.002**	-.066	.195	**-.084**	**<.001**
Gender (Girls=0, Boys=1)	.002	.941	**.133**	**.009**	-.019	.390
School: Total number of pupils	-.015	.455	**-.125**	**.014**	.012	.571
School: Percentage of girls	**.045**	**.027**	**-.152**	**.003**	**.052**	**.018**
School: Percentage of EAL	**.127**	**<.001**	**.176**	**<.001**	**.119**	**<.001**
School: Percentage of FSM	**.100**	**<.001**	**.111**	**.029**	**.076**	**.001**
School: Percentage of SEN	.025	.215	.056	.267	.010	.654
Teaching/learning experiences: interaction/debate/discussion	**.308**	**<.001**	**.297**	**<.001**	**.303**	**<.001**
Teaching/learning experiences: practical/experimental	**.379**	**<.001**	**.281**	**<.001**	**.390**	**<.001**
Teaching/learning experiences: relevance/applications	**.348**	**<.001**	**.319**	**<.001**	**.349**	**<.001**
Perceptions of teachers	**.227**	**<.001**	**.247**	**<.001**	**.214**	**<.001**
Books at home	**.107**	**<.001**	**.105**	**.040**	**.124**	**<.001**
Family science (science-related job, qualifications, talks science)	**.327**	**<.001**	**.252**	**<.001**	**.341**	**<.001**
Home support for science/chemistry achievement	**.496**	**<.001**	**.399**	**<.001**	**.513**	**<.001**
Extra-curricular engagement with science/chemistry	**.461**	**<.001**	**.343**	**<.001**	**.479**	**<.001**
Encouragement/shared extra-curricular engagement	**.240**	**<.001**	**.132**	**.014**	**.263**	**<.001**
Encouragement to continue: from parents	**.574**	**<.001**	**.574**	**<.001**	**.575**	**<.001**
Encouragement to continue: from teachers	**.539**	**<.001**	**.484**	**<.001**	**.548**	**<.001**
Encouragement to continue: from friends	**.610**	**<.001**	**.566**	**<.001**	**.618**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.537**	**<.001**	**.495**	**<.001**	**.547**	**<.001**
Achievement motivation	**.198**	**<.001**	**.180**	**<.001**	**.207**	**<.001**
Grades: Science grade this year	**.311**	**<.001**	**.355**	**<.001**	**.318**	**<.001**
Grades: Expected GCSE science/chemistry grade	**.370**	**<.001**	**.446**	**<.001**	**.373**	**<.001**
Grades: Expected grade if A-Level chemistry were to be taken	**.447**	**<.001**	**.549**	**<.001**	**.428**	**<.001**

Notes: Results from both cohorts combined. The table shows Pearson correlation coefficients (R values) and their significance ('Sig. (p)'; p-values).

9.2.3. Predicting students' chemistry aspirations (scale score: A-Level, university, jobs) as of Year 11

Considering the students' overall aspirations towards chemistry (across A-Level studying, university studying, and careers; **Table 9-2**), when only modelling students' background characteristics (**Table 9-2**, model 1), the students' aspirations were positively predicted by more advantaged socio-economic circumstances (as reflected by higher number of books at home) and by higher school-level percentages of students where English was not their first language. The younger cohort were predicted to express more positive aspirations than the older cohort. Those receiving the Chemistry for All programme were predicted to express higher aspirations than those in comparison schools. The students' gender was not significantly predictive, when controlling for these other predictors at this stage of modelling.

The modelling then also included the students' reports of their family science capital/context, which encompassed people in the family having science-related jobs, qualifications, and/or interest in talking about science (**Table 9-2**, model 2). Higher family science capital/context predicted higher aspirations, accounting for the other predictors.

The modelling then also included students' other reports of their home circumstances and contexts (**Table 9-2**, model 3). Students' participation in science extra-curricular activities (which could occur at home and/or at school) was positively associated with their aspirations, while the association between aspirations and number of books at home was reduced but remained significant. Additionally, home support for science/chemistry achievement (students' agreeing that someone in the family wanted them to be successful in chemistry, helping them with homework/learning, and/or taking to them about their work), and parents encouraging students to continue with non-compulsory chemistry after GCSEs, both positively associated with the students' aspirations. At this stage, the effect of family science capital (encompassing someone in the family having a science-related job, a science-related qualification, and/or likes to talk about science) lost significance; this suggested that having explicit support and/or encouragement may be more important than having the potential for support though capital/context. It is also plausible that family science capital entails that parents are more likely to facilitate or provide more extra-curricular activities, home support for science/chemistry achievement, and/or encouragement (which explains how capital/context may broadly foster aspirations).

The modelling then also included students' reports of their school circumstances and contexts, including their experiences/perceptions of various teaching approaches in science (**Table 9-2**, model 4). Teaching the applications of science and teaching that used hands-on activities both had positive associations with the students' chemistry aspirations. The influence of more books at home (reflecting students' socio-economic circumstances) remained predictive. There was also a significant positive impact of teachers encouraging students to continue with chemistry after their GCSEs. Additionally, the students' competitiveness with their peers ('I want to be one of the best students in my class') had an independent and positive association with their chemistry aspirations. This affirms and extends previous research, which found that students who held competitive personality traits were more likely to express higher aspirations, which was particularly prominent in girls with high physics aspirations (Mujtaba & Reiss, 2013, 2014, 2016).

The modelling then also included the students' personal attitudes and beliefs about chemistry (**Table 9-2**, model 5). Students' interest/enjoyment (intrinsic motivation), perceived utility value (extrinsic motivation), and personal value of chemistry all had significant positive associations with their chemistry aspirations. Perceived utility value of chemistry (chemistry being valued as facilitating careers, jobs, and future opportunities in general) had the strongest magnitude of association, mirroring previous research focused on physics (Mujtaba & Reiss, 2014) and science (Sheldrake, Mujtaba, & Reiss, 2017a).

Finally, the modelling also included students' expected grades if A-Level chemistry were to be taken, and the students' self-confidence beliefs about their abilities in chemistry (**Table 9-2**, model 6); both of these indicators positively associated with the students' aspirations. Ultimately (**Table 9-2**, model 6), the following predictors were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility of chemistry/ extrinsic motivation;
- personal value of chemistry;
- encouragement to continue studying chemistry after GCSEs from teachers;
- expected A-Level grade if chemistry were to be taken;
- experiencing more hands-on activities within teaching/learning;
- self-confidence beliefs in chemistry;
- home support for achievement in chemistry (a measure of the home learning environment);
- and participation in extra-curricular science/ chemistry activities.

Additionally, students in Chemistry for All schools were also predicted to express higher aspirations than students in comparison schools. Students in the younger cohort were also predicted to express higher aspirations than the older cohort. It is possible that the programme may have been refined to some extent for the younger cohort, and different cohorts of students may unavoidably experience various other influences within their lives.

Additionally, boys were predicted to express lower aspirations than girls. This finding may also link with the various interrelated impacts of the Chemistry for All programme on students' aspirations and attitudes (even when controlling for the programme status and other predictors, the programme impact of reducing gender differences in aspirations and attitudes may be reflected within this result).

Students' attitudes and beliefs (their perceived utility/extrinsic motivation, interest/enjoyment, and personal value of chemistry) appeared to particularly reduce the influence of socio-economic disadvantage (books at home) through eliminating the difference in aspirations between the most disadvantaged group and the most advantaged group. Given that the students who experienced the Chemistry for All programme reported higher aspirations and also higher perceived utility, interest/enjoyment, and personal value of chemistry than students in comparison schools, these findings broadly suggest and/or affirm how the programme's various impacts help foster aspirations and support disadvantaged students.

Table 9-2: Students' views at Year 11 predicting their overall aspirations towards chemistry (full scale)

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	N/A	<.001	N/A	<.001	N/A	.001	N/A	.958	N/A	.011	N/A	.003
School: Percentage of EAL	.116	.014	.112	.017	.021	.430	.041	.161	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.143	.015	.138	.019	.102	.008	.087	.028	.062	.048	.065	.045
Cohort (Younger=0, Older=1)	-.079	<.001	-.065	.005	-.062	.002	-.070	<.001	-.062	<.001	-.056	.001
Gender (Girls=0, Boys=1)	.040	.060	.035	.107	.020	.293	.001	.936	-.025	.096	-.040	.010
Books at home: 0-10 compared to 500+	-.269	<.001	-.178	<.001	-.091	.025	-.088	.026	-.058	.074	-.052	.115
Books at home: 11-25 compared to 500+	-.170	<.001	-.108	.015	-.081	.036	-.091	.016	-.086	.005	-.081	.010
Books at home: 26-100 compared to 500+	-.201	<.001	-.156	.001	-.110	.006	-.118	.003	-.089	.006	-.080	.014
Books at home: 101-200 compared to 500+	-.114	.001	-.110	.003	-.090	.004	-.085	.006	-.067	.007	-.064	.013
Books at home: 201-500 compared to 500+	-.061	.043	-.062	.046	-.056	.037	-.062	.019	-.046	.031	-.042	.057
Family science (science-related job, qualifications, talks science)			.298	<.001	-.050	.033	-.068	.003	-.008	.659	-.009	.620
Home support for science/chemistry achievement					.157	<.001	.077	.006	.046	.039	.051	.022
Encouragement to continue: parents					.401	<.001	.300	<.001	-	-	-	-
Extra-curricular engagement with science/chemistry					.213	<.001	.145	<.001	.049	.006	.041	.023
Teaching/learning experiences: practical/experimental							.148	<.001	.064	.001	.057	.003
Teaching/learning experiences: relevance/applications							.044	.049	-.060	.002	-.059	.002
Teaching/learning experiences: interaction/debate/discussion							-.023	.327	-.046	.018	-.040	.040
Encouragement to continue: teacher							.192	<.001	.141	<.001	.110	<.001
'I want to be one of the best students in my class'							.050	.007	-.063	<.001	-.078	<.001
Interest in chemistry									.069	.002	.036	.125
Personal value of chemistry									.274	<.001	.252	<.001
Perceived utility of chemistry									.400	<.001	.401	<.001
Self-confidence in chemistry											.057	.008
Grades: Expected grade if A-Level chemistry were to be taken											.072	<.001
Explained variance	4.8%		10.9%		38.3%		42.6%		61.5%		61.9%	
Unexplained variance (residual)	91.6%		85.9%		60.8%		56.2%		37.7%		37.3%	
Unexplained variance (school)	3.6%		3.3%		.9%		1.2%		.8%		.8%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

9.2.4. Predicting students' chemistry aspirations for A-Level as of Year 11

Further modelling explored what factors were associated with the students' specific chemistry A-Level aspirations (**Table 9-3**). The model steps alongside the findings were very similar to the overall chemistry construct scale.

Ultimately, the following indicators were found to have independent positive associations with students' aspirations to continue with chemistry at A-Level (in order of descending magnitudes):

- perceived utility value of chemistry/ extrinsic motivation;
- personal value of chemistry;
- encouragement from teachers to undertake chemistry after GCSEs;
- expected grade if chemistry were to be studied at A-Level;
- participation in extra-curricular science/ chemistry activities;
- interest/enjoyment in chemistry;
- experiences of practical/experimental work within teaching/learning.

Receiving the Chemistry for All programme did not independently associate with aspirations, when accounting for the other predictors (which nevertheless suggests that the programme may have had indirect impact via other predictors within the model, given the difference in reported aspirations across Chemistry for All and comparison students). The influence of socio-economic disadvantage was reduced, although it remained significantly predictive. Additionally, students from the younger cohort were predicted to express higher aspirations. When accounting for the various other predictors, boys were predicted to express lower aspirations than girls.

Elements of the students' home learning environment (home support for achievement in chemistry, and families encouraging students to continue with chemistry after GCSE), alongside family science capital, were not significant predictors of A-Level chemistry aspirations in the final model.

Table 9-3: Students' views at Year 11 predicting their specific aspirations towards studying chemistry at A-Level

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	N/A	<.001	N/A	<.001	N/A	.012	N/A	.731	N/A	.012	N/A	.003
School: Percentage of EAL	.136	.004	.127	.007	.042	.169	.059	.067	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.107	.051	.103	.060	.071	.073	.061	.123	.036	.325	.040	.276
Cohort (Younger=0, Older=1)	-.072	.001	-.065	.006	-.064	.002	-.077	<.001	-.070	<.001	-.065	<.001
Gender (Girls=0, Boys=1)	.045	.035	.043	.052	.026	.177	.009	.638	-.016	.342	-.034	.047
Books at home: 0-10 compared to 500+	-.241	<.001	-.170	<.001	-.083	.045	-.085	.038	-.055	.125	-.039	.285
Books at home: 11-25 compared to 500+	-.167	<.001	-.124	.006	-.094	.018	-.108	.006	-.102	.003	-.089	.010
Books at home: 26-100 compared to 500+	-.188	<.001	-.157	.001	-.108	.009	-.119	.003	-.091	.010	-.077	.033
Books at home: 101-200 compared to 500+	-.111	.002	-.112	.002	-.088	.007	-.087	.006	-.070	.011	-.064	.023
Books at home: 201-500 compared to 500+	-.040	.181	-.045	.157	-.035	.209	-.044	.107	-.029	.222	-.025	.293
Family science (science-related job, qualifications, talks science)			.277	<.001	-.055	.022	-.074	.002	-.016	.435	-.017	.423
Home support for science/chemistry achievement					.118	<.001	.046	.114	.032	.185	.038	.124
Encouragement to continue: parents					.413	<.001	.315	<.001	-	-	-	-
Extra-curricular engagement with science/ chemistry					.211	<.001	.144	<.001	.063	.001	.058	.004
Teaching/learning experiences: practical/ experimental							.123	<.001	.049	.019	.043	.040
Teaching/learning experiences: relevance/ applications							.042	.074	-.056	.008	-.056	.009
Teaching/learning experiences: interaction/ debate/discussion							-.032	.192	-.060	.005	-.051	.019
Encouragement to continue: teacher							.198	<.001	.163	<.001	.132	<.001
'I want to be one of the best students in my class'							.057	.003	-.043	.012	-.061	<.001
Interest in chemistry									.091	<.001	.052	.043
Personal value of chemistry									.200	<.001	.181	<.001
Perceived utility of chemistry									.393	<.001	.389	<.001
Self-confidence in chemistry											.033	.159
Grades: Expected grade if A-Level chemistry were to be taken											.113	<.001
Explained variance	4.3%		8.9%		34.5%		38.6%		52.7%		53.6%	
Unexplained variance (residual)	92.5%		88.1%		64.3%		60.1%		45.9%		45.0%	
Unexplained variance (school)	3.2%		2.9%		1.2%		1.4%		1.4%		1.4%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

9.2.5. Predicting students' chemistry aspirations for careers as of Year 11

Further modelling considered what factors associated with students' aspirations towards chemistry careers (**Table 9-4**). The model steps alongside the findings were very similar to the overall chemistry construct scale.

Ultimately, the following indicators were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility value of chemistry/ extrinsic motivation;
- personal value of chemistry;
- encouragement from teachers to undertake chemistry after GCSEs;
- expected grade if chemistry were to be studied at A-Level;
- experiences of practical/experimental work in teaching/learning;
- home support for achievement in chemistry;
- interest/enjoyment in chemistry.

Additionally, receiving the Chemistry for All programme predictively associated with higher chemistry career aspirations, compared to students in comparison schools. The influence of socio-economic disadvantage was reduced although it remained significant. Students from the younger cohort were also predicted to express more positive aspirations. Boys were also predicted to express lower aspirations.

Table 9-4: Students' views at Year 11 predicting their specific aspirations towards careers in chemistry

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	N/A	.922	**N/A**	**.002**	**N/A**	**.001**
School: Percentage of EAL	.072	.072	.071	.081	-.015	.503	.008	.756	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	**.144**	**.007**	**.030**	**.180**	**.100**	**.004**	**.085**	**.024**	**.059**	**.014**	**.060**	**.024**
Cohort (Younger=0, Older=1)	**-.070**	**.002**	**.136**	**.013**	**-.047**	**.017**	**-.050**	**.012**	**-.039**	**.012**	**-.036**	**.027**
Gender (Girls=0, Boys=1)	.036	.091	**-.052**	**.026**	.015	.437	-.003	.865	-.026	.079	**-.036**	**.022**
Books at home: 0-10 compared to 500+	**-.279**	**<.001**	**-.182**	**<.001**	**-.090**	**.033**	-.075	.068	-.046	.168	-.049	.151
Books at home: 11-25 compared to 500+	**-.166**	**<.001**	**-.099**	**.029**	-.067	.092	-.065	.096	-.063	.050	**-.067**	**.042**
Books at home: 26-100 compared to 500+	**-.200**	**<.001**	**-.151**	**.001**	**-.099**	**.017**	**-.096**	**.019**	**-.068**	**.043**	**-.067**	**.049**
Books at home: 101-200 compared to 500+	**-.111**	**.002**	**-.107**	**.004**	**-.082**	**.012**	**-.068**	**.033**	**-.051**	**.049**	**-.053**	**.045**
Books at home: 201-500 compared to 500+	**-.065**	**.032**	-.061	.055	-.053	.060	-.051	.061	-.037	.097	-.034	.133
Family science (science-related job, qualifications, talks science)			**.283**	**<.001**	**-.054**	**.025**	**-.073**	**.002**	-.015	.440	-.013	.495
Home support for science/chemistry achievement					**.163**	**<.001**	**.089**	**.002**	.044	.054	**.050**	**.032**
Encouragement to continue: parents					**.380**	**<.001**	**.269**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.198**	**<.001**	**.134**	**<.001**	.035	.059	.028	.139
Teaching/learning experiences: practical/ experimental							**.146**	**<.001**	**.057**	**.003**	**.053**	**.007**
Teaching/learning experiences: relevance/ applications							**.046**	**.047**	**-.059**	**.003**	**-.062**	**.002**
Teaching/learning experiences: interaction/debate/discussion							-.020	.421	-.039	.054	-.033	.111
Encouragement to continue: teacher							**.196**	**<.001**	**.133**	**<.001**	**.110**	**<.001**
'I want to be one of the best students in my class'							**.042**	**.030**	**-.077**	**<.001**	**-.087**	**<.001**
Interest in chemistry									**.071**	**.002**	**.048**	**.045**
Personal value of chemistry									**.269**	**<.001**	**.254**	**<.001**
Perceived utility of chemistry									**.409**	**<.001**	**.408**	**<.001**
Self-confidence in chemistry											.038	.088
Grades: Expected grade if A-Level chemistry were to be taken											**.056**	**.003**
Explained variance	4.0%		9.1%		34.2%		38.6%		59.0%		59.3%	
Unexplained variance (residual)	93.5%		88.5%		65.4%		60.5%		40.9%		40.4%	
Unexplained variance (school)	2.6%		2.5%		.4%		.9%		.1%		.3%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

9.2.6. Predicting students' chemistry aspirations for university as of Year 11

Further modelling considered what factors associated with students' aspirations towards studying chemistry at university (**Table 9-5**). The model steps alongside the findings were very similar to the overall chemistry construct scale.

Ultimately, the following indicators were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility of chemistry/ extrinsic motivation;
- personal value of chemistry;
- self-confidence in chemistry;
- home support for achievement in chemistry;
- experiences of practical/experimental work in teaching/learning;
- encouragement from teachers to undertake chemistry after GCSEs.

Additionally, receiving the Chemistry for All programme predictively associated with higher aspirations, compared to students in comparison schools. The influence of socio-economic disadvantage was reduced although it remained significant. Students from the younger cohort were also predicted to express more positive aspirations. Boys were also predicted to express lower aspirations.

Table 9-5: Students' views at Year 11 predicting their specific aspirations towards studying chemistry at university

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	N/A	.310	**N/A**	**.622**	**N/A**	**.402**
School: Percentage of EAL	**.108**	**.024**	**.108**	**.019**	.027	.342	.042	.147	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	**.153**	**.011**	**.148**	**.012**	**.115**	**.005**	**.099**	**.014**	**.076**	**.026**	**.076**	**.022**
Cohort (Younger=0, Older=1)	**-.079**	**<.001**	**-.064**	**.007**	**-.063**	**.003**	**-.069**	**.001**	**-.064**	**<.001**	**-.057**	**.002**
Gender (Girls=0, Boys=1)	.034	.111	.027	.221	.014	.467	-.004	.847	-.029	.093	**-.041**	**.021**
Books at home: 0-10 compared to 500+	**-.248**	**<.001**	**-.164**	**.001**	**-.098**	**.024**	**-.104**	**.016**	**-.076**	**.043**	-.076	.050
Books at home: 11-25 compared to 500+	**-.153**	**<.001**	**-.093**	**.039**	-.076	.064	**-.094**	**.021**	**-.088**	**.014**	**-.085**	**.020**
Books at home: 26-100 compared to 500+	**-.192**	**<.001**	**-.149**	**.002**	**-.119**	**.006**	**-.134**	**.002**	**-.106**	**.005**	**-.100**	**.009**
Books at home: 101-200 compared to 500+	**-.110**	**.002**	**-.105**	**.005**	**-.095**	**.005**	**-.098**	**.003**	**-.081**	**.006**	**-.076**	**.011**
Books at home: 201-500 compared to 500+	**-.074**	**.014**	**-.080**	**.011**	**-.081**	**.005**	**-.090**	**.002**	**-.075**	**.003**	**-.069**	**.007**
Family science (science-related job, qualifications, talks science)			**.271**	**<.001**	-.036	.151	**-.046**	**.064**	.005	.828	.001	.969
Home support for science/chemistry achievement					**.159**	**<.001**	**.090**	**.003**	**.059**	**.022**	**.063**	**.016**
Encouragement to continue: parents					**.328**	**<.001**	**.253**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.184**	**<.001**	**.123**	**<.001**	.035	.091	.025	.236
Teaching/learning experiences: practical/ experimental							**.147**	**<.001**	**.070**	**.001**	**.060**	**.007**
Teaching/learning experiences: relevance/ applications							.036	.145	**-.051**	**.024**	**-.046**	**.043**
Teaching/learning experiences: interaction/debate/discussion							-.008	.748	-.022	.331	-.024	.301
Encouragement to continue: teacher							**.136**	**<.001**	**.090**	**<.001**	**.058**	**.014**
'I want to be one of the best students in my class'							**.041**	**.042**	**-.060**	**.001**	**-.071**	**<.001**
Interest in chemistry									.031	.215	-.001	.972
Personal value of chemistry									**.311**	**<.001**	**.285**	**<.001**
Perceived utility of chemistry									**.306**	**<.001**	**.316**	**<.001**
Self-confidence in chemistry											**.096**	**<.001**
Grades: Expected grade if A-Level chemistry were to be taken											.021	.325
Explained variance	4.4%		9.4%		30.2%		33.3%		48.8%		48.9%	
Unexplained variance (residual)	91.7%		87.4%		68.8%		65.7%		50.4%		50.4%	
Unexplained variance (school)	3.8%		3.2%		1.0%		1.0%		.8%		.7%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

9.3. Results for science as of Year 11

The analysis considered students' responses from Year 11, focusing on what factors predictively associated with the students' aspirations to continue with science. The findings are backed by qualitative data in Year 11 where students report that, at Year 11, extra-curricular engagement factors led by the Chemistry for All programme boosted aspirations.

Highlights and key findings

Predictive modelling considered four outcomes, as expressed by students during Year 11: overall aspirations towards science (across A-Level studying, university studying, and careers); specific aspirations towards studying science at A-Level; specific aspirations towards studying science at university; and specific aspirations towards science careers.

- Broadly similar findings were revealed when considering students' overall aspirations towards science (across A-Level studying, university studying, and careers) and when considering students' specific aspirations towards A-Level studying, university studying, and careers in turn.
- Students in the Chemistry for All schools were predicted to express similar aspirations to those from comparison schools, when accounting for the other predictors, for all four outcomes models. Given the influence of Chemistry for All on the chemistry outcomes, it is possible that particular events/activities were more relevant to chemistry rather than science in general.
- The influence of socio-economic disadvantage was eliminated between the most disadvantaged group and the most advantaged group for all four outcomes (although there were still some differences between some of the other categories of disadvantage). The overall magnitude of social disadvantage was reduced at Year 11.
- The effect of family science capital (encompassing someone in the family having a science-related job, a science-related qualification, and/or interest in talking about science) lost significance when accounting for other predictors, including the students' perceived utility value of chemistry.
- Higher school-level percentages of students where English was not their first language predicted students' expressing higher aspirations.
- Students' participation in science/chemistry extra-curricular activities was positively associated with students' aspirations within all four of the outcome models, prior to modelling for the impact of students' perceived utility value of chemistry.
- Students' engagement in extra-curricular activities predicted aspirations, over and above their perceived utility value of chemistry, for their overall aspirations towards chemistry (across A-Level studying, university studying, and careers) and their specific aspirations towards A-Level studying and university studying.
- Encouragement from teachers to continue studying science/chemistry predicted higher aspirations for all four outcomes.
- Reporting that families provided a positive home learning environment for chemistry predicted higher aspirations in science for all four outcomes.
- Personal value of chemistry predicted higher aspirations for all four science outcomes.
- Competitiveness/achievement motivation predicted higher aspirations in science, although this lost significance when accounting for the students' attitudes towards chemistry.
- The largest predictor of Year 11 students' aspirations in science was their perceived utility value (extrinsic value/motivation) for all of the science outcomes except for science A-Level aspirations.
- Interest/enjoyment (intrinsic value/motivation) of chemistry was positively associated with the students' overall science aspirations and A-Level aspirations.
- The students' chemistry self-confidence beliefs did not predict their science aspirations, when accounting for the other predictors.
- Students' expected grades at GCSE science were associated with all four science outcomes.
- Boys were predicted to express lower aspirations than girls.
- The qualitative results indicate that Year 11 students reported that they had been positively influenced to select A-Level chemistry because of the Chemistry for All programme at Year 11.
- Year 11 interviews indicate that students who had more exposure to the Chemistry for All programme, where they were able to participate in hands-on activities, selected A-Level Chemistry at the end of Year 11.

9.3.1. Predicting students' science aspirations (A-Level, university, jobs) as of Year 11

Considering the students' overall aspirations to study and work within science (across A-Level, university, and careers; **Table 9-6**), when only modelling students' background characteristics (**Table 9-6**, model 1), the students' socio-economic circumstances, as measured by the number of books at home, positively predicted their aspirations. Higher school-level percentages of students where English was not their first language also predicted higher aspirations.

Subsequently, the modelling also included the students' reports of their family science capital/contexts (**Table 9-6**, model 2); higher family science capital/context predicted higher aspirations, accounting for the other predictors.

Subsequently, including the students' participation in science/chemistry extra-curricular activities (**Table 9-6**, model 3) highlighted that this was positively associated with their aspirations. The effect of social disadvantage (the number of books at home) became non-significant, when accounting for the predictors at this stage of modelling, indicating that there was no difference in aspirations between students from disadvantaged and advantaged backgrounds. Students who came from a family who provided support in achieving well in science were predicted to express higher aspirations. There was a further positive impact of parents/family encouraging students to continue with chemistry after GCSEs.

When also considering students' experiences/ perceptions of various science teaching/learning approaches (**Table 9-6**, model 4), teaching that conveyed the wider applications/relevance of science and experimental/practical work in teaching/learning both had positive associations with students' science aspirations. There was also a significant positive impact of teachers encouraging students to continue with science after GCSEs. The students' achievement motivation was also found to have an independent positive association with science aspirations.

When considering students' chemistry attitudes (**Table 9-6**, model 5), students' interest/enjoyment for chemistry (intrinsic motivation), perceived utility value of chemistry (extrinsic motivation), and personal value of chemistry had significant positive associations with science aspirations. Of the three, and of all measures within the modelling, perceived utility value of chemistry had the strongest magnitude of association.

Finally (**Table 9-6**, model 6), students' expected grades at GCSE science and students' self-confidence in their chemistry abilities/capabilities were included; expected GCSE grades in science were positively associated with science aspirations, although the students' self-confidence beliefs were negatively associated with science aspirations. This pattern of coefficients might suggest mediation effects, or more complex patterns of direct and indirect associations that would need to be explored through further modelling. For example, it is possible that students' (current) self-confidence in chemistry associates with their expected (future) GCSE science grades, which then associates with aspirations.

Ultimately, the following indicators were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility of chemistry (extrinsic motivation);
- personal value of chemistry;
- encouragement to continue with chemistry from teachers;
- expected GCSE grades in science;
- home support for achievement in chemistry;
- interest/enjoyment in chemistry (intrinsic motivation);
- participation in extra-curricular science/ chemistry activities.

The influence of socio-economic disadvantage (books at home) was eliminated when accounting for the other predictors (involving students' home circumstances and support). Boys were predicted to express lower aspirations. There was no predicted difference between students in the Chemistry for All schools and the students in comparison schools in their aspirations in science, when accounting for the various predictors in the modelling.

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	N/A	.334	N/A	.204	**N/A**	**.006**
School: Percentage of EAL	**.114**	**.021**	**.095**	**.031**	.005	.848	.017	.505	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.041	.478	.016	.755	-.023	.505	-.031	.348	-.048	.122	-.018	.582
Cohort (Younger=0, Older=1)	-.022	.327	-.018	.452	-.010	.618	-.018	.339	-.012	.495	-.004	.836
Gender (Girls=0, Boys=1)	.021	.315	.018	.408	.007	.689	-.017	.355	**-.040**	**.013**	**-.043**	**.011**
Books at home: 0-10 compared to 500+	**-.215**	**<.001**	**-.129**	**.006**	-.045	.258	-.031	.425	-.004	.908	.037	.317
Books at home: 11-25 compared to 500+	**-.087**	**.045**	-.029	.523	-.002	.949	-.002	.957	.006	.856	.032	.362
Books at home: 26-100 compared to 500+	**-.100**	**.027**	-.064	.173	-.019	.633	-.021	.595	.007	.841	.026	.469
Books at home: 101-200 compared to 500+	-.036	.310	-.034	.357	-.018	.554	-.010	.740	.009	.740	.010	.709
Books at home: 201-500 compared to 500+	-.007	.820	-.008	.788	-.003	.907	-.006	.810	.009	.715	.013	.578
Family science (science-related job, qualifications, talks science)			**.298**	**<.001**	**-.091**	**<.001**	**-.107**	**<.001**	**-.055**	**.008**	**-.044**	**.033**
Home support for science/chemistry achievement					**.200**	**<.001**	**.125**	**<.001**	**.133**	**<.001**	**.141**	**<.001**
Encouragement to continue: parents					**.439**	**<.001**	**.327**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.183**	**<.001**	**.124**	**<.001**	**.053**	**.006**	**.045**	**.022**
Teaching/learning experiences: practical/ experimental							**.071**	**.002**	.006	.779	-.003	.895
Teaching/learning experiences: relevance/ applications							**.059**	**.008**	-.022	.292	-.025	.238
Teaching/learning experiences: interaction/debate/discussion							-.038	.102	**-.060**	**.004**	-.042	.053
Encouragement to continue: teacher							**.225**	**<.001**	**.213**	**<.001**	**.194**	**<.001**
'I want to be one of the best students in my class'							**.075**	**<.001**	-.011	.531	-.028	.112
Interest in chemistry									**.063**	**.008**	**.054**	**.034**
Personal value of chemistry									**.203**	**<.001**	**.217**	**<.001**
Perceived utility of chemistry									**.327**	**<.001**	**.303**	**<.001**
Self-confidence in chemistry											**-.073**	**.002**
Grades: Expected GCSE science/chemistry grade											**.165**	**<.001**
Explained variance	3.4%		10.7%		41.1%		44.9%		54.5%		55.6%	
Unexplained variance (residual)	92.5%		86.5%		57.9%		54.2%		44.8%		43.5%	
Unexplained variance (school)	4.0%		2.8%		1.0%		.9%		.7%		.9%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Table 9-6: Students' views at Year 11 predicting their overall aspirations towards science (full scale)

9.3.2. Predicting students' science aspirations for A-Level as of Year 11

Further modelling considered the students' specific aspirations towards studying science at A-Level (**Table 9-7**). The model steps alongside the findings were very similar to the overall science aspirations scale.

Ultimately, the following indicators were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility of chemistry (extrinsic value/motivation);
- encouragement by teachers to continue science/chemistry after GCSEs;
- expected GCSE science grades;
- personal value of chemistry;
- home support for achievement in science/chemistry;
- interest/enjoyment for chemistry (intrinsic value/motivation);
- extra-curricular engagement in science/chemistry.

The influence of socio-economic disadvantage was eliminated when accounting for the other predictors (involving students' home circumstances and support). With respect to gender, boys were predicted to express lower aspirations.

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	N/A	.185	N/A	.758	**N/A**	**.078**
School: Percentage of EAL	**.134**	**.013**	**.117**	**.017**	.033	.311	.043	.164	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.022	.721	.001	.979	-.034	.411	-.043	.271	-.061	.118	-.033	.383
Cohort (Younger=0, Older=1)	-.033	.145	-.032	.180	-.023	.261	-.030	.128	-.024	.200	-.014	.460
Gender (Girls=0, Boys=1)	.025	.251	.023	.298	.013	.496	-.008	.683	-.030	.093	**-.037**	**.043**
Books at home: 0-10 compared to 500+	**-.224**	**<.001**	**-.157**	**.001**	-.076	.067	-.057	.160	-.030	.436	.010	.801
Books at home: 11-25 compared to 500+	**-.117**	**.007**	-.073	.108	-.050	.201	-.042	.275	-.033	.366	-.008	.836
Books at home: 26-100 compared to 500+	**-.110**	**.016**	-.086	.069	-.045	.272	-.041	.313	-.015	.703	.001	.978
Books at home: 101-200 compared to 500+	-.060	.090	-.065	.082	-.052	.107	-.039	.214	-.019	.534	-.016	.578
Books at home: 201-500 compared to 500+	-.006	.848	-.013	.685	-.008	.782	-.008	.780	.007	.792	.008	.747
Family science (science-related job, qualifications, talks science)			**.263**	**<.001**	**-.095**	**<.001**	**-.106**	**<.001**	**-.057**	**.011**	**-.046**	**.038**
Home support for science/chemistry achievement					**.152**	**<.001**	**.082**	**.005**	**.104**	**<.001**	**.107**	**<.001**
Encouragement to continue: parents					**.441**	**<.001**	**.326**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.169**	**<.001**	**.114**	**<.001**	**.056**	**.009**	**.047**	**.029**
Teaching/learning experiences: practical/ experimental							**.057**	**.014**	**-.001**	.955	-.010	.651
Teaching/learning experiences: relevance/ applications							**.058**	**.012**	-.015	.505	-.012	.610
Teaching/learning experiences: interaction/debate/discussion							**-.051**	**.036**	**-.078**	**.001**	**-.059**	**.011**
Encouragement to continue: teacher							**.233**	**<.001**	**.233**	**<.001**	**.212**	**<.001**
'I want to be one of the best students in my class'							**.070**	**<.001**	-.001	.966	-.025	.179
Interest in chemistry									**.081**	**.002**	**.060**	**.027**
Personal value of chemistry									**.156**	**<.001**	**.169**	**<.001**
Perceived utility of chemistry									**.297**	**<.001**	**.272**	**<.001**
Self-confidence in chemistry											**-.065**	**.010**
Grades: Expected GCSE science/chemistry grade											**.190**	**<.001**
Explained variance	4.1%		9.4%		36.5%		40.2%		46.4%		48.2%	
Unexplained variance (residual)	91.0%		87.0%		61.8%		58.5%		52.3%		50.4%	
Unexplained variance (school)	4.8%		3.6%		1.7%		1.3%		1.4%		1.3%	

Table 9-7: Students' views at Year 11 predicting their specific aspirations towards studying science at A-Level

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

9.3.3. Predicting students' science aspirations for careers as of Year 11

Further modelling considered students' specific aspirations for science careers (**Table 9-8**). The model steps alongside the findings were very similar to the overall science aspirations scale. The final model revealed that the following were independent predictors:

- perceived utility value of chemistry (extrinsic value/motivation);
- personal value of chemistry;
- encouragement by teachers to continue science/chemistry after GCSEs;
- expected science GCSE grades;
- home support for achievement in science/chemistry.

The influence of socio-economic disadvantage was eliminated when accounting for the various other predictors.

Table 9-8: Students' views at Year 11 predicting their specific aspirations towards careers in science

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	N/A	.307	N/A	.138	**N/A**	**.007**
School: Percentage of EAL	.064	.085	.045	.147	-.027	.184	-.013	.507	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.024	.600	-.005	.907	-.041	.124	-.049	.068	**-.062**	**.024**	-.039	.159
Cohort (Younger=0, Older=1)	.001	.976	.006	.810	.015	.453	.004	.836	.014	.430	.021	.247
Gender (Girls=0, Boys=1)	.029	.172	.026	.238	.017	.361	-.007	.717	-.023	.183	-.017	.330
Books at home: 0-10 compared to 500+	**-.182**	**<.001**	-.091	.058	-.011	.799	-.018	.669	.010	.804	.046	.234
Books at home: 11-25 compared to 500+	-.051	.251	.013	.777	.043	.291	.024	.554	.032	.380	.052	.155
Books at home: 26-100 compared to 500+	-.067	.149	-.022	.647	.029	.499	.005	.911	.031	.413	.043	.263
Books at home: 101-200 compared to 500+	-.014	.697	-.007	.858	.012	.712	.006	.845	.024	.415	.023	.440
Books at home: 201-500 compared to 500+	-.004	.899	.001	.964	.012	.662	.001	.975	.016	.542	.017	.500
Family science (science-related job, qualifications, talks science)			**.284**	**<.001**	**-.076**	**.002**	**-.098**	**<.001**	**-.050**	**.025**	-.042	.060
Home support for science/chemistry achievement					**.205**	**<.001**	**.134**	**<.001**	**.127**	**<.001**	**.136**	**<.001**
Encouragement to continue: parents					**.376**	**<.001**	**.277**	**<.001**	-	-	-	-
Extra-curricular engagement with science/chemistry					**.175**	**<.001**	**.114**	**<.001**	.040	.055	.039	.063
Teaching/learning experiences: practical/experimental							**.054**	**.026**	-.005	.813	-.010	.641
Teaching/learning experiences: relevance/applications							**.077**	**.001**	.001	.979	-.002	.947
Teaching/learning experiences: interaction/debate/discussion							-.007	.763	-.023	.309	-.007	.774
Encouragement to continue: teacher							**.189**	**<.001**	**.163**	**<.001**	**.151**	**<.001**
'I want to be one of the best students in my class'							**.070**	**<.001**	-.018	.323	-.030	.113
Interest in chemistry									.038	.137	.038	.162
Personal value of chemistry									**.194**	**<.001**	**.204**	**<.001**
Perceived utility of chemistry									**.335**	**<.001**	**.315**	**<.001**
Self-confidence in chemistry											**-.089**	**<.001**
Grades: Expected GCSE science/chemistry grade											**.146**	**<.001**
Explained variance	2.2%		8.4%		33.5%		36.7%		47.0%		48.0%	
Unexplained variance (residual)	95.8%		90.5%		66.3%		63.2%		52.8%		51.7%	
Unexplained variance (school)	2.0%		1.1%		.2%		.2%		.3%		.4%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

9.3.4. Predicting students' science aspirations for university as of Year 11

Further modelling considered students' specific aspirations for studying science at university (**Table 9-9**). The model steps alongside the findings were very similar to the overall science aspirations scale. The final model revealed that the following were independent predictors:

- perceived utility value of chemistry (extrinsic motivation);
- personal value of chemistry;
- encouragement by teachers to continue in science/chemistry after GCSEs;
- home support for achievement in science/chemistry;
- expected GCSE science grades;
- extra-curricular engagement in science/chemistry.

The influence of socio-economic disadvantage was eliminated when accounting for the various other predictors.

Table 9-9: Students' views at Year 11 predicting their specific aspirations towards studying science at university

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**.004**	N/A	.768	N/A	.117	**N/A**	**.011**
School: Percentage of EAL	**.113**	**.019**	**.093**	**.032**	.007	.805	.002	.952	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.068	.234	.046	.368	.012	.736	-.029	.140	-.014	.638	.002	.936
Cohort (Younger=0, Older=1)	-.034	.137	-.029	.217	-.024	.225	-.036	.058	-.025	.173	-.020	.294
Gender (Girls=0, Boys=1)	-.003	.880	-.008	.721	-.017	.381	-.016	.697	**-.058**	**.001**	**-.064**	**<.001**
Books at home: 0-10 compared to 500+	**-.202**	**<.001**	**-.120**	**.012**	-.038	.360	.010	.802	.009	.808	.042	.281
Books at home: 11-25 compared to 500+	-.084	.054	-.028	.538	.002	.961	-.023	.575	.018	.617	.040	.287
Books at home: 26-100 compared to 500+	**-.112**	**.015**	-.077	.104	-.034	.420	.003	.927	.004	.925	.019	.617
Books at home: 101-200 compared to 500+	-.036	.322	-.033	.375	-.012	.703	-.013	.639	.020	.515	.024	.435
Books at home: 201-500 compared to 500+	-.014	.652	-.018	.565	-.014	.623	.018	.492	.001	.954	.008	.766
Family science (science-related job, qualifications, talks science)			**.278**	**<.001**	**-.084**	**<.001**	**-.094**	**<.001**	**-.046**	**.039**	-.037	.100
Home support for science/chemistry achievement					**.190**	**<.001**	**.130**	**<.001**	**.141**	**<.001**	**.141**	**<.001**
Encouragement to continue: parents					**.411**	**<.001**	**.308**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.163**	**<.001**	**.115**	**<.001**	**.051**	**.017**	**.047**	**.028**
Teaching/learning experiences: practical/ experimental							**.084**	**<.001**	.024	.292	.012	.596
Teaching/learning experiences: relevance/ applications							.024	.303	**-.047**	**.039**	**-.048**	**.039**
Teaching/learning experiences: interaction/debate/discussion							-.039	.109	**-.061**	**.009**	**-.050**	**.034**
Encouragement to continue: teacher							**.196**	**<.001**	**.191**	**<.001**	**.180**	**<.001**
'I want to be one of the best students in my class'							**.065**	**.001**	-.012	.522	-.024	.222
Interest in chemistry									**.057**	**.029**	.042	.133
Personal value of chemistry									**.211**	**<.001**	**.217**	**<.001**
Perceived utility of chemistry									**.274**	**<.001**	**.258**	**<.001**
Self-confidence in chemistry											-.026	.307
Grades: Expected GCSE science/chemistry grade											**.111**	**<.001**
Explained variance	3.1%		8.7%		35.3%		38.1%		45.9%		46.3%	
Unexplained variance (residual)	93.1%		88.6%		63.7%		61.1%		53.5%		53.0%	
Unexplained variance (school)	3.8%		2.8%		1.0%		.8%		.5%		.7%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

9.3.5. Summary of similarities and differences between chemistry and science outcomes as of Year 11

Similarities and differences in results across the Year 11 chemistry and Year 11 science models included the following points:

- The predictive association between socio-economic disadvantage (books at home) and aspirations was reduced for both chemistry and science outcomes when accounting for other aspects of life and students' various attitudes and beliefs.
- Family science capital/context initially associated with both chemistry and science aspirations. The initial association was reduced in magnitude when accounting for students' perceived utility value, interest/enjoyment, and personal value of chemistry.
- Encouragement from teachers to continue with science/chemistry after GCSEs predicted higher aspirations for both science and chemistry.
- Students reporting that their families provided a positive home learning environment for science/chemistry predicted higher aspirations for both chemistry and science.
- Students who had a high personal value of chemistry were predicted to express higher chemistry and science aspirations.
- Students with higher levels of competitiveness (higher agreement with 'I want to be one of the best students in my class') were predicted to express higher aspirations. It is possible that higher general motivation for achievement may link with recognising the utility value, and/or focusing on extrinsic gains.
- Interest/enjoyment for chemistry was positively associated with both A-Level chemistry and science aspirations.
- The strongest predictor of Year 11 students' aspirations in chemistry and science was perceived utility value (extrinsic value/motivation).
- Students in schools that received the Chemistry for All programme were often predicted to express higher chemistry aspirations than students in comparison schools, even when accounting for the various other predictors. However, the Chemistry for All programme had no independent association with science aspirations when accounting for the various other predictors.
- Students' extra-curricular engagement with science/chemistry had an independent influence on students' aspirations in chemistry for all four outcomes. However, for science outcomes, this association was only apparent for university aspirations, A-Level aspirations, and for overall science aspirations.
- The largest predictor of Year 11 students' aspirations in science was their perceived utility value of chemistry (extrinsic value/motivation), followed by personal value of chemistry, for all four chemistry outcomes; however, for science outcomes, whilst extrinsic motivation was similarly important, the personal value of chemistry was less important.
- The students' chemistry self-confidence beliefs were not associated with science outcomes but was associated with chemistry outcomes.

9.4. Results for science as of Year 9

Students may initially encounter science as a specific subject (rather than through separate subjects for biology, chemistry, and physics) during primary education and secondary education; separate subjects for biology, chemistry, and physics (and/or increased differentiation between these subjects) may become more prevalent when studying GCSE or equivalent qualifications during Year 10 and Year 11. In order to increase accessibility, many items on the questionnaire referred to science in Year 7, Year 8, and Year 9, and then referred to chemistry in Year 10 and Year 11 in order to gain specific insights.

Highlights and key findings

Predictive modelling considered four outcomes, as expressed by students during Year 9: overall aspirations towards science (across A-Level studying, university studying, and careers); specific aspirations towards studying science at A-Level; specific aspirations towards studying science at university; and specific aspirations towards science careers.

The findings for the students' overall science aspirations were somewhat similar to the findings for the students' specific models looking at A-Level, university, and career aspirations in turn:

- Students in the Chemistry for All schools were predicted to express similar aspirations to those from the comparison schools, when accounting for the various other predictors, across the four different outcomes. Given differences in expressed aspirations across Chemistry for All and comparison students at Year 11 and/or Year 10, it may be less realistic to see impacts at Year 9 within predictive models. Additionally, within predictive modelling, the programme indicator reflects the remaining effect of the programme that cannot be explained by any of the other predictors. The Chemistry for All programme may have numerous indirect effects, for example through potentially fostering utility value, which then fosters aspirations.
- The influence of socio-economic disadvantage tended to be reduced or eliminated between the most disadvantaged group and the most advantaged group. In many cases, when

accounting for the various other predictors, those from disadvantaged backgrounds with lower numbers of books at home were predicted to express higher aspirations than those with the highest number of books at home.

- Family science capital had an initial association with science aspirations, but lost any impact when accounting for home support for science/chemistry achievement, extra-curricular engagement, and encouragement to continue studying from parents. Essentially, family science capital may reflect the potential for support, which fosters the provision of actual support, activities, and encouragement, which then fosters aspirations.
- Students' participation in science extra-curricular activities was positively associated with students' aspirations, but this measure tended to lose significance when accounting for students' attitudes and beliefs (their perceived utility value or extrinsic motivation, interest/enjoyment, and personal value). Essentially, extra-curricular activities may foster attitudes and beliefs, which then foster aspirations.
- Students who reported that their families provided a positive home learning environment for science were predicted to express higher aspirations in science for all four science outcomes.
- Students who expressed higher personal value of science were predicted to express higher science aspirations for all four outcomes.
- The strongest predictor of students' aspirations in science/chemistry at Year 9 was their perceived utility value of science (extrinsic value/motivation) for all four science outcomes.
- Interest/enjoyment (intrinsic value/motivation) of science was positively associated with all four outcomes.
- Teachers encouraging students to continue with science after GCSEs predicted higher aspirations all four science outcomes.
- The students' self-confidence beliefs for science were associated with their overall aspirations, their specific aspirations towards studying science at A-Level, and their specific aspirations towards careers in science.
- Boys were predicted to express lower aspirations, when accounting for the other predictors, for overall aspirations (across A-Level, university, and careers) and for specific aspirations towards studying science at A-Level and for specific aspirations towards science careers.

9.4.1. Predicting students' science aspirations (A-Level, university, jobs) as of Year 9

In addition to exploring associations at Year 11, predictive modelling also considered the students' aspirations at Year 9. Considering students' overall aspirations (across A-Level studying, university studying, and careers; **Table 9-10**), when only modelling students' background characteristics (**Table 9-10**, model 1), students' socio-economic circumstances as measured by the number of books at home predicted to express lower aspirations. Higher school-level percentages of students with English as a second or additional language also predicted higher aspirations.

Subsequently, the modelling also included the students' reports of their family science capital/contexts (**Table 9-10**, model 2). Higher family science capital/context predicted higher aspirations, accounting for the other predictors.

The modelling then also included students' other reports of their home circumstances and contexts (**Table 9-10**, model 3). Students' participation in science/chemistry extra-curricular activities, home support for science/chemistry achievement, and encouragement to continue studying science/chemistry from parents were all positively associated with aspirations.

The effect of family science capital/context (family members having science-related jobs, qualifications, and/or interest in talking about science) lost significance at this stage of modelling.

The modelling then also included students' reports of their school circumstances and contexts, including their experiences/perceptions of various teaching approaches in science (**Table 9-10**, model 4). Teaching that conveyed the applications/relevance of science and teaching that was interactive with students (such as class discussions) had positive associations with science aspirations. Achievement motivation against peers (agreement with 'I want to be one of the best students in my class') also positively associated with science aspirations.

The modelling then also included the students' personal attitudes and beliefs about science/chemistry (**Table 9-10**, model 5). Students' interest/enjoyment (intrinsic motivation), perceived utility value (extrinsic motivation), and personal value of science all had significant positive associations with science aspirations. Perceived utility value had the strongest magnitude.

Finally (**Table 9-10**, model 6), students' expected grades at GCSE science and students' self-confidence beliefs were also included, where self-confidence beliefs positively predicted aspirations. Ultimately, the following measures were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility value of science (extrinsic value/motivation);
- personal value of science;
- intrinsic value of science;
- home support for achievement in science;
- self-confidence beliefs.

The influence of socio-economic disadvantage was eliminated between the most disadvantaged group and the most advantaged group; in fact, students from disadvantaged backgrounds were predicted to express higher aspirations once accounting for the other predictors. With respect to gender, boys were predicted to express lower aspirations than girls, when accounting for the various predictors.

▶ Table 9-10: Students' views at Year 9 predicting their Year 9 overall aspirations towards science (full scale)

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**.414**	**N/A**	**<.001**	**N/A**	**<.001**
School: Percentage of EAL	**.094**	**.047**	.061	.139	-.013	.626	-.006	.818	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	-.021	.679	-.042	.354	-.048	.125	-.061	.053	.003	.880	.004	.837
Cohort (Younger=0, Older=1)	-.006	.766	-	-	-	-	-	-	-	-	-	-
Gender (Girls=0, Boys=1)	.026	.216	.045	.091	.027	.227	.010	.670	**-.043**	**.017**	**-.064**	**.001**
Books at home: 0-10 compared to 500+	**-.101**	**.023**	.022	.705	**.123**	**.014**	**.107**	**.032**	**.093**	**.019**	**.105**	**.012**
Books at home: 11-25 compared to 500+	-.009	.831	.102	.067	**.125**	**.008**	**.109**	**.022**	**.088**	**.020**	**.097**	**.014**
Books at home: 26-100 compared to 500+	-.015	.744	.056	.331	.096	.050	.062	.207	.066	.093	.078	.058
Books at home: 101-200 compared to 500+	.017	.623	.073	.096	.070	.064	.048	.200	.042	.154	.054	.084
Books at home: 201-500 compared to 500+	.042	.143	.017	.652	.028	.388	.008	.796	.027	.297	.036	.188
Family science (science-related job, qualifications, talks science)			**.305**	**<.001**	.010	.724	.004	.888	-.006	.777	-.024	.310
Home support for science/chemistry achievement					**.068**	**.038**	.010	.767	**.092**	**<.001**	**.096**	**<.001**
Encouragement to continue: parents					**.471**	**<.001**	**.450**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.217**	**<.001**	**.182**	**<.001**	**.050**	**.019**	.041	.075
Teaching/learning experiences: practical/ experimental							.026	.333	-.019	.374	-.025	.284
Teaching/learning experiences: relevance/ applications							**.059**	**.029**	**-.085**	**<.001**	**-.084**	**<.001**
Teaching/learning experiences: interaction/debate/discussion							**.098**	**.001**	-.008	.729	-.009	.716
'I want to be one of the best students in my class'							**.075**	**.002**	**-.054**	**.006**	**-.067**	**.002**
Interest in chemistry									**.167**	**<.001**	**.154**	**<.001**
Personal value of chemistry									**.299**	**<.001**	**.296**	**<.001**
Perceived utility of chemistry									**.430**	**<.001**	**.416**	**<.001**
Self-confidence in chemistry											**.069**	**.009**
Grades: Expected GCSE science/chemistry grade											.034	.127
Explained variance	2.8%		11.1%		39.2%		40.9%		62.1%		62.0%	
Unexplained variance (residual)	92.9%		86.3%		60.0%		58.4%		37.6%		37.8%	
Unexplained variance (school)	4.3%		2.6%		.8%		.7%		.3%		.1%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

9.4.2. Predicting students' science aspirations for A-Level as of Year 9

The model steps for Year 9 science A-Levels (**Table 9-11**) were very similar to the overall science aspirations scale. Ultimately, the following measures were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility value of science;
- personal value of science;
- interest/enjoyment of science;
- home support for achievement in science;
- science self-confidence beliefs.

The influence of socio-economic disadvantage was eliminated between the most disadvantaged group and the most advantaged group; ultimately, students from disadvantaged backgrounds were predicted to express higher aspirations once accounting for the other predictors. With respect to gender, boys were predicted to express lower aspirations than girls, when accounting for the other predictors.

Table 9-11: Students' views at Year 9 predicting their Year 9 specific aspirations towards studying science at A-Level

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	N/A	**<.001**	N/A	**<.001**	N/A	**<.001**	N/A	**.140**	N/A	**.015**	N/A	**.002**
School: Percentage of EAL	**.093**	**.048**	.061	.159	-.006	.848	-.003	.928	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	-.026	.610	-.044	.354	-.049	.154	-.061	.079	-.003	.879	-.001	.959
Cohort (Younger=0, Older=1)	.024	.260	-	-	-	-	-	-	-	-	-	-
Gender (Girls=0, Boys=1)	.019	.364	.040	.137	.028	.249	.011	.668	-.034	.101	**-.066**	**.003**
Books at home: 0-10 compared to 500+	**-.094**	**.037**	<.001	.999	.094	.077	.087	.104	.070	.127	.093	.054
Books at home: 11-25 compared to 500+	-.012	.773	.081	.152	**.107**	**.034**	.095	.062	.074	.094	**.095**	**.037**
Books at home: 26-100 compared to 500+	-.020	.651	.031	.594	.075	.156	.051	.338	.051	.267	.076	.110
Books at home: 101-200 compared to 500+	.004	.899	.041	.364	.042	.300	.026	.525	.019	.582	.040	.266
Books at home: 201-500 compared to 500+	.046	.114	.009	.816	.020	.566	.004	.906	.021	.486	.032	.310
Family science (science-related job, qualifications, talks science)			**.271**	**<.001**	.016	.595	.018	.529	.009	.734	-.007	.794
Home support for science/chemistry achievement					.057	.104	.002	.957	**.082**	**.003**	**.087**	**.003**
Encouragement to continue: parents					**.428**	**<.001**	**.408**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.172**	**<.001**	**.139**	**<.001**	.025	.319	.010	.715
Teaching/learning experiences: practical/ experimental							-.013	.665	-.047	.058	-.048	.070
Teaching/learning experiences: relevance/ applications							**.075**	**.009**	-.047	.069	-.047	.084
Teaching/learning experiences: interaction/debate/discussion							**.099**	**.001**	.004	.885	-.006	.846
'I want to be one of the best students in my class'							**.067**	**.010**	**-.054**	**.019**	**-.063**	**.010**
Interest in chemistry									**.128**	**<.001**	**.118**	**.001**
Personal value of chemistry									**.269**	**<.001**	**.279**	**<.001**
Perceived utility of chemistry									**.393**	**<.001**	**.364**	**<.001**
Self-confidence in chemistry											**.070**	**.021**
Grades: Expected GCSE science/chemistry grade											.049	.057
Explained variance	2.9%		7.7%		30.5%		32.0%		48.7%		49.7%	
Unexplained variance (residual)	92.9%		89.3%		68.5%		67.0%		51.3%		50.3%	
Unexplained variance (school)	4.2%		3.0%		1.1%		1.0%		.1%		.0%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

9.4.3. Predicting students' science aspirations for university as of Year 9

Further predictive modelling considered students' aspirations to continue studying science at university (**Table 9-12**). Ultimately, the following measures were found to have independent positive associations with students' aspirations (in order of descending magnitudes):

- perceived utility value of science/chemistry (extrinsic motivation);
- personal value of science;
- home support for achievement in science/chemistry;
- interest/enjoyment of science/chemistry;
- extra-curricular engagement with science/chemistry.

The influence of socio-economic disadvantage again was eliminated between the most disadvantaged group and the most advantaged group; ultimately, those from disadvantaged backgrounds were predicted to express higher aspirations to study science at university, when accounting for the various other predictors within the modelling.

Table 9-12: Students' views at Year 9 predicting their Year 9 specific aspirations towards studying science at university

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**.085**	**N/A**	**.540**	**N/A**	**<.001**	**N/A**	**<.001**
School: Percentage of EAL	**.102**	**.038**	.071	.148	-.004	.904	.002	.948	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	-.016	.769	-.033	.529	-.037	.330	-.047	.235	.009	.717	.006	.822
Cohort (Younger=0, Older=1)	-.004	.837	-	-	-	-	-	-	-	-	-	-
Gender (Girls=0, Boys=1)	.013	.547	.045	.098	.028	.248	.016	.511	-.034	.096	-.041	.074
Books at home: 0-10 compared to 500+	**-.095**	**.035**	.081	.172	**.183**	**<.001**	**.158**	**.002**	**.143**	**.001**	**.144**	**.003**
Books at home: 11-25 compared to 500+	-.019	.654	**.139**	**.014**	**.165**	**.001**	**.146**	**.003**	**.124**	**.004**	**.129**	**.005**
Books at home: 26-100 compared to 500+	-.025	.575	.096	.102	**.136**	**.008**	.097	.058	**.097**	**.028**	**.098**	**.039**
Books at home: 101-200 compared to 500+	-.004	.902	.088	.050	**.090**	**.021**	.064	.101	.054	.110	.053	.147
Books at home: 201-500 compared to 500+	.020	.493	.021	.591	.035	.304	.016	.644	.027	.359	.027	.398
Family science (science-related job, qualifications, talks science)			**.285**	**<.001**	-.001	.973	-.006	.821	-.017	.497	-.019	.482
Home support for science/chemistry achievement					**.068**	**.044**	.015	.664	**.112**	**<.001**	**.109**	**<.001**
Encouragement to continue: parents					**.447**	**<.001**	**.433**	**<.001**	-	-	-	-
Extra-curricular engagement with science/chemistry					**.215**	**<.001**	**.186**	**<.001**	**.070**	**.004**	**.059**	**.026**
Teaching/learning experiences: practical/experimental							.027	.337	-.015	.541	-.018	.493
Teaching/learning experiences: relevance/applications							.050	.073	**-.078**	**.002**	**-.073**	**.008**
Teaching/learning experiences: interaction/debate/discussion							**.077**	**.010**	-.009	.721	-.001	.968
'I want to be one of the best students in my class'							**.061**	**.015**	**-.048**	**.030**	**-.053**	**.031**
Interest in chemistry									**.121**	**<.001**	**.105**	**.003**
Personal value of chemistry									**.304**	**<.001**	**.311**	**<.001**
Perceived utility of chemistry									**.365**	**<.001**	**.349**	**<.001**
Self-confidence in chemistry											.042	.167
Grades: Expected GCSE science/chemistry grade											.011	.657
Explained variance	2.5%		8.0%		34.6%		35.8%		52.1%		50.0%	
Unexplained variance (residual)	93.0%		87.9%		63.6%		62.4%		47.4%		49.5%	
Unexplained variance (school)	4.5%		4.2%		1.8%		1.8%		.5%		.5%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

9.4.4. Predicting students’ science aspirations for careers as of Year 9

Further predictive modelling considered students’ aspirations for science careers (**Table 9-13**). Ultimately, the following measures were found to have independent positive associations with students’ aspirations (in order of descending magnitudes):

- perceived utility value of science/chemistry (extrinsic motivation);
- interest/enjoyment of science/chemistry;
- personal value of science/chemistry;
- self-confidence beliefs in science/chemistry;
- home support for achievement in science/chemistry.

The influence of socio-economic disadvantage was eliminated between the most disadvantaged group and the most advantaged group.

Table 9-13: Students’ views at Year 9 predicting their Year 9 specific aspirations towards careers in science

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**.319**	**N/A**	**<.001**	**N/A**	**<.001**
School: Percentage of EAL	.004	.114	.002	.346	-.002	.180	-.001	.310	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	-.021	.666	-.043	.264	-.048	.086	**-.061**	**.013**	.008	.794	.007	.806
Cohort (Younger=0, Older=1)	-1.270	.120	-	-	-	-	-	-	-	-	-	-
Gender (Girls=0, Boys=1)	.029	.096	.027	.203	.014	.467	.001	.967	**-.045**	**.007**	**-.057**	**.001**
Books at home: 0-10 compared to 500+	**-.099**	**.020**	-.026	.647	.048	.341	.039	.432	.040	.338	.045	.308
Books at home: 11-25 compared to 500+	-.011	.793	.049	.365	.061	.206	.049	.304	.041	.297	.037	.380
Books at home: 26-100 compared to 500+	-.008	.855	.023	.680	.046	.353	.019	.710	.032	.445	.035	.414
Books at home: 101-200 compared to 500+	.027	.412	.055	.190	.049	.200	.031	.414	.034	.281	.042	.202
Books at home: 201-500 compared to 500+	.039	.160	.010	.785	.017	.599	.003	.922	.020	.457	.033	.254
Family science (science-related job, qualifications, talks science)			**.280**	**<.001**	.023	.413	.010	.714	.005	.819	-.022	.394
Home support for science/chemistry achievement					.049	.159	-.001	.975	.049	.062	**.057**	**.041**
Encouragement to continue: parents					**.395**	**<.001**	**.372**	**<.001**	-	-	-	-
Extra-curricular engagement with science/ chemistry					**.213**	**<.001**	**.176**	**<.001**	.040	.103	.041	.126
Teaching/learning experiences: practical/ experimental							**.057**	**.033**	.012	.582	.001	.955
Teaching/learning experiences: relevance/ applications							.034	.196	**-.091**	**<.001**	**-.091**	**<.001**
Teaching/learning experiences: interaction/debate/discussion							**.089**	**.003**	-.015	.562	-.014	.599
‘I want to be one of the best students in my class’							**.072**	**.002**	-.037	.066	**-.054**	**.013**
Interest in chemistry									**.237**	**<.001**	**.227**	**<.001**
Personal value of chemistry									**.241**	**<.001**	**.215**	**<.001**
Perceived utility of chemistry									**.454**	**<.001**	**.463**	**<.001**
Self-confidence in chemistry											**.074**	**.010**
Grades: Expected GCSE science/chemistry grade											.010	.256
Explained variance	2.8%		10.7%		31.7%		33.9%		53.0%		54.0%	
Unexplained variance (residual)	94.3%		88.3%		68.1%		66.1%		46.0%		45.7%	
Unexplained variance (school)	2.9%		1.0%		.2%		.0%		1.0%		.3%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient (‘β’) and significance (‘Sig. (p)’; p-values) per predictor.

9.4.5. Summary of similarities and differences between science outcomes as of Year 9 and Year 11

Similarities and differences in findings across the Year 9 science and Year 11 science models were as follows:

- The influence of socio-economic disadvantage (inferred from the number of books at home) tended to be reduced or eliminated between the most disadvantaged group and the most advantaged group, when accounting for the various other predictors.
- Family science capital had an initial association with science aspirations, but the association tended to be reduced when accounting for home support for science/chemistry achievement, extra-curricular engagement, and encouragement to continue studying from parents (and/or students' attitudes and beliefs). Essentially, family science capital may reflect the potential for support, which fosters the provision of actual support, activities, and encouragement (and/or attitudes and beliefs), which then fosters aspirations.
- For Year 11 and Year 9, students who reported that their families provided a positive home learning environment for science were predicted to express higher aspirations in science for all four science outcomes.
- For Year 11 and Year 9 students, higher personal value of science predicted higher science aspirations for all four science outcomes.
- The strongest predictor of aspirations at Year 11 and at Year 9 was the students' perceived utility value of science/chemistry (extrinsic value/motivation).
- At Year 9, the students' interest/enjoyment of science/chemistry (intrinsic value/motivation) positively predicted all four aspiration outcomes. At Year 11, the students' interest/enjoyment of chemistry was only positively associated with the students' overall science aspirations and their specific aspirations towards studying A-Level science (and was not predictively associated with aspirations towards careers and university studying, when accounting for the various other predictors).
- At Year 11 and Year 9, there was also a significant positive impact of teachers encouraging students to continue with science/chemistry after GCSEs for all eight science/chemistry outcomes.
- At Year 11, the students' expected science grades at GCSE tended to be more positively predictive of their science aspirations than their science/chemistry self-confidence beliefs. Conversely, at Year 9, the students' science/chemistry self-confidence tended to be more positively predictive of their aspirations (while their expected grades tended to be not significantly predictive when accounting for the various other predictors).
- At Year 9 and at Year 11, boys were predicted to express lower aspirations than girls for many, but not necessarily all, of the aspiration measures, when accounting for the various other predictors.

10

Associations between students' views: cross-sectional modelling exploring whether attitudes at Year 8 or Year 11 are more important for Year 11 aspirations

10. Associations between students' views: cross-sectional modelling exploring whether attitudes at Year 8 or Year 11 are more important for Year 11 aspirations

Highlights and key findings

- Increases in extra-curricular engagement, interest/enjoyment, and self-confidence beliefs across Year 8 to Year 11 were not independently associated with students' aspirations as of Year 11 when also accounting for increases in perceived utility value.
- Increases in perceived utility value (science/chemistry being valued as facilitating careers, jobs, and future opportunities in general) across Year 8 to Year 11 positively predicted chemistry aspirations as of Year 11 and science aspirations as of Year 11.
- Students' personal value of chemistry as of Year 11 and encouragement from parents to continue studying science/chemistry as of Year 11 also positively predicted chemistry aspirations as of Year 11 and science aspirations as of Year 11.

10.1. Factors influencing students' aspirations in chemistry

Predictive (multi-level) modelling explored which (changing) attitudes at Year 8 and/or Year 11 associated with students' aspirations at Year 11. Preliminary models indicated that perceived utility value (extrinsic value/motivation) had the strongest association with aspirations. Many preliminary models also indicated that, to varying extents, engagement with extra-curricular activities, interest/enjoyment, and self-confidence beliefs associated with aspirations.

The following modelling therefore focused on changes in perceived utility value between Year 8 and Year 11, and explored what impact this had on students' aspirations at Year 11. Preliminary modelling also considered changes in engagement in science extra-curricular activities, interest/enjoyment, and self-confidence beliefs, and whether/how these associated with students' aspirations at Year 11; individually, these measures tended to show significant associations with Year 11 aspirations in chemistry and science but when perceived utility value was also modelled there were no significant associations. These measures were therefore excluded from the final modelling. Nevertheless, these preliminary findings are informative in themselves, and suggest that increasing participation in extra-curricular activities year on year is not necessarily required for an effective intervention to raise aspirations.

The modelling considered four aspirations outcomes for science and four for chemistry.

The modelling considered the students' overall aspirations (across A-Level, university, and career aspirations) and then considered separate and specific aspirations towards A-Level studying, university studying, and careers.

10.1.1. Predicting students' chemistry aspirations (A-Level, university, jobs) as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Year 8 and Year 11 were predicted to express higher overall aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 overall aspirations towards chemistry is shown in **Table 10-1**. Students' overall aspirations towards chemistry at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry at Year 11, by encouragement to continue studying science/chemistry from parents at Year 11, and by receiving the Chemistry for All programme. The predictive influence of the Chemistry for All programme reflects an impact that is not explained by any of the other predictors within the model.

The various indicators as of Year 8 were generally not predictive, when accounting for the indicators as of Year 11. This does not necessarily mean that early views and/or engagement are unimportant. Pragmatically, students' aspirations as of Year 11 are likely to associate with their other contemporary views as of Year 11.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor in the final model.

Students' gender: There was not a significant effect of gender in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations.

Intervention status: There was a significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital were predicted to express higher aspirations, but this was ultimately not significant in the final model when controlling for students' attitudes.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent encouragement as of Year 11.

Predictors	β	Sig. (p)
Intercept	N/A	.942
School: Percentage of EAL	.006	.825
Programme (Comparison=0, Chemistry for All=1)	**.085**	**.047**
Cohort (Younger=0, Older=1)	-.053	.052
Gender (Girls=0, Boys=1)	-.041	.081
Books at home: 0-10 compared to 500+	-.082	.185
Books at home: 11-25 compared to 500+	-.110	.060
Books at home: 26-100 compared to 500+	-.050	.416
Books at home: 101-200 compared to 500+	-.100	.029
Books at home: 201-500 compared to 500+	-.061	.111
Year 11: Family science (science-related job, qualifications, talks science)	-.046	.095
Year 8: Extra-curricular engagement with science/chemistry	.036	.191
Year 11: Extra-curricular engagement with science/chemistry	.035	.257
Year 8: Self-confidence in science/chemistry	.054	.059
Year 11: Self-confidence in chemistry	.057	.073
Year 8: Interest in science/chemistry	.006	.840
Year 11: Interest in science/chemistry	.056	.090
Year 11: Personal value of chemistry	**.429**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.214**	**<.001**
Year 8: Encouragement to continue: parents	.040	.136
Year 11: Encouragement to continue: parents	**.196**	**<.001**
Explained variance	62.0%	
Unexplained variance (residual)	37.7%	
Unexplained variance (school)	.3%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Table 10-1: Students' views at Year 8 and at Year 11 predicting their Year 11 overall aspirations towards chemistry (full scale)

10.1.2. Predicting students' chemistry aspirations for A-Level as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Year 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor; in the final model this lost significance after accounting for students' attitudes.

Students' gender: There was not a significant effect of gender in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was no significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital were predicted to express higher aspirations, but this was ultimately not significant when controlling for students' attitudes. In the final model there was an odd effect of a reversal of the trend.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model this was apparent for encouragement as of Year 8 and as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 aspirations towards studying chemistry at A-Level is shown in **Table 10-2**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by encouragement to continue studying from parents as of Year 8 and as of Year 11, and by personal value as of Year 11, but negatively predicted by family science capital/context as of Year 11. This negative association may suggest more complex patterns of mediation, where family science capital/context may predict one or more of the other indicators, which then predicts aspirations.

Table 10-2: Students' views at Year 8 and at Year 11 predicting their Year 11 specific aspirations towards studying chemistry at A-Level

Predictors	β	Sig. (p)
Intercept	N/A	.515
School: Percentage of EAL	.019	.503
Programme (Comparison=0, Chemistry for All=1)	.056	.201
Cohort (Younger=0, Older=1)	-.040	.169
Gender (Girls=0, Boys=1)	-.033	.204
Books at home: 0-10 compared to 500+	-.064	.342
Books at home: 11-25 compared to 500+	-.107	.093
Books at home: 26-100 compared to 500+	-.038	.566
Books at home: 101-200 compared to 500+	-.080	.107
Books at home: 201-500 compared to 500+	-.026	.527
Year 11: Family science (science-related job, qualifications, talks science)	**-.064**	**.033**
Year 8: Extra-curricular engagement with science/chemistry	.027	.355
Year 11: Extra-curricular engagement with science/chemistry	.066	.051
Year 8: Self-confidence in science/chemistry	.033	.294
Year 11: Self-confidence in chemistry	.054	.118
Year 8: Interest in science/chemistry	-.009	.780
Year 11: Interest in chemistry	**.082**	**.022**
Year 11: Personal value of chemistry	**.356**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.204**	**<.001**
Year 8: Encouragement to continue: parents	**.084**	**.004**
Year 11: Encouragement to continue: parents	**.201**	**<.001**
Explained variance	55.1%	
Unexplained variance (residual)	44.5%	
Unexplained variance (school)	.4%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

10.1.3. Predicting students' chemistry aspirations for careers as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Years 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor of aspirations; students from more advantaged backgrounds were predicted to express higher aspirations, although this lost significance in the final model.

Students' gender: There was not a significant effect of gender in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was initially an effect of the Chemistry for All programme (compared to comparison schools), although this lost significance in the final model when accounting for students' attitudes.

Family science capital: Those students who reported having more family science capital were predicted to express higher aspirations, but this was ultimately not significant in the final model when controlling for students' attitudes.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent for encouragement as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 aspirations towards chemistry careers is shown in **Table 10-3**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry as of Year 11, and by encouragement to continue studying from parents as of Year 11.

10.1.4. Predicting students' chemistry aspirations for university as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Year 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Table 10-3: Students' views at Year 8 and at Year 11 predicting their Year 11 specific aspirations towards chemistry careers

Predictors	β	Sig. (p)
Intercept	N/A	.829
School: Percentage of EAL	-.026	.314
Programme (Comparison=0, Chemistry for All=1)	.081	.056
Cohort (Younger=0, Older=1)	-.044	.107
Gender (Girls=0, Boys=1)	-.044	.070
Books at home: 0-10 compared to 500+	-.066	.300
Books at home: 11-25 compared to 500+	-.084	.163
Books at home: 26-100 compared to 500+	-.047	.457
Books at home: 101-200 compared to 500+	-.092	.053
Books at home: 201-500 compared to 500+	-.047	.239
Year 11: Family science (science-related job, qualifications, talks science)	-.032	.263
Year 8: Extra-curricular engagement with science/chemistry	.045	.113
Year 11: Extra-curricular engagement with science/chemistry	.021	.506
Year 8: Self-confidence in science/chemistry	.050	.091
Year 11: Self-confidence in chemistry	.015	.655
Year 8: Interest in science/chemistry	.053	.101
Year 11: Interest in chemistry	.055	.108
Year 11: Personal value of chemistry	**.423**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.232**	**<.001**
Year 8: Encouragement to continue: parents	.027	.328
Year 11: Encouragement to continue: parents	**.192**	**<.001**
Explained variance	59.3%	
Unexplained variance (residual)	40.6%	
Unexplained variance (school)	.1%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor of aspirations; students from more advantaged backgrounds were predicted to express higher aspirations.

Students' gender: There was not a significant effect of gender in the final model.

Students' age/cohort: There was a significant effect of age in the final model; younger students had higher aspirations.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was a significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital were predicted to express higher aspirations, but this was ultimately not significant in the final model when controlling for students' attitudes.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent with encouragement as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 aspirations towards studying chemistry at university is shown in **Table 10-4**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry as of Year 11, by encouragement from parents to continue studying chemistry as of Year 11, by being in a school that received the Chemistry for All programme (compared to being in a comparison school), and by their self-confidence in science/chemistry as of Year 8 and as of Year 11, but were negatively predicted by the cohort indicator (being in the older cohort predictively associated with lower aspirations than the younger cohort when accounting for the various other predictors).

Table 10-4: Students' views at Year 8 and at Year 11 predicting their Year 11 specific aspirations towards studying chemistry at university

Predictors	β	Sig. (p)
Intercept	N/A	.225
School: Percentage of EAL	.017	.583
Programme (Comparison=0, Chemistry for All=1)	**.107**	**.026**
Cohort (Younger=0, Older=1)	**-.067**	**.037**
Gender (Girls=0, Boys=1)	-.039	.174
Books at home: 0-10 compared to 500+	-.106	.150
Books at home: 11-25 compared to 500+	-.126	.071
Books at home: 26-100 compared to 500+	-.067	.361
Books at home: 101-200 compared to 500+	-.125	.022
Books at home: 201-500 compared to 500+	-.109	.017
Year 11: Family science (science-related job, qualifications, talks science)	-.024	.465
Year 8: Extra-curricular engagement with science/chemistry	.026	.430
Year 11: Extra-curricular engagement with science/chemistry	.005	.893
Year 8: Self-confidence in science/chemistry	**.072**	**.033**
Year 11: Self-confidence in chemistry	**.088**	**.022**
Year 8: Interest in science/chemistry	-.027	.463
Year 11: Interest in chemistry	.018	.639
Year 11: Personal value of chemistry	**.428**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.156**	**<.001**
Year 8: Encouragement to continue: parents	-.011	.740
Year 11: Encouragement to continue: parents	**.155**	**<.001**
Explained variance	46.2%	
Unexplained variance (residual)	53.3%	
Unexplained variance (school)	.5%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

10.2. Factors influencing students' aspirations in science

10.2.1. Predicting students' science aspirations (A-Level, university, jobs) as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Year 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor; students from the most advantaged backgrounds of having more than 500 books were predicted to express higher aspirations. However, this lost significance once students' attitudes were accounted for in the final model.

Students' gender: Boys were predicted to express higher aspirations than girls before controlling for student attitudes, but there was no significant association in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was no significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital were predicted to express higher aspirations, but this was ultimately not significant in the final model when controlling for students' attitudes.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent with encouragement as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their overall Year 11 aspirations towards science is shown in **Table 10-5**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry as of Year 11, by encouragement to continue studying from parents as of Year 11, by extra-curricular engagement as of Year 11, and by self-confidence as of Year 8.

Table 10-5: Students' views at Year 8 and at Year 11 predicting their Year 11 overall aspirations towards science (full scale)

Predictors	β	Sig. (p)
Intercept	N/A	.452
School: Percentage of EAL	.015	.718
Programme (Comparison=0, Chemistry for All=1)	-.076	.223
Cohort (Younger=0, Older=1)	-.014	.662
Gender (Girls=0, Boys=1)	-.019	.471
Books at home: 0-10 compared to 500+	-.020	.766
Books at home: 11-25 compared to 500+	.007	.909
Books at home: 26-100 compared to 500+	.028	.675
Books at home: 101-200 compared to 500+	-.014	.787
Books at home: 201-500 compared to 500+	-.014	.738
Year 11: Family science (science-related job, qualifications, talks science)	-.039	.207
Year 8: Extra-curricular engagement with science/chemistry	.026	.391
Year 11: Extra-curricular engagement with science/chemistry	**.088**	**.011**
Year 8: Self-confidence in science/chemistry	**.067**	**.035**
Year 11: Self-confidence in chemistry	-.012	.742
Year 8: Interest in science/chemistry	.037	.286
Year 11: Interest in chemistry	.033	.367
Year 11: Personal value of chemistry	**.311**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.178**	**<.001**
Year 8: Encouragement to continue: parents	.030	.318
Year 11: Encouragement to continue: parents	**.311**	**<.001**
Explained variance	52.3%	
Unexplained variance (residual)	45.7%	
Unexplained variance (school)	2.0%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

10.2.2. Predicting students' science aspirations for A-Level as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Year 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor; students from the most advantaged backgrounds of having more than 500 books were predicted to express higher aspirations. However, this lost statistical significance once students' attitudes were accounted for in the final model.

Students' gender: There was not a significant effect of gender in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was no significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital had higher aspirations, but this lost significance once students' attitudes were accounted for.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent with encouragement as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 aspirations towards studying science at A-Level is shown in **Table 10-6**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry as of Year 11, by encouragement from parents to continue studying as of Year 11, but were negatively predicted by family science capital/context as of Year 11. This negative association may again suggest more complex patterns of mediation, where family science capital/context may predict one or more of the other indicators, which then predicts aspirations.

10.2.3. Predicting students' science aspirations for careers as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Years 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Table 10-6: Students' views at Year 8 and at Year 11 predicting their Year 11 specific aspirations towards studying science at A-Level

Predictors	β	Sig. (p)
Intercept	N/A	.388
School: Percentage of EAL	.047	.220
Programme (Comparison=0, Chemistry for All=1)	-.093	.114
Cohort (Younger=0, Older=1)	-.008	.814
Gender (Girls=0, Boys=1)	.009	.747
Books at home: 0-10 compared to 500+	-.071	.318
Books at home: 11-25 compared to 500+	-.033	.620
Books at home: 26-100 compared to 500+	.003	.970
Books at home: 101-200 compared to 500+	-.043	.415
Books at home: 201-500 compared to 500+	-.014	.755
Year 11: Family science (science-related job, qualifications, talks science)	**-.063**	**.049**
Year 8: Extra-curricular engagement with science/chemistry	.016	.619
Year 11: Extra-curricular engagement with science/chemistry	.063	.076
Year 8: Self-confidence in science/chemistry	.064	.052
Year 11: Self-confidence in chemistry	-.007	.853
Year 8: Interest in chemistry	.023	.518
Year 11: Interest in science/chemistry	.038	.323
Year 11: Personal value of chemistry	**.280**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.152**	**<.001**
Year 8: Encouragement to continue: parents	.017	.582
Year 11: Encouragement to continue: parents	**.336**	**<.001**
Explained variance	49.5%	
Unexplained variance (residual)	49.1%	
Unexplained variance (school)	1.4%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor; students from the most advantaged backgrounds of having more than 500 books were predicted to express higher aspirations. However, this lost statistical significance once students' attitudes were accounted for in the final model.

Students' gender: There was not a significant effect of gender in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was no significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital had higher aspirations, but this was not significant in the final model when controlling for attitudes.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent with encouragement as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 aspirations towards science careers is shown in **Table 10-7**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry as of Year 11, by encouragement from parents to continue studying as of Year 11, and by extra-curricular engagement as of Year 11.

Predictors	β	Sig. (p)
Intercept	N/A	.287
School: Percentage of EAL	-.025	.498
Programme (Comparison=0, Chemistry for All=1)	-.086	.126
Cohort (Younger=0, Older=1)	.012	.727
Gender (Girls=0, Boys=1)	-.006	.837
Books at home: 0-10 compared to 500+	-.016	.825
Books at home: 11-25 compared to 500+	.003	.967
Books at home: 26-100 compared to 500+	.007	.923
Books at home: 101-200 compared to 500+	-.016	.758
Books at home: 201-500 compared to 500+	-.021	.635
Year 11: Family science (science-related job, qualifications, talks science)	-.024	.454
Year 8: Extra-curricular engagement with science/chemistry	.038	.228
Year 11: Extra-curricular engagement with science/chemistry	**.093**	**.011**
Year 8: Self-confidence in science/chemistry	.048	.146
Year 11: Self-confidence in chemistry	-.031	.409
Year 8: Interest in science/chemistry	.066	.072
Year 11: Interest in chemistry	.020	.596
Year 11: Personal value of chemistry	**.311**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.200**	**<.001**
Year 8: Encouragement to continue: parents	.035	.267
Year 11: Encouragement to continue: parents	**.263**	**<.001**
Explained variance	47.4%	
Unexplained variance (residual)	51.4%	
Unexplained variance (school)	1.2%	

Table 10-7: Students' views at Year 8 and at Year 11 predicting their Year 11 specific aspirations towards careers in science

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

10.2.4. Predicting students' science aspirations for university as of Year 11

Change in perceived utility value/extrinsic motivation between Year 8 and Year 11: Students who developed more positive views about the perceived utility of science/chemistry (such as the benefits of chemistry/science qualifications) between Years 8 and Year 11 were more likely to report positive aspirations at Year 11. This had the largest magnitude of association with aspirations, larger than any other attitude, or change in attitude, or other modelled indicator.

Change in students' participation in science extra-curricular activities between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in intrinsic motivation between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Change in self-confidence between Year 8 and Year 11: Within preliminary analysis, these changes were not linked with aspirations, when accounting for the other predictors including change in perceived utility value. This indicator was therefore not included within the final model for clarity; this also ensured that there was a focus on changes in perceived utility value.

Controls

Socio-economic disadvantage: Students' socio-economic circumstances as measured by the number of books at home was a significant predictor; students from the most advantaged backgrounds of having more than 500 books were predicted to express higher aspirations. However, this lost statistical significance once students' attitudes were accounted for in the final model.

Students' gender: There was a significant effect of gender in the final model.

Students' age/cohort: There was not a significant effect of age in the final model.

School type: Higher school-level percentages of students where English was not their first language associated with students' expressing higher aspirations, but this was not significant in the final model.

Intervention status: There was no significant effect of the Chemistry for All programme (compared to comparison schools) in the final model.

Family science capital: Those students who reported having more family science capital had higher aspirations, but this was not significant in the final model once we controlled for attitudes.

Positive home learning environment: Students with positive home learning environments in chemistry who reported that their family encouraged them to continue studying science/chemistry after GCSEs were predicted to express higher aspirations; in the final model, this was only apparent with encouragement as of Year 11.

The final model of students' views at Year 8 and at Year 11 predicting their Year 11 aspirations towards studying science at university is shown in **Table 10-8**. Students' aspirations at Year 11 were positively predicted by their change in perceived utility value of chemistry/extrinsic motivation (between Year 8 and Year 11), by their personal value of chemistry as of Year 11, by encouragement from parents to continue studying as of Year 11, and by extra-curricular engagement as of Year 11.

Predictors	β	Sig. (p)
Intercept	N/A	.790
School: Percentage of EAL	.019	.675
Programme (Comparison=0, Chemistry for All=1)	-.030	.657
Cohort (Younger=0, Older=1)	-.044	.220
Gender (Girls=0, Boys=1)	**-.060**	**.042**
Books at home: 0-10 compared to 500+	.028	.711
Books at home: 11-25 compared to 500+	.044	.539
Books at home: 26-100 compared to 500+	.066	.376
Books at home: 101-200 compared to 500+	.012	.832
Books at home: 201-500 compared to 500+	-.008	.858
Year 11: Family science (science-related job, qualifications, talks science)	-.027	.426
Year 8: Extra-curricular engagement with science/chemistry	.026	.441
Year 11: Extra-curricular engagement with science/chemistry	**.086**	**.023**
Year 8: Self-confidence in science/chemistry	.067	.055
Year 11: Self-confidence in chemistry	.000	.997
Year 8: Interest in science/chemistry	.015	.701
Year 11: Interest in chemistry	.031	.446
Year 11: Personal value of chemistry	**.270**	**<.001**
Change from Year 8 to Year 11: Perceived utility of science/chemistry	**.150**	**<.001**
Year 8: Encouragement to continue: parents	.025	.457
Year 11: Encouragement to continue: parents	**.279**	**<.001**
Explained variance	41.9%	
Unexplained variance (residual)	55.5%	
Unexplained variance (school)	2.5%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Table 10-8: Students' views at Year 8 and at Year 11 predicting their Year 11 specific aspirations towards studying science at university

11

Associations between students' views via path analysis

11. Associations between students' views via path analysis

Highlights and key findings

- Many aspects of life have direct and/or indirect associations with students' aspirations.
- Combining direct and indirect predictive associations, students' chemistry aspirations at Year 11 most strongly associated with their perceived utility, personal value, expected grades if A-Level chemistry were to be taken, encouragement to continue studying (from friends and from parents), extra-curricular engagement, and teaching/learning experiences of practical/experimental work.

11.1. Path analysis

Associations between students' responses were revealed through path analysis (structural combinations of predictive models) undertaken through 'structural equation modelling'. The analysis predicted the students' perceived utility value of chemistry, interest/enjoyment in chemistry, self-confidence in chemistry, perceived value of chemistry to society, and their personal value of chemistry, using the various indicators of the students' school and home contexts and experiences. Concurrently, all of the indicators, including the students' perceived utility value of chemistry and their other attitudes and beliefs, also predicted the students' aspirations towards chemistry. The modelling considered students' reports from Year 11, the last year of secondary education before upper-secondary education or other pathways in life.

The modelling was therefore able to reveal direct associations, indirect associations, and total (overall) associations. For example, the students' experiences of teaching/learning might predict their perceived utility value, and either, or both, of these may then predict the students' aspirations. The students' experiences of teaching/learning may have direct predictive associations with aspirations, and also indirect associations (through predicting students' perceived utility value and/or other attitudes and beliefs, which then predict aspirations). The total association was the combination of the direct and indirect associations.

11.2. Predictors of students' views

Students' overall aspirations

Modelling considered students' chemistry aspirations at Year 11 (encompassing A-Level, university, and career intentions; **Table 11-1** and **Table 11-2**). The strongest direct predictive associations onto students' chemistry aspirations at Year 11 (encompassing A-Level, university, and career intentions) were:

- Perceived utility of chemistry;
- Personal value of chemistry;
- Encouragement to continue studying science/chemistry from friends;
- Encouragement to continue studying science/chemistry from parents.

The strongest indirect predictive associations onto students' chemistry aspirations at Year 11 (encompassing A-Level, university, and career intentions) were:

- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from friends.

The strongest total (overall) predictive associations onto students' chemistry aspirations at Year 11 (encompassing A-Level, university, and career intentions) were:

- Perceived utility of chemistry;
- Encouragement to continue studying science/chemistry from friends;
- Personal value of science/chemistry;
- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from parents;
- Extra-curricular engagement with science/chemistry;
- Teaching/learning experiences of practical/experimental work.

Additional insights were revealed through considering predictors of the students' attitudes and beliefs. These results did not consider predictive associations across the students' attitudes and beliefs, for example where students' interest/enjoyment might also predict their perceived utility value.

The students' perceived utility value of science/chemistry was most strongly and positively predicted by:

- Parents/teachers conveying the value of science;
- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from friends;
- Achievement motivation;
- Extra-curricular engagement with science/chemistry;
- Encouragement to continue studying science/chemistry from parents;
- Teaching/learning experiences of the relevance/applications of science/chemistry.

The students' interest/enjoyment of chemistry was most strongly and positively predicted by:

- Teaching/learning experiences of teachers conveying relevance/applications;
- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from parents;
- Expected GCSE science/chemistry grade;
- Perceptions of teachers;
- Teaching/learning experiences of interaction, debate, and/or discussion;
- Teaching/learning experiences of practical/experimental work.

The students' self-confidence in science/chemistry was most strongly and positively predicted by:

- Expected grade if A-Level chemistry were to be taken;
- Expected GCSE science/chemistry grade;
- Encouragement to continue studying science/chemistry from friends;
- Teaching/learning experiences of interaction, debate, and/or discussion.

The students' perceived value of science/chemistry to society was most strongly and positively predicted by:

- Teaching/learning experiences of teachers conveying relevance/applications;
- Parents/teachers conveying the value of science;
- Extra-curricular engagement with science chemistry.

The students' personal value of science to their identity was most strongly and positively predicted by:

- Encouragement to continue studying science/chemistry from friends;
- Expected grade if A-Level chemistry were to be taken;
- Extra-curricular engagement with science/chemistry;
- Teaching/learning experiences of practical/experimental work.

Numerous other indicators were also associated with the various indicators of students' aspirations at varying magnitudes.

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	-	-	-	-	-	-	-	-	-	-	**.405**	**<.001**
Interest in chemistry	-	-	-	-	-	-	-	-	-	-	**.055**	**.008**
Self-confidence in chemistry	-	-	-	-	-	-	-	-	-	-	.050	.072
Value of chemistry to society	-	-	-	-	-	-	-	-	-	-	**-.044**	**.027**
Personal value of chemistry	-	-	-	-	-	-	-	-	-	-	**.220**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.048**	**.006**	.007	.761	.027	.107	.003	.879	.024	.274	**.045**	**<.001**
Cohort (Younger=0, Older=1)	-.036	.188	-.021	.264	-.009	.745	-.015	.254	-.006	.841	**-.049**	**<.001**
Gender (Girls=0, Boys=1)	-.008	.455	-.006	.582	**.097**	**<.001**	**.044**	**.003**	.016	.308	**-.027**	**.041**
School: Total number of pupils	.003	.839	-.005	.776	-.040	.088	**.029**	**.013**	.005	.721	**.041**	**.007**
School: Percentage of girls	**.044**	**.015**	.036	.309	.007	.780	**.057**	**.037**	.035	.101	-.014	.440
School: Percentage of EAL	-.027	.236	.004	.881	.026	.149	-.020	.312	-.004	.823	**.077**	**<.001**
School: Percentage of FSM	-.024	.284	**-.057**	**.012**	-.027	.310	-.025	.145	-.042	.158	-.001	.957
School: Percentage of SEN	.051	.104	**.091**	**.007**	**.062**	**.014**	**.055**	**.006**	**.064**	**.017**	**.055**	**<.001**
Teaching/learning experiences: interaction/ debate/discussion	.019	.541	**.110**	**<.001**	**.121**	**<.001**	-.003	.926	.014	.648	-.010	.615
Teaching/learning experiences: practical/ experimental	**.069**	**.001**	**.104**	**<.001**	**.093**	**<.001**	.024	.329	**.101**	**.001**	**.046**	**.007**
Teaching/learning experiences: relevance/ applications	**.101**	**<.001**	**.231**	**<.001**	.019	.238	**.275**	**<.001**	**.094**	**.001**	**-.033**	**.029**
Perceptions of teachers	-.021	.322	**.126**	**<.001**	.014	.670	**.080**	**<.001**	-.031	.200	**-.050**	**.009**
Books at home	-.007	.656	.003	.823	-.037	.055	.033	.116	.002	.924	.011	.496
Family science (science-related job, qualifications, talks science)	**-.101**	**<.001**	**-.051**	**.007**	**.052**	**.025**	.047	.063	**-.058**	**<.001**	-.006	.801
Home support for science/chemistry achievement	.062	.146	.049	.111	.014	.623	-.028	.384	.029	.357	-.006	.828
Extra-curricular engagement with science/ chemistry	**.121**	**<.001**	**.098**	**<.001**	**.090**	**.004**	**.128**	**<.001**	**.165**	**<.001**	.035	.157
Encouragement/shared extra-curricular engagement	**-.045**	**.012**	-.012	.511	-.022	.373	-.004	.872	-.003	.887	-.020	.262
Encouragement to continue: parents	**.108**	**<.001**	**.146**	**<.001**	.060	.132	.070	.069	**.091**	**.007**	**.108**	**<.001**
Encouragement to continue: teacher	.038	.190	.016	.522	**.091**	**.001**	.027	.319	-.002	.959	.040	.069
Encouragement to continue: friends	**.134**	**<.001**	.030	.529	**.134**	**.003**	-.034	.242	**.232**	**<.001**	**.132**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.194**	**<.001**	.017	.663	.002	.964	**.251**	**<.001**	**.094**	**.020**	-.022	.509
Achievement motivation	**.128**	**<.001**	.009	.679	**-.031**	**.037**	**.062**	**.013**	**.072**	**<.001**	**-.068**	**<.001**
Grades: Science grade this year	-.044	.261	**-.082**	**.031**	.021	.507	.055	.216	-.051	.205	.033	.229
Grades: Expected GCSE science/chemistry grade	.062	.053	**.131**	**.002**	**.175**	**<.001**	.045	.210	.024	.497	**-.061**	**.028**
Grades: Expected grade if A-Level chemistry were to be taken	**.171**	**<.001**	**.161**	**<.001**	**.191**	**<.001**	.026	.135	**.200**	**<.001**	**.077**	**<.001**
Intercept / constant	.315	.077	-.176	.364	.325	.076	.251	.138	-.135	.468	**-.395**	**.015**
Explained variance	53.3%		57.1%		53.6%		51.4%		50.3%		63.3%	

Table 11-1: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards chemistry (full scale): direct associations

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Table 11-2: Path modelling (both cohorts at Year 11): Predicting aspirations towards chemistry (full scale): all associations

Predictors	Direct association with aspirations towards chemistry (full-scale)		Indirect association with aspirations towards chemistry (full-scale)		Total association with aspirations towards chemistry (full-scale)	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	**.405**	**<.001**	-	-	**.405**	**<.001**
Interest in chemistry	**.055**	**.008**	-	-	**.055**	**.008**
Self-confidence in chemistry	.050	.073	-	-	.050	.073
Value of chemistry to society	-.044	.029	-	-	**-.044**	**.029**
Personal value of chemistry	**.220**	**<.001**	-	-	**.220**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.045**	**<.001**	**.026**	**.043**	**.072**	**<.001**
Cohort (Younger=0, Older=1)	**-.049**	**<.001**	-.017	.383	**-.066**	**.012**
Gender (Girls=0, Boys=1)	**-.027**	**.042**	.003	.711	-.024	.098
School: Total number of pupils	**.041**	**.007**	-.001	.925	.040	.082
School: Percentage of girls	-.014	.440	.025	.067	.012	.671
School: Percentage of EAL	**.077**	**<.001**	-.009	.520	**.068**	**.001**
School: Percentage of FSM	-.001	.957	-.023	.144	-.023	.148
School: Percentage of SEN	**.055**	**<.001**	**.040**	**.043**	**.095**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	-.010	.615	.023	.268	.013	.643
Teaching/learning experiences: practical/experimental	**.046**	**.007**	**.059**	**<.001**	**.105**	**<.001**
Teaching/learning experiences: relevance/applications	**-.033**	**.026**	**.063**	**.001**	.031	.108
Perceptions of teachers	**-.050**	**.008**	-.011	.410	**-.061**	**.002**
Books at home	.011	.497	-.006	.623	.005	.814
Family science (science-related job, qualifications, talks science)	-.006	.801	**-.056**	**<.001**	**-.062**	**.027**
Home support for science/chemistry achievement	-.006	.829	.036	.132	.030	.372
Extra-curricular engagement with science/chemistry	.035	.154	**.090**	**<.001**	**.125**	**<.001**
Encouragement/shared extra-curricular engagement	-.020	.264	-.021	.073	**-.040**	**.035**
Encouragement to continue: parents	**.108**	**<.001**	**.072**	**<.001**	**.179**	**<.001**
Encouragement to continue: teacher	.040	.073	.019	.277	**.059**	**.036**
Encouragement to continue: friends	**.132**	**<.001**	**.115**	**<.001**	**.248**	**<.001**
Parents/teachers conveying the value of science/chemistry	-.022	.511	**.089**	**<.001**	**.067**	**.049**
Achievement motivation	**-.068**	**<.001**	**.064**	**<.001**	-.005	.797
Grades: Science grade this year	.033	.231	-.035	.184	-.002	.950
Grades: Expected GCSE science/chemistry grade	**-.061**	**.030**	**.045**	**.028**	-.017	.603
Grades: Expected grade if A-Level chemistry were to be taken	**.077**	**<.001**	**.131**	**<.001**	**.208**	**<.001**

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Students' aspirations for A-Level chemistry

Specifically considering the students' aspirations towards A-Level chemistry (**Table 11-3** and **Table 11-4**), the strongest direct predictive associations were:

- Perceived utility of chemistry;
- Encouragement to continue studying science/chemistry from friends;
- Personal value of chemistry;
- Encouragement to continue studying science/chemistry from parents.

The strongest indirect predictive association onto students' aspirations towards A-Level chemistry was:

- Expected grade if A-Level chemistry were to be taken.

The strongest total (overall) predictive associations onto students' aspirations towards A-Level chemistry were:

- Perceived utility of chemistry;
- Encouragement to continue studying science/chemistry from friends;
- Encouragement to continue studying science/chemistry from parents;
- Expected grade if A-Level chemistry were to be taken;
- Personal value of chemistry;
- Extra-curricular engagement with science/chemistry.

Table 11-3: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards chemistry A-Level studying (item): direct associations

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	-	-	-	-	-	-	-	-	-	-	**.372**	**<.001**
Interest in chemistry	-	-	-	-	-	-	-	-	-	-	**.070**	**.003**
Self-confidence in chemistry	-	-	-	-	-	-	-	-	-	-	.013	.664
Value of chemistry to society	-	-	-	-	-	-	-	-	-	-	-.041	.073
Personal value of chemistry	-	-	-	-	-	-	-	-	-	-	**.148**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.048**	**.006**	.007	.750	.027	.107	.003	.879	.025	.268	**.030**	**.004**
Cohort (Younger=0, Older=1)	-.036	.185	-.022	.246	-.009	.747	-.015	.255	-.007	.830	**-.053**	**<.001**
Gender (Girls=0, Boys=1)	-.008	.440	-.007	.542	**.097**	**<.001**	**.044**	**.003**	.015	.329	-.015	.226
School: Total number of pupils	.003	.847	-.005	.761	-.040	.088	**.029**	**.013**	.005	.734	**.052**	**<.001**
School: Percentage of girls	**.044**	**.015**	.036	.316	.007	.779	**.057**	**.037**	.035	.105	.012	.546
School: Percentage of EAL	-.027	.239	.004	.876	.026	.149	-.020	.312	-.004	.829	**.088**	**<.001**
School: Percentage of FSM	-.024	.290	**-.057**	**.014**	-.027	.309	-.025	.145	-.042	.164	-.002	.935
School: Percentage of SEN	.051	.104	**.091**	**.008**	**.062**	**.014**	**.055**	**.006**	**.064**	**.017**	**.054**	**.001**
Teaching/learning experiences: interaction/debate/discussion	.018	.548	**.109**	**<.001**	**.121**	**<.001**	-.003	.926	.014	.659	-.023	.345
Teaching/learning experiences: practical/experimental	**.069**	**.001**	**.105**	**<.001**	**.093**	**<.001**	.024	.329	**.101**	**.001**	.028	.165
Teaching/learning experiences: relevance/applications	**.101**	**<.001**	**.231**	**<.001**	.019	.238	**.275**	**<.001**	**.094**	**.001**	**-.032**	**.032**
Perceptions of teachers	-.021	.322	**.126**	**<.001**	.014	.670	**.080**	**<.001**	-.031	.200	-.033	.162
Books at home	-.007	.671	.004	.775	-.037	.055	.033	.117	.003	.906	.008	.669
Family science (science-related job, qualifications, talks science)	**-.101**	**<.001**	**-.051**	**.008**	**.052**	**.025**	.047	.063	**-.058**	**<.001**	-.012	.599
Home support for science/chemistry achievement	.062	.147	.049	.113	.014	.623	-.028	.384	.029	.361	-.038	.240
Extra-curricular engagement with science/chemistry	**.121**	**<.001**	**.098**	**<.001**	**.090**	**.004**	**.128**	**<.001**	**.165**	**<.001**	**.054**	**.040**
Encouragement/shared extra-curricular engagement	**-.046**	**.012**	-.013	.506	-.022	.373	-.004	.872	-.003	.883	-.032	.145
Encouragement to continue: parents	**.108**	**<.001**	**.147**	**<.001**	.060	.132	.070	.069	**.091**	**.007**	**.133**	**<.001**
Encouragement to continue: teacher	.038	.189	.017	.510	**.091**	**.001**	.027	.319	-.002	.965	.043	.051
Encouragement to continue: friends	**.135**	**<.001**	.031	.517	**.134**	**.003**	-.034	.242	**.232**	**<.001**	**.163**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.194**	**<.001**	.017	.670	.002	.963	**.251**	**<.001**	**.093**	**.021**	-.030	.365
Achievement motivation	**.128**	**<.001**	.009	.671	**-.031**	**.037**	**.062**	**.013**	**.072**	**<.001**	**-.050**	**.007**
Grades: Science grade this year	-.044	.259	**-.082**	**.029**	.021	.506	.055	.216	-.052	.202	.052	.062
Grades: Expected GCSE science/chemistry grade	.063	.053	**.132**	**.002**	**.175**	**<.001**	.045	.210	.024	.494	-.027	.481
Grades: Expected grade if A-Level chemistry were to be taken	**.171**	**<.001**	**.161**	**<.001**	**.191**	**<.001**	.026	.135	**.200**	**<.001**	**.087**	**<.001**
Intercept / constant	.315	.077	-.177	.362	.325	.076	.251	.138	-.135	.466	**-.628**	**<.001**
Explained variance	53.4%		57.2%		53.6%		51.4%		50.4%		57.6%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Predictors	Direct association with aspirations for A-Level chemistry studying		Indirect association with aspirations for A-Level chemistry studying		Total association with aspirations for A-Level chemistry studying	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	**.372**	**<.001**	-	-	**.372**	**<.001**
Interest in chemistry	**.070**	**.003**	-	-	**.070**	**.003**
Self-confidence in chemistry	.013	.665	-	-	.013	.665
Value of chemistry to society	-.041	.077	-	-	-.041	.077
Personal value of chemistry	**.148**	**<.001**	-	-	**.148**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.030**	**.006**	**.022**	**.037**	**.052**	**<.001**
Cohort (Younger=0, Older=1)	**-.053**	**<.001**	-.016	.325	**-.069**	**.002**
Gender (Girls=0, Boys=1)	-.015	.223	-.002	.791	-.017	.186
School: Total number of pupils	**.052**	**<.001**	<.001	.985	**.051**	**.013**
School: Percentage of girls	.012	.547	.022	.067	.033	.181
School: Percentage of EAL	**.088**	**<.001**	-.009	.470	**.079**	**<.001**
School: Percentage of FSM	-.002	.935	-.019	.167	-.020	.258
School: Percentage of SEN	**.054**	**.001**	.034	.058	**.088**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	-.023	.345	.018	.302	-.005	.873
Teaching/learning experiences: practical/experimental	.028	.164	**.048**	**<.001**	**.076**	**.001**
Teaching/learning experiences: relevance/applications	**-.032**	**.030**	**.057**	**<.001**	.025	.175
Perceptions of teachers	-.033	.158	-.007	.568	-.040	.093
Books at home	.008	.669	-.004	.698	.005	.827
Family science (science-related job, qualifications, talks science)	-.012	.598	**-.051**	**<.001**	-.063	.017
Home support for science/chemistry achievement	-.038	.241	.032	.120	-.006	.862
Extra-curricular engagement with science/chemistry	**.054**	**.040**	**.072**	**<.001**	**.126**	**<.001**
Encouragement/shared extra-curricular engagement	-.032	.145	-.018	.060	**-.051**	**.034**
Encouragement to continue: parents	**.133**	**<.001**	**.062**	**<.001**	**.195**	**<.001**
Encouragement to continue: teacher	.043	.053	.015	.316	**.058**	**.035**
Encouragement to continue: friends	**.163**	**<.001**	**.090**	**.001**	**.253**	**<.001**
Parents/teachers conveying the value of science/chemistry	-.030	.368	**.077**	**<.001**	.047	.107
Achievement motivation	**-.050**	**.006**	**.056**	**<.001**	.007	.701
Grades: Science grade this year	.052	.062	-.032	.151	.020	.466
Grades: Expected GCSE science/chemistry grade	-.027	.481	**.037**	**.027**	.010	.811
Grades: Expected grade if A-Level chemistry were to be taken	**.087**	**<.001**	**.106**	**<.001**	**.193**	**<.001**

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-4: Path modelling (both cohorts at Year 11): Predicting aspirations towards chemistry A-Level studying (item): all associations

Students' aspirations for A-Level science

Specifically considering the students' aspirations towards A-Level science (**Table 11-5** and **Table 11-6**), the strongest direct predictive associations were:

- Perceived utility of chemistry;
- Encouragement to continue studying science/ chemistry from friends;
- Personal value of chemistry;
- Encouragement to continue studying science/ chemistry from parents.

The strongest indirect predictive associations onto students' aspirations towards A-Level science was:

- Expected grade if A-Level chemistry were to be taken.

The strongest total (overall) predictive associations onto students' aspirations towards A-Level science were:

- Perceived utility of chemistry;
- Encouragement to continue studying science/ chemistry from friends;
- Encouragement to continue studying science/ chemistry from parents;
- Expected grade if A-Level chemistry were to be taken;
- Personal value of chemistry;
- Extra-curricular engagement with science/ chemistry.

Table 11-5: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards science A-Level studying (item): direct associations

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	-	-	-	-	-	-	-	-	-	-	**.227**	**<.001**
Interest in chemistry	-	-	-	-	-	-	-	-	-	-	**.078**	**.013**
Self-confidence in chemistry	-	-	-	-	-	-	-	-	-	-	**-.099**	**<.001**
Value of chemistry to society	-	-	-	-	-	-	-	-	-	-	-.036	.180
Personal value of chemistry	-	-	-	-	-	-	-	-	-	-	**.145**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.047**	**.008**	.007	.729	.027	.101	.006	.754	.026	.239	**-.037**	**.019**
Cohort (Younger=0, Older=1)	-.037	.171	-.023	.244	-.010	.732	-.015	.256	-.009	.789	-.005	.834
Gender (Girls=0, Boys=1)	-.010	.350	-.007	.504	**.096**	**<.001**	**.046**	**.002**	.016	.312	-.021	.199
School: Total number of pupils	.002	.884	-.006	.748	-.041	.082	**.029**	**.010**	.004	.772	.016	.120
School: Percentage of girls	**.042**	**.018**	.035	.328	.007	.769	**.057**	**.037**	.036	.088	-.037	.140
School: Percentage of EAL	-.028	.221	.003	.906	.026	.148	-.019	.314	-.005	.762	**.086**	**.001**
School: Percentage of FSM	-.021	.356	**-.056**	**.016**	-.027	.309	-.026	.142	-.041	.175	**.049**	**.009**
School: Percentage of SEN	.049	.118	**.091**	**.008**	**.061**	**.015**	**.057**	**.006**	**.063**	**.020**	.031	.228
Teaching/learning experiences: interaction/ debate/discussion	.018	.567	**.109**	**<.001**	**.121**	**<.001**	-.004	.894	.011	.708	-.021	.416
Teaching/learning experiences: practical/ experimental	**.068**	**.003**	**.104**	**<.001**	**.093**	**<.001**	.025	.304	**.106**	**<.001**	-.018	.463
Teaching/learning experiences: relevance/ applications	**.100**	**<.001**	**.231**	**<.001**	.019	.222	**.275**	**<.001**	**.092**	**.002**	.007	.733
Perceptions of teachers	-.020	.353	**.127**	**<.001**	.013	.680	**.079**	**<.001**	-.031	.202	**-.057**	**.012**
Books at home	-.005	.777	.004	.808	-.037	.060	.033	.130	.003	.920	-.001	.944
Family science (science-related job, qualifications, talks science)	**-.100**	**<.001**	**-.051**	**.007**	**.052**	**.025**	.042	.089	**-.058**	**<.001**	**-.076**	**.003**
Home support for science/chemistry achievement	.060	.153	.048	.126	.014	.625	-.025	.429	.029	.351	-.031	.182
Extra-curricular engagement with science/ chemistry	**.122**	**<.001**	**.098**	**<.001**	**.091**	**.004**	**.124**	**<.001**	.166	<.001	.013	.525
Encouragement/shared extra-curricular engagement	**-.046**	**.012**	-.011	.570	-.022	.380	.002	.913	-.002	.917	.002	.910
Encouragement to continue: parents	**.107**	**<.001**	**.147**	**<.001**	.061	.130	.071	.066	**.090**	**.007**	**.142**	**<.001**
Encouragement to continue: teacher	.036	.208	.015	.543	**.090**	**.001**	.028	.304	-.003	.922	**.079**	**.002**
Encouragement to continue: friends	**.136**	**<.001**	.032	.501	**.135**	**.003**	-.036	.212	**.234**	**<.001**	**.175**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.195**	**<.001**	.015	.698	.001	.983	**.252**	**<.001**	**.093**	**.022**	**.112**	**<.001**
Achievement motivation	**.130**	**<.001**	.009	.667	**-.031**	**.035**	**.063**	**.012**	**.072**	**<.001**	-.010	.524
Grades: Science grade this year	-.044	.257	**-.082**	**.029**	.021	.514	.055	.223	-.052	.198	**.132**	**<.001**
Grades: Expected GCSE science/chemistry grade	.063	.051	**.133**	**.001**	**.174**	**<.001**	.046	.203	.024	.496	.053	.147
Grades: Expected grade if A-Level chemistry were to be taken	**.170**	**<.001**	**.160**	**<.001**	**.190**	**<.001**	.026	.132	**.198**	**<.001**	.020	.463
Intercept / constant	.317	.074	-.172	.379	.331	.072	.245	.153	-.132	.487	-.227	.171
Explained variance	53.3%		57.1%		53.5%		51.4%		50.4%		53.9%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Predictors	Direct association with aspirations for A-Level science studying		Indirect association with aspirations for A-Level science studying		Total association with aspirations for A-Level science studying	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	**.227**	**<.001**	-	-	**.227**	**<.001**
Interest in chemistry	**.078**	**.012**	-	-	**.078**	**.012**
Self-confidence in chemistry	**-.099**	**<.001**	-	-	**-.099**	**<.001**
Value of chemistry to society	-.036	.183	-	-	-.036	.183
Personal value of chemistry	**.145**	**<.001**	-	-	**.145**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**-.037**	**.019**	.012	.085	-.025	.164
Cohort (Younger=0, Older=1)	-.005	.834	-.010	.321	-.015	.480
Gender (Girls=0, Boys=1)	-.021	.198	**-.012**	**.001**	**-.032**	**.042**
School: Total number of pupils	.016	.120	.004	.485	.020	.124
School: Percentage of girls	-.037	.140	.015	.063	-.022	.404
School: Percentage of EAL	**.086**	**.001**	-.009	.307	**.077**	**.004**
School: Percentage of FSM	**.049**	**.008**	-.012	.297	.037	.103
School: Percentage of SEN	.031	.229	.019	.102	**.050**	**.039**
Teaching/learning experiences: interaction/debate/discussion	-.021	.416	.002	.850	-.019	.400
Teaching/learning experiences: practical/experimental	-.018	.463	**.029**	**.001**	.011	.637
Teaching/learning experiences: relevance/applications	.007	.733	**.043**	**.005**	**.049**	**.021**
Perceptions of teachers	**-.057**	**.012**	-.003	.749	**-.060**	**.011**
Books at home	-.001	.944	.002	.753	.001	.956
Family science (science-related job, qualifications, talks science)	**-.076**	**.003**	**-.042**	**<.001**	**-.118**	**<.001**
Home support for science/chemistry achievement	-.031	.183	.021	.088	-.010	.706
Extra-curricular engagement with science/chemistry	.013	.524	**.046**	**<.001**	**.059**	**.001**
Encouragement/shared extra-curricular engagement	.002	.910	-.009	.114	-.007	.747
Encouragement to continue: parents	**.142**	**<.001**	**.040**	**.001**	**.183**	**<.001**
Encouragement to continue: teacher	**.079**	**.002**	-.001	.932	**.078**	**.015**
Encouragement to continue: friends	**.175**	**<.001**	**.055**	**.001**	**.230**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.112**	**<.001**	**.050**	**.006**	**.162**	**<.001**
Achievement motivation	-.010	.523	**.041**	**<.001**	.031	.054
Grades: Science grade this year	**.132**	**<.001**	-.028	.054	**.104**	**.003**
Grades: Expected GCSE science/chemistry grade	.053	.146	.009	.512	.062	.105
Grades: Expected grade if A-Level chemistry were to be taken	.020	.465	**.060**	**<.001**	**.080**	**.010**

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-6: Path modelling (both cohorts at Year 11): Predicting aspirations towards science A-Level studying (item): all associations

Students' aspirations for university chemistry

Specifically considering the students' aspirations towards studying chemistry at university (**Table 11-7** and **Table 11-8**), the strongest direct predictive associations were:

- Perceived utility of chemistry;
- Personal value of chemistry;
- Self-confidence in chemistry;
- Encouragement to continue studying science/chemistry from friends;
- Encouragement to continue studying science/chemistry from parents.

The strongest indirect predictive association onto students' aspirations towards studying chemistry at university were:

- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from friends;
- Extra-curricular engagement with science/chemistry;
- Parents/teachers conveying the relevance of science/chemistry;
- Encouragement to continue studying science/chemistry from parents.

The strongest total (overall) predictive associations onto students' aspirations towards studying chemistry at university were:

- Perceived utility of chemistry;
- Personal value of chemistry;
- Encouragement to continue studying science/chemistry from friends;
- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from parents;
- Extra-curricular engagement with science/chemistry;
- Teaching/learning experiences of practical/experimental work;
- Self-confidence in chemistry.

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of science/chemistry	-	-	-	-	-	-	-	-	-	-	**.330**	**<.001**
Interest in science/chemistry	-	-	-	-	-	-	-	-	-	-	.015	.589
Self-confidence in science/chemistry	-	-	-	-	-	-	-	-	-	-	**.101**	**.002**
Value of science/chemistry to society	-	-	-	-	-	-	-	-	-	-	**-.062**	**.009**
Personal value of science/chemistry	-	-	-	-	-	-	-	-	-	-	**.262**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.047**	**.008**	.007	.737	.027	.106	.005	.783	.026	.246	**.047**	**<.001**
Cohort (Younger=0, Older=1)	-.036	.190	-.022	.250	-.009	.754	-.015	.259	-.008	.804	**-.050**	**.002**
Gender (Girls=0, Boys=1)	-.007	.455	-.007	.540	**.097**	**<.001**	**.045**	**.002**	.018	.245	**-.038**	**.013**
School: Total number of pupils	.001	.930	-.005	.767	-.040	.090	**.030**	**.009**	.005	.713	.025	.082
School: Percentage of girls	**.045**	**.013**	.034	.344	.006	.785	**.057**	**.036**	.037	.091	**-.050**	**.001**
School: Percentage of EAL	-.027	.230	.006	.815	.025	.162	-.019	.323	-.007	.719	**.088**	**<.001**
School: Percentage of FSM	-.024	.287	**-.057**	**.013**	-.027	.299	-.027	.117	-.042	.168	.014	.388
School: Percentage of SEN	.052	.107	**.090**	**.008**	**.063**	**.013**	**.057**	**.004**	**.064**	**.018**	**.041**	**.007**
Teaching/learning experiences: interaction/debate/discussion	.019	.543	**.110**	**<.001**	**.121**	**<.001**	-.004	.879	.012	.698	.009	.708
Teaching/learning experiences: practical/experimental	**.068**	**.003**	**.105**	**<.001**	**.093**	**<.001**	.027	.266	**.103**	**.001**	**.053**	**.006**
Teaching/learning experiences: relevance/applications	**.102**	**<.001**	**.230**	**<.001**	.018	.271	**.274**	**<.001**	**.094**	**.001**	-.014	.517
Perceptions of teachers	-.021	.341	**.126**	**<.001**	.014	.662	**.078**	**<.001**	-.031	.215	**-.059**	**.001**
Books at home	-.006	.728	.005	.742	-.037	.054	.032	.130	.002	.921	.016	.370
Family science (science-related job, qualifications, talks science)	**-.101**	**<.001**	**-.050**	**.008**	.052	.026	.046	.064	**-.059**	**<.001**	.011	.718
Home support for science/chemistry achievement	.059	.158	.048	.120	.015	.611	-.027	.398	.030	.335	.025	.364
Extra-curricular engagement with science/chemistry	.119	<.001	**.098**	**<.001**	**.091**	**.004**	**.128**	**<.001**	**.166**	**<.001**	.027	.287
Encouragement/shared extra-curricular engagement	**-.045**	**.014**	-.012	.539	-.022	.379	-.003	.893	-.003	.875	-.024	.166
Encouragement [advice/pressure] to continue: parents	**.110**	**<.001**	**.145**	**<.001**	.060	.132	.071	.070	**.092**	**.005**	**.095**	**.008**
Encouragement [advice/pressure] to continue: teacher	.037	.196	.016	.515	**.091**	**.001**	.028	.304	-.002	.944	.012	.656
Encouragement [advice/pressure] to continue: friends	**.134**	**<.001**	.031	.507	**.133**	**.004**	-.035	.235	**.231**	**<.001**	**.099**	**.008**
Parents/teachers conveying the value of science/chemistry	**.194**	**<.001**	.016	.679	.002	.953	**.251**	**<.001**	**.093**	**.020**	-.032	.357
Achievement motivation	**.129**	**<.001**	.009	.685	**-.030**	**.042**	**.063**	**.013**	**.073**	**<.001**	**-.065**	**<.001**
Grades: Science grade this year	-.044	.260	**-.082**	**.028**	.020	.537	.054	.233	-.052	.202	-.004	.905
Grades: Expected GCSE science/chemistry grade	.062	.055	**.131**	**.002**	**.175**	**<.001**	.047	.192	.024	.505	**-.075**	**.015**
Grades: Expected grade if A-Level chemistry were to be taken	**.171**	**<.001**	**.162**	**<.001**	**.191**	**<.001**	.026	.134	**.199**	**<.001**	.048	.051
Intercept / constant	.313	.075	-.175	.366	**.323**	**.080**	.242	.155	-.144	.450	-.019	.916
Explained variance (%)	53.3%		57.2%		53.4%		51.4%		50.3%		50.0%	

Table 11-7: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards chemistry university studying (item): direct associations

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-8: Path modelling (both cohorts at Year 11): Predicting aspirations towards chemistry university studying (item): all associations

Predictors	Direct association		Indirect association		Total association	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of science/chemistry	**.330**	**<.001**	-	-	**.330**	**<.001**
Interest in science/chemistry	.015	.589	-	-	.015	.589
Self-confidence in science/chemistry	**.101**	**.002**	-	-	**.101**	**.002**
Value of science/chemistry to society	**-.062**	**.011**	-	-	**-.062**	**.011**
Personal value of science/chemistry	**.262**	**<.001**	-	-	**.262**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.047**	**<.001**	.025	.053	**.072**	**<.001**
Cohort (Younger=0, Older=1)	**-.050**	**.002**	-.014	.463	**-.064**	**.028**
Gender (Girls=0, Boys=1)	**-.038**	**.012**	.009	.272	-.029	.062
School: Total number of pupils	.025	.080	-.004	.728	.021	.355
School: Percentage of girls	**-.050**	**.002**	.022	.099	-.028	.303
School: Percentage of EAL	**.088**	**<.001**	-.007	.598	**.081**	**<.001**
School: Percentage of FSM	.014	.390	-.021	.145	-.007	.659
School: Percentage of SEN	**.041**	**.008**	**.038**	**.035**	**.079**	**.001**
Teaching/learning experiences: interaction/debate/discussion	.009	.708	.023	.220	.032	.176
Teaching/learning experiences: practical/experimental	**.053**	**.006**	**.059**	**<.001**	**.112**	**<.001**
Teaching/learning experiences: relevance/applications	-.014	.514	**.046**	**.026**	.033	.149
Perceptions of teachers	**-.059**	**.001**	-.017	.231	**-.076**	**<.001**
Books at home	.016	.375	-.007	.533	.009	.704
Family science (science-related job, qualifications, about science)	.011	.719	**-.047**	**<.001**	-.036	.251
Home support for science/chemistry achievement	.025	.361	.032	.150	.056	.092
Extra-curricular engagement with science/chemistry	.027	.283	**.085**	**<.001**	**.112**	**<.001**
Encouragement/shared extra-curricular engagement	-.024	.171	-.018	.121	**-.042**	**.013**
Encouragement [advice/pressure] to continue: parents	**.095**	**.008**	**.064**	**<.001**	**.159**	**<.001**
Encouragement [advice/pressure] to continue: teacher	.012	.657	.019	.242	.031	.356
Encouragement [advice/pressure] to continue: friends	**.099**	**.008**	**.121**	**<.001**	**.220**	**<.001**
Parents/teachers conveying the value of science/chemistry	-.032	.361	**.073**	**.001**	.042	.267
Achievement motivation	**-.065**	**<.001**	**.055**	**.001**	-.010	.640
Grades: Science grade this year	-.004	.905	-.031	.212	-.034	.332
Grades: Expected GCSE science/chemistry grade	**-.075**	**.016**	**.043**	**.036**	-.031	.394
Grades: Expected grade if A-Level chemistry were to be taken	.048	.052	**.129**	**<.001**	**.179**	**<.001**

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Students' aspirations for university science

Specifically considering the students' aspirations towards studying science at university (**Table 11-9** and **Table 11-10**), the strongest direct predictive associations were:

- Encouragement to continue studying science/chemistry from friends;
- Perceived utility of chemistry;
- Personal value of chemistry;
- Parents/teachers conveying the relevance of science/chemistry;
- Current science grades;
- Interest/enjoyment in chemistry.

The strongest indirect predictive association onto students' aspirations towards studying science at university were:

- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/chemistry from friends;
- Parents/teachers conveying the relevance of science/chemistry;
- Extra-curricular engagement with science/chemistry.

The strongest total (overall) predictive associations onto students' aspirations towards studying science at university were:

- Encouragement to continue studying science/chemistry from friends;
- Perceived utility of chemistry;
- Parents/teachers conveying the relevance of science/chemistry;

- Personal value of chemistry;
- Encouragement to continue studying science/chemistry from parents;
- Current science grades;
- Expected grade if A-Level chemistry were to be taken;
- Interest/enjoyment in chemistry;
- Extra-curricular engagement with science/chemistry.

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of science/chemistry	-	-	-	-	-	-	-	-	-	-	**.216**	**<.001**
Interest in science/chemistry	-	-	-	-	-	-	-	-	-	-	**.076**	**.013**
Self-confidence in science/chemistry	-	-	-	-	-	-	-	-	-	-	**-.075**	**.001**
Value of science/chemistry to society	-	-	-	-	-	-	-	-	-	-	-.027	.228
Personal value of science/chemistry	-	-	-	-	-	-	-	-	-	-	**.189**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.047**	**.008**	.006	.766	.027	.103	.004	.820	.026	.253	-.004	.798
Cohort (Younger=0, Older=1)	-.035	.197	-.021	.279	-.009	.756	-.014	.280	-.007	.822	-.014	.452
Gender (Girls=0, Boys=1)	-.008	.438	-.006	.592	**.097**	**<.001**	**.046**	**.002**	.016	.297	**-.049**	**.026**
School: Total number of pupils	.004	.820	-.005	.798	-.040	.089	**.029**	**.012**	.006	.679	.005	.613
School: Percentage of girls	**.043**	**.016**	.036	.315	.007	.771	**.058**	**.035**	.037	.082	**-.054**	**.033**
School: Percentage of EAL	-.028	.223	.003	.897	.026	.151	-.020	.303	-.005	.787	**.057**	**.033**
School: Percentage of FSM	-.022	.326	**-.055**	**.014**	-.028	.301	-.026	.141	-.043	.150	.039	.065
School: Percentage of SEN	.050	.107	**.090**	**.008**	**.063**	**.012**	**.056**	**.005**	**.064**	**.017**	.016	.452
Teaching/learning experiences: interaction/debate/discussion	.018	.554	**.110**	**<.001**	**.121**	**<.001**	-.004	.882	.013	.663	<.001	.984
Teaching/learning experiences: practical/experimental	**.067**	**.003**	**.104**	**<.001**	**.093**	**<.001**	.026	.282	**.104**	**.001**	<.001	.982
Teaching/learning experiences: relevance/applications	**.102**	**<.001**	**.230**	**<.001**	.018	.271	**.275**	**<.001**	**.093**	**.001**	-.034	.220
Perceptions of teachers	-.021	.344	**.127**	**<.001**	.014	.671	**.079**	**<.001**	-.031	.206	**-.077**	**<.001**
Books at home	-.006	.740	.004	.798	-.037	.051	.032	.133	.002	.938	-.015	.366
Family science (science-related job, qualifications, talks science)	**-.101**	**<.001**	**-.051**	**.007**	**.052**	**.025**	.046	.068	**-.059**	**<.001**	**-.074**	**.002**
Home support for science/chemistry achievement	.060	.153	.049	.114	.014	.630	-.026	.414	.030	.344	-.007	.823
Extra-curricular engagement with science/chemistry	**.120**	**<.001**	**.098**	**<.001**	**.091**	**.004**	**.128**	**<.001**	**.166**	**<.001**	.019	.375
Encouragement/shared extra-curricular engagement	**-.046**	**.011**	-.012	.512	-.021	.390	-.003	.895	-.002	.917	.005	.778
Encouragement [advice/pressure] to continue: parents	**.107**	**<.001**	**.145**	**<.001**	.059	.137	.070	.072	**.090**	**.007**	**.097**	**.032**
Encouragement [advice/pressure] to continue: teacher	.037	.196	.016	.526	**.091**	**.001**	.027	.316	-.002	.965	.035	.169
Encouragement [advice/pressure] to continue: friends	**.136**	**<.001**	.031	.515	**.134**	**.003**	-.036	.224	**.232**	**<.001**	**.221**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.195**	**<.001**	.017	.663	.002	.958	**.252**	**<.001**	**.093**	**.020**	**.145**	**<.001**
Achievement motivation	**.129**	**<.001**	.009	.675	-.032	**.032**	**.062**	**.013**	**.071**	**<.001**	-.008	.529
Grades: Science grade this year	-.043	.274	**-.081**	**.032**	.022	.504	.055	.220	-.051	.208	**.117**	**.001**
Grades: Expected GCSE science/chemistry grade	.062	.053	**.131**	**.002**	**.174**	**<.001**	.045	.206	.022	.536	-.015	.634
Grades: Expected grade if A-Level chemistry were to be taken	**.171**	**<.001**	**.161**	**<.001**	**.191**	**<.001**	.026	.132	**.200**	**<.001**	.013	.552
Intercept / constant	.307	.081	-.178	.359	.325	.080	.247	.146	-.137	.466	-.057	.741
Explained variance (%)	53.4%		57.1%		53.6%		51.4%		50.4%		52.2%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-9: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards science university studying (item): direct associations

Table 11-10: Path modelling (both cohorts at Year 11): Predicting aspirations towards science university studying (item): all associations

Predictors	Direct association		Indirect association		Total association	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of science/chemistry	**.216**	**<.001**	-	-	**.216**	**<.001**
Interest in science/chemistry	**.076**	**.013**	-	-	**.076**	**.013**
Self-confidence in science/chemistry	**-.075**	**.001**	-	-	**-.075**	**.001**
Value of science/chemistry to society	-.027	.230	-	-	-.027	.230
Personal value of science/chemistry	**.189**	**<.001**	-	-	**.189**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	-.004	.798	.013	.097	.009	.600
Cohort (Younger=0, Older=1)	-.014	.452	-.010	.412	-.024	.270
Gender (Girls=0, Boys=1)	**-.049**	**.025**	-.008	.099	**-.057**	**.009**
School: Total number of pupils	.005	.613	.004	.538	.009	.426
School: Percentage of girls	**-.054**	**.033**	.017	.060	-.037	.194
School: Percentage of EAL	**.057**	**.033**	-.008	.378	.049	.066
School: Percentage of FSM	.039	.061	-.014	.247	.025	.311
School: Percentage of SEN	.016	.454	.024	.062	.040	.076
Teaching/learning experiences: interaction/debate/discussion	<.001	.984	.006	.634	.005	.787
Teaching/learning experiences: practical/experimental	<.001	.982	**.034**	**<.001**	.035	.176
Teaching/learning experiences: relevance/applications	-.034	.220	**.048**	**.007**	.014	.570
Perceptions of teachers	**-.077**	**<.001**	-.004	.637	**-.081**	**<.001**
Books at home	-.015	.368	.001	.839	-.014	.487
Family science (science-related job, qualifications, about science)	**-.074**	**.001**	**-.042**	**<.001**	**-.115**	**<.001**
Home support for science/chemistry achievement	-.007	.823	.022	.119	.015	.613
Extra-curricular engagement with science/chemistry	.019	.375	**.054**	**<.001**	**.074**	**.002**
Encouragement/shared extra-curricular engagement	.005	.778	-.010	.159	-.005	.811
Encouragement [advice/pressure] to continue: parents	**.097**	**.033**	**.045**	**<.001**	**.142**	**.002**
Encouragement [advice/pressure] to continue: teacher	.035	.168	.001	.911	.036	.249
Encouragement [advice/pressure] to continue: friends	**.221**	**<.001**	**.066**	**.001**	**.287**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.145**	**<.001**	**.054**	**.002**	**.199**	**<.001**
Achievement motivation	-.008	.528	.043	<.001	.034	.044
Grades: Science grade this year	**.117**	**.001**	-.028	.114	**.089**	**.006**
Grades: Expected GCSE science/chemistry grade	-.015	.634	.013	.409	-.002	.945
Grades: Expected grade if A-Level chemistry were to be taken	.013	.553	**.072**	**<.001**	**.085**	**.001**

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Students' career aspirations

Similar findings arose for students' aspirations towards chemistry careers (**Table 11-11** and **Table 11-12**) and aspirations towards science careers (**Table 11-13** and **Table 11-14**), affirming the importance of students' perceived utility of chemistry and personal value of chemistry, along with numerous other views and aspects of life.

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	-	-	-	-	-	-	-	-	-	-	**.421**	**<.001**
Interest in chemistry	-	-	-	-	-	-	-	-	-	-	**.065**	**.001**
Self-confidence in chemistry	-	-	-	-	-	-	-	-	-	-	.036	.223
Value of chemistry to society	-	-	-	-	-	-	-	-	-	-	-.019	.320
Personal value of chemistry	-	-	-	-	-	-	-	-	-	-	**.220**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.048**	**.006**	.007	.731	.028	.081	.004	.823	.028	.199	**.050**	**.002**
Cohort (Younger=0, Older=1)	-.036	.190	-.021	.268	-.009	.757	-.014	.264	-.006	.850	-.035	.056
Gender (Girls=0, Boys=1)	-.007	.470	-.005	.615	**.097**	**<.001**	**.045**	**.002**	.018	.245	-.024	.252
School: Total number of pupils	.004	.816	-.005	.791	-.040	.093	**.029**	**.012**	.006	.667	**.033**	**.034**
School: Percentage of girls	**.045**	**.010**	.037	.298	.007	.767	**.058**	**.036**	.037	.085	-.004	.865
School: Percentage of EAL	-.027	.231	.003	.892	.026	.151	-.020	.302	-.006	.744	**.038**	**.027**
School: Percentage of FSM	-.025	.283	**-.057**	**.011**	-.027	.306	-.026	.139	-.043	.147	-.012	.494
School: Percentage of SEN	.052	.101	**.091**	**.007**	**.061**	**.014**	**.055**	**.006**	**.064**	**.015**	**.055**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	.019	.538	**.110**	**<.001**	**.121**	**<.001**	-.003	.901	.012	.692	-.010	.616
Teaching/learning experiences: practical/experimental	**.068**	**.003**	**.104**	**<.001**	**.093**	**<.001**	.026	.286	**.105**	**<.001**	**.046**	**.022**
Teaching/learning experiences: relevance/applications	**.102**	**<.001**	**.230**	**<.001**	.018	.249	**.274**	**<.001**	**.093**	**.001**	**-.043**	**.018**
Perceptions of teachers	-.021	.346	**.127**	**<.001**	.014	.670	**.079**	**<.001**	-.032	.199	**-.047**	**.012**
Books at home	-.005	.753	.004	.793	-.037	.059	.032	.133	.002	.927	.008	.616
Family science (science-related job, qualifications, talks science)	**-.102**	**<.001**	**-.052**	**.007**	**.050**	**.033**	.046	.068	**-.060**	**<.001**	-.015	.453
Home support for science/chemistry achievement	.060	.149	.049	.112	.014	.622	-.026	.404	.029	.362	.003	.922
Extra-curricular engagement with science/chemistry	**.119**	**<.001**	**.097**	**<.001**	**.091**	**.004**	**.128**	**<.001**	**.166**	**<.001**	.012	.700
Encouragement/shared extra-curricular engagement	**-.045**	**.014**	-.012	.531	-.021	.403	-.003	.899	-.001	.953	.003	.886
Encouragement to continue: parents	**.109**	**<.001**	**.146**	**<.001**	.059	.134	.070	.071	**.090**	**.008**	**.071**	**.025**
Encouragement to continue: teacher	.038	.185	.016	.516	**.092**	**.001**	.027	.316	-.001	.975	.052	.055
Encouragement to continue: friends	**.135**	**<.001**	.030	.530	**.134**	**.003**	-.035	.237	**.232**	**<.001**	**.104**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.195**	**<.001**	.017	.657	.002	.955	**.252**	**<.001**	**.095**	**.020**	-.001	.975
Achievement motivation	**.129**	**<.001**	.009	.675	**-.031**	**.035**	**.062**	**.014**	**.072**	**<.001**	**-.078**	**<.001**
Grades: Science grade this year	-.044	.261	**-.082**	**.031**	.021	.525	.055	.221	-.051	.203	.041	.209
Grades: Expected GCSE science/chemistry grade	.062	.053	**.131**	**.002**	**.175**	**<.001**	.045	.208	.025	.485	**-.079**	**.001**
Grades: Expected grade if A-Level chemistry were to be taken	**.171**	**<.001**	**.161**	**<.001**	**.190**	**<.001**	.026	.142	**.198**	**<.001**	**.075**	**<.001**
Intercept / constant	.302	.085	-.182	.348	.322	.080	.251	.141	-.148	.427	**-.401**	**.010**
Explained variance	53.4%		57.1%		53.6%		51.4%		50.4%		59.2%	

Table 11-11: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards chemistry jobs (item): direct associations

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-12: Path modelling (both cohorts at Year 11): Predicting aspirations towards chemistry jobs (item): all associations

Predictors	Direct association with aspirations for chemistry jobs		Indirect association with aspirations for chemistry jobs		Total association with aspirations for chemistry jobs	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	.421	<.001	-	-	.421	<.001
Interest in chemistry	.065	.001	-	-	.065	.001
Self-confidence in chemistry	.036	.222	-	-	.036	.222
Value of chemistry to society	-.019	.320	-	-	-.019	.320
Personal value of chemistry	.220	<.001	-	-	.220	<.001
Programme (Comparison=0, Chemistry for All=1)	.050	.002	.028	.034	.077	<.001
Cohort (Younger=0, Older=1)	-.035	.053	-.018	.364	-.053	.059
Gender (Girls=0, Boys=1)	-.024	.254	.003	.679	-.021	.364
School: Total number of pupils	.033	.034	.001	.951	.034	.125
School: Percentage of girls	-.004	.865	.029	.033	.025	.407
School: Percentage of EAL	.038	.027	-.011	.455	.027	.232
School: Percentage of FSM	-.012	.492	-.024	.130	-.036	.091
School: Percentage of SEN	.055	<.001	.043	.035	.098	<.001
Teaching/learning experiences: interaction/debate/discussion	-.010	.616	.022	.309	.012	.678
Teaching/learning experiences: practical/experimental	.046	.022	.061	<.001	.108	<.001
Teaching/learning experiences: relevance/applications	-.043	.016	.074	<.001	.030	.163
Perceptions of teachers	-.047	.011	-.008	.544	-.055	.005
Books at home	.008	.617	-.003	.769	.005	.827
Family science (science-related job, qualifications, talks science)	-.015	.449	-.059	<.001	-.074	.005
Home support for science/chemistry achievement	.003	.922	.036	.142	.039	.223
Extra-curricular engagement with science/chemistry	.012	.699	.094	<.001	.105	<.001
Encouragement/shared extra-curricular engagement	.003	.886	-.021	.068	-.018	.427
Encouragement to continue: parents	.071	.022	.076	<.001	.147	<.001
Encouragement to continue: teacher	.052	.056	.019	.280	.072	.013
Encouragement to continue: friends	.104	<.001	.115	<.001	.219	<.001
Parents/teachers conveying the value of science/chemistry	-.001	.975	.099	<.001	.098	.007
Achievement motivation	-.078	<.001	.068	<.001	-.009	.638
Grades: Science grade this year	.041	.214	-.035	.197	.005	.864
Grades: Expected GCSE science/chemistry grade	-.079	.002	.046	.032	-.033	.214
Grades: Expected grade if A-Level chemistry were to be taken	.075	<.001	.132	<.001	.207	<.001

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-13: Path modelling (both cohorts at Year 11): Predicting attitudes and aspirations towards science jobs (item): direct associations

Predictors	Utility		Interest		Self-confidence		Value to society		Personal value		Aspirations	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	-	-	-	-	-	-	-	-	-	-	**.267**	**<.001**
Interest in chemistry	-	-	-	-	-	-	-	-	-	-	**.057**	**.038**
Self-confidence in chemistry	-	-	-	-	-	-	-	-	-	-	**-.138**	**<.001**
Value of chemistry to society	-	-	-	-	-	-	-	-	-	-	.001	.978
Personal value of chemistry	-	-	-	-	-	-	-	-	-	-	**.180**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	**.047**	**.008**	.007	.752	.029	.095	.003	.866	.027	.235	-.029	.106
Cohort (Younger=0, Older=1)	-.035	.203	-.022	.253	-.011	.690	-.015	.253	-.006	.865	.014	.549
Gender (Girls=0, Boys=1)	-.010	.322	-.005	.670	**.100**	**<.001**	**.044**	**.002**	.016	.307	-.013	.258
School: Total number of pupils	.004	.816	-.005	.775	-.041	.068	**.029**	**.012**	.006	.687	.007	.690
School: Percentage of girls	**.042**	**.024**	.038	.285	.011	.629	**.058**	**.037**	.036	.094	-.038	.107
School: Percentage of EAL	-.026	.257	.001	.956	.023	.183	-.021	.295	-.003	.884	.018	.523
School: Percentage of FSM	-.024	.292	**-.057**	**.013**	-.027	.305	-.026	.135	-.044	.140	.002	.936
School: Percentage of SEN	.051	.108	**.091**	**.007**	**.063**	**.011**	**.056**	**.007**	**.065**	**.016**	.029	.303
Teaching/learning experiences: interaction/ debate/discussion	.021	.501	**.108**	**<.001**	**.118**	**<.001**	-.003	.899	.015	.638	.020	.361
Teaching/learning experiences: practical/ experimental	**.065**	**.003**	**.106**	**<.001**	**.097**	**<.001**	.026	.297	**.103**	**.001**	-.015	.450
Teaching/learning experiences: relevance/ applications	**.102**	**<.001**	**.231**	**<.001**	.019	.220	**.274**	**<.001**	**.094**	**.001**	-.013	.723
Perceptions of teachers	-.021	.335	**.126**	**<.001**	.014	.659	**.078**	**<.001**	-.031	.214	-.039	.052
Books at home	-.004	.791	.003	.843	-.040	.043	.033	.120	.002	.938	-.021	.236
Family science (science-related job, qualifications, talks science)	**-.100**	**<.001**	**-.051**	**.007**	**.050**	**.026**	.047	.059	**-.059**	**<.001**	**-.081**	**<.001**
Home support for science/chemistry achievement	.057	.182	.052	.090	.020	.491	-.027	.390	.028	.376	-.012	.603
Extra-curricular engagement with science/ chemistry	**.122**	**<.001**	**.097**	**<.001**	**.087**	**.004**	**.129**	**<.001**	**.166**	**<.001**	.011	.662
Encouragement/shared extra-curricular engagement	**-.048**	**.010**	-.012	.523	-.020	.409	-.004	.865	-.002	.907	.014	.473
Encouragement to continue: parents	**.112**	**<.001**	**.144**	**<.001**	.056	.149	.070	.075	**.095**	**.003**	.053	.114
Encouragement to continue: teacher	.040	.161	.016	.536	**.086**	**.001**	.032	.231	-.002	.944	.028	.386
Encouragement to continue: friends	**.132**	**<.001**	.031	.514	**.139**	**.002**	-.037	.216	**.229**	**<.001**	**.181**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.194**	**<.001**	.017	.655	.003	.935	**.251**	**<.001**	**.094**	**.020**	**.196**	**<.001**
Achievement motivation	**.131**	**<.001**	.008	.692	**-.033**	**.019**	**.062**	**.013**	**.073**	**<.001**	-.021	.230
Grades: Science grade this year	-.043	.278	**-.082**	**.031**	.021	.517	.055	.217	-.051	.205	**.090**	**.008**
Grades: Expected GCSE science/chemistry grade	.060	.055	**.133**	**.002**	**.176**	**<.001**	.044	.214	.022	.533	.026	.486
Grades: Expected grade if A-Level chemistry were to be taken	**.171**	**<.001**	**.160**	**<.001**	**.191**	**<.001**	.025	.161	**.201**	**<.001**	**.046**	**.040**
Intercept / constant	.310	.080	-.177	.364	.329	.073	.261	.125	-.154	.414	-.043	.774
Explained variance	53.3%		56.9%		53.5%		51.2%		50.3%		51.1%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

Table 11-14: Path modelling (both cohorts at Year 11): Predicting aspirations towards science jobs (item): all associations

Predictors	Direct association with aspirations for science jobs		Indirect association with aspirations for science jobs		Total association with aspirations for science jobs	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Perceived utility of chemistry	**.267**	**<.001**	-	-	**.267**	**<.001**
Interest in chemistry	**.057**	**.038**	-	-	**.057**	**.038**
Self-confidence in chemistry	**-.138**	**<.001**	-	-	**-.138**	**<.001**
Value of chemistry to society	.001	.978	-	-	.001	.978
Personal value of chemistry	**.180**	**<.001**	-	-	**.180**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	-.029	.106	.014	.088	-.015	.390
Cohort (Younger=0, Older=1)	.014	.549	-.010	.360	.004	.866
Gender (Girls=0, Boys=1)	-.013	.257	**-.014**	**.007**	**-.027**	**.035**
School: Total number of pupils	.007	.690	.008	.182	.014	.323
School: Percentage of girls	-.038	.110	**.019**	**.021**	-.019	.431
School: Percentage of EAL	.018	.525	-.011	.261	.007	.758
School: Percentage of FSM	.002	.936	-.014	.280	-.012	.713
School: Percentage of SEN	.029	.303	.022	.093	**.051**	**.034**
Teaching/learning experiences: interaction/debate/discussion	.020	.361	-.002	.889	.018	.416
Teaching/learning experiences: practical/experimental	-.015	.450	**.028**	**.004**	.014	.522
Teaching/learning experiences: relevance/applications	-.013	.724	**.055**	**<.001**	.042	.227
Perceptions of teachers	-.039	.052	-.006	.564	**-.045**	**.031**
Books at home	-.021	.238	.005	.476	-.016	.407
Family science (science-related job, qualifications, talks science)	**-.081**	**<.001**	**-.047**	**<.001**	**-.128**	**<.001**
Home support for science/chemistry achievement	-.012	.603	.020	.155	.009	.715
Extra-curricular engagement with science/chemistry	.011	.662	**.056**	**<.001**	**.067**	**.006**
Encouragement/shared extra-curricular engagement	.014	.474	-.011	.069	.003	.888
Encouragement to continue: parents	.053	.114	**.047**	**.001**	**.100**	**.002**
Encouragement to continue: teacher	.028	.385	-.001	.968	.027	.457
Encouragement to continue: friends	**.181**	**<.001**	**.059**	**.001**	**.240**	**<.001**
Parents/teachers conveying the value of science/chemistry	**.196**	**<.001**	**.070**	**.001**	**.265**	**<.001**
Achievement motivation	-.021	.232	**.053**	**<.001**	.032	.096
Grades: Science grade this year	**.090**	**.008**	-.028	.124	**.062**	**.017**
Grades: Expected GCSE science/chemistry grade	.026	.486	.003	.849	.029	.425
Grades: Expected grade if A-Level chemistry were to be taken	**.046**	**.040**	**.065**	**<.001**	**.111**	**<.001**

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor for each outcome.

11.3. Summary

Path analysis revealed that many aspects of life have direct and/or indirect associations with students' aspirations. The strongest direct predictive associations onto students' overall chemistry aspirations at Year 11 (encompassing A-Level, university, and career intentions) were:

- Perceived utility of chemistry;
- Personal value of chemistry;
- Encouragement to continue studying science/ chemistry from friends;
- Encouragement to continue studying science/ chemistry from parents.

The strongest indirect predictive associations onto students' overall chemistry aspirations at Year 11 (via students' perceived utility value, interest/enjoyment, self-confidence, perceived value to society, and/or personal value) were:

- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/ chemistry from friends.

Combining direct and indirect associations, the strongest total predictive associations onto students' overall chemistry aspirations at Year 11 were:

- Perceived utility of chemistry;
- Encouragement to continue studying science/ chemistry from friends;
- Personal value of chemistry;
- Expected grade if A-Level chemistry were to be taken;
- Encouragement to continue studying science/ chemistry from parents;
- Extra-curricular engagement with science/chemistry;
- Teaching/learning experiences of practical/ experimental work.

Essentially, many aspects of life such as extra-curricular engagement with science/chemistry associate with students' personal attitudes and beliefs related to science/chemistry (perceived utility value, interest/ enjoyment, self-confidence, perceived value to society, and/or personal value), which then associate with their aspirations. Many aspects of life may be more important than they initially appear from some forms of modelling.

These findings also suggest how some Chemistry for All programme benefits might reach students. Various extra-curricular activities, experiences of teaching/ learning, and other aspects of life may associate with students' attitudes and beliefs, which then associate with their studying and career aspirations. The models also highlighted that the Chemistry for All programme associated with students' aspirations directly, and indirectly via the students' perceived utility value. The direct predictive association between the Chemistry for All programme and students' aspirations reflects something that is not explained by any of the other indicators within the modelling.

These findings follow from generalising across both cohorts of students and accounting for their schools receiving or not receiving the Chemistry for All programme and other factors. Essentially, the findings also reveal potential avenues to help foster students' aspirations, attitudes, and beliefs, regardless of schools applying formalised programmes of activities/events. From a wider perspective, the findings also highlighted the relevance of many aspects of life that may be outside of the scope of programmes such as Chemistry for All. For example, encouragement to continue with chemistry from friends, parents, and (to a lesser extent) from teachers each had independent and positive overall associations with aspirations (encompassing direct and indirect associations). This highlights the inherent challenge of supporting students, who experience diverse influences across many aspects of life.

From a wider perspective, students' perceived utility value, interest/enjoyment, self-confidence, perceived value to society, and their personal value of science/ chemistry all positively correlate, but it remains unclear whether and/or which of these might best predict the others. It is also possible that associations are reciprocal (forming positive feedback cycles), for example where interest/enjoyment might associate with self-confidence, and where self-confidence might associate with interest/enjoyment. Further research would be needed to explore potential pathways and associations in more detail.

12

Mixed methods analysis: How social inequalities map out onto the perceptions of students' experiences and lives

12. Mixed methods analysis: How social inequalities map out onto the perceptions of students' experiences and lives

Highlights and key findings

Qualitative interviews highlighted several key areas of importance for progression to post-16 chemistry.

- Students conveyed that they felt that Chemistry for All helped them recognise the utility value of chemistry (chemistry extrinsic motivation), foster their interest in chemistry, and enhance their self-confidence in chemistry.
- By the end of the Chemistry for All programme, students stating that they intended to choose A-level chemistry recognised that chemistry qualifications provide opportunities later in life.
- Those who had attended Chemistry for All events that specifically covered the topic of careers became more enthused about chemistry and were able to make more informed decisions.
- The focus on future opportunities by Chemistry for All provided a positive reach towards disadvantaged students; this focus on the extrinsic benefits of post-16 qualifications proved particularly effective in helping students to align their future selves with chemistry which might not have been otherwise possible.
- Many aspects of the Chemistry for All programme, including trips to outside organisations, chemistry after-school clubs, and demonstrations and experiments, helped to create connections between students' identities and chemistry. Students also highlighted that Chemistry for All helped show the relevance of chemistry to everyday life.
- The quantitative results revealed that perceived utility value, followed by personal value of chemistry were the strongest predictors of aspirations. The qualitative results indicated that the two measures worked in slightly different ways. If students lack a personal value of chemistry yet recognise the utility value of chemistry, they may pursue chemistry A-Level in order to gain careers or professions in other areas such as medicine rather than chemistry. A personal value of chemistry is important to continue within the chemistry pipeline.
- Enjoyment and interest in chemistry remained relevant for students' choices, together with role models and/or encouragement to continue studying chemistry.
- Students' positive self-concept in chemistry was reinforced/developed by the Chemistry for All clubs and activities that they attended.
- Being a part of the Chemistry for All activities helped students develop a chemistry identity.
- The interviewees who aspired to study chemistry post-16 were all able to cite the Chemistry for All programme as having had a positive effect on their chemistry identity and that it was because of this positive identity that they aspired to study chemistry post-16.
- One important task that the Chemistry for All programme was able to do that schools were not able to do as well was to show practically the relevance of chemistry to everyday life.

Key issues around social inequalities

- Social inequalities such as those arising from socio-economic circumstances, gender, family science capital/context, and home learning environments were associated with students' aspirations.
- The discourse of 'natural cleverness' discouraged disadvantaged and/or ethnic minority girls away from trajectories towards chemistry studies and careers. Students who were naturally good at chemistry with little effort were seen as the (only) ones who could legitimately remain within the chemistry pipeline.
- Many girls felt that chemistry required and involved hard work. Hard-working girls and women may challenge or not cohere with socially constructed images of 'naturally clever' chemists and scientists.
- Students who identified with the notion of natural ability/cleverness often protected their own chemistry identity; a trait which was usually seen amongst boys. Some girls internalised problems with learning chemistry, whereas some boys externalised problems.
- Boys from families with high family science capital were the most confident in their abilities in chemistry.
- Despite the challenges, some girls from less advantaged socio-economic and ethnic minority backgrounds intended to continue studying chemistry after their GCSEs, and some attributed this to the support from the Chemistry for All programme. These girls often had high motivations towards achievement in general, competitive personalities, conveyed high aspirations in general, and particularly enjoyed chemistry. The Chemistry for All programme helped them align the idea of their future selves with chemistry, particularly when they were able to recognise the benefits of a qualification in chemistry.

- Some girls with high abilities (often from ethnic minority backgrounds) nevertheless felt that they did not having a strong enough chemistry identity to remain in chemistry.
- Students with a supportive home learning environment in chemistry and/or with higher levels of family science capital often had more opportunities to experience, be recognised in and feel connected to chemistry, and expected to continue with it.
- Students with more advantaged socio-economic backgrounds were more likely to have higher levels of family science capital.
- Students with higher levels of family science capital expressed higher perceived value of chemistry, higher aspirations, more positive views about engaging in extra-curricular science activities and positive perceptions of science teaching, and were more confident in their abilities in chemistry. Students with higher levels of family science capital were also were more likely to be aware of the benefits of having a post-16 chemistry qualification.
- Students in more advantaged socio-economic circumstances expressed higher chemistry aspirations, higher perceived utility, greater interest/enjoyment, more positive views about engaging in extra-curricular science activities, and more positive perceptions of science teaching, and showed more positive self-confidence, and other positive attitudes towards science.
- The Chemistry for All programme appeared to support some of the most disadvantaged students within the study, and appeared to alleviate the difference in aspirations between the most advantaged and disadvantaged students.
- A particular issue for girls is that there is no room for 'hard-working females' to challenge or fit in with the notion of the socially constructed phenomenon of naturally clever chemists/scientists.
- The Chemistry for All programme enabled students from less advantaged socio-economic backgrounds and/or backgrounds with lower family science capital to experience and engage with extra-curricular activities, which helped to raise their understanding about the relevance of science/chemistry to society. Teaching that showed the wider applications of chemistry was also found to be important.

Further statistical analysis triangulated with the qualitative work

- Girls tended to be less confident in their chemistry abilities than boys.
- Girls with higher aspirations to undertake chemistry A-Level expressed similar views, attitudes and perceptions of chemistry as boys with higher aspirations with regards to undertaking chemistry A-Level, with the exception that these girls nevertheless reported lower self-confidence beliefs than these boys.
- Higher beliefs in students' chemistry ability (their self-confidence beliefs) associated with their interest/enjoyment of chemistry, personal value of chemistry, encouragement to continue with chemistry studies, experiencing practical work and discussion work within teaching, engaging in extra-curricular activities, and possessing family science capital. Boys were also predicted to express more positive self-confidence beliefs than girls.
- Positive views about the value of chemistry/science for society associated with teaching that conveyed the wider applications of science, perceived utility value, family science capital/context, participation in extra-curricular activities, interest/enjoyment in chemistry, perceptions of teachers, teachers encouraging students to study chemistry after GCSEs, and students being motivated to achieve compared with their peers. With respect to gender, boys had more positive perceptions about the value of science to society. The effect of coming from a family with high science capital remained significant.

12.1. Intersectionality: Social disadvantage, gender, and ethnic background

The quantitative analysis helped to illuminate which key factors shape students' aspirations towards studying and careers in chemistry (and science). The quantitative analysis was able to point to issues around existing social inequalities that influence aspirations and differences in the home learning environment (some students possess greater family science capital or come from home learning environments that are more likely to support chemistry learning and continuation), and other social inequalities such as those to do with socio-economic circumstances and gender. Students with a positive home learning environment in chemistry and/or with higher levels of family science capital may have had opportunities to experience, be recognised in and feel connected with chemistry, and expect to continue with it; such students tended to have more advantaged socio-economic backgrounds. Whilst some of the quantitative analysis indicated that effects of existing social inequalities on aspirations (such as those linking with gender, home learning environment, family science capital and socio-economic status) could be explained by other factors, these inequalities were nonetheless pervasive, particularly if students had not developed more positive chemistry attitudes (e.g. in the perceived utility/extrinsic motivation, value of chemistry).

In order to gain greater insights into students' aspirations, and their wider connections and identifications with chemistry, the students' narratives were analysed and contextualised with further findings from the students' questionnaire responses. There are a range of factors that influence students' chemistry aspirations, which often have interrelated connections. The qualitative analysis particularly explored some of these complex interrelated relationships.

The relationship between family science capital and socio-economic status amongst Year 11 students

Students with more advantaged socio-economic circumstances were more likely to have higher levels of family science capital (**Table 12-1**). The number of books at home was used as an indicator of students' socio-economic circumstances: at Year 11, 16.6% of students with lower levels of science capital had over 100 books at home, while 27.4% of students with higher levels of family science capital had over 100 books at home.

Family science capital and students' perceptions and attitudes towards chemistry

At Year 11, students with higher levels of family science capital were more likely to express higher levels of perceived utility value (science/chemistry being valued as facilitating careers, jobs, and future opportunities in general) than those with lower levels of family science capital (**Table 12-2**). Perceived utility value was one of the most important factors that associated with students' aspirations towards studying and careers in science/ chemistry. Students with higher levels of family science capital at Year 11 also expressed more positive views about engaging in extra-curricular science activities, expressed more positive perceptions of science teaching, they were more confident in their abilities in chemistry, and they also conveyed other positive attitudes. Essentially, pre-existing social inequalities are reflected within students' views, and may entail an unequal basis for students' wider progressions and trajectories towards or away from chemistry and/or science. Students who come from backgrounds with higher levels of family science capital may be already prepped to appreciate and learn about sciences, together with having a home learning environment which encourages learning in science and chemistry, and with encouragement to continue studying sciences after GCSEs. Such differences at Year 11 (the end of the Chemistry for All programme for some students) highlights the wider challenges for programmes of support concerning reaching and supporting students with less advantaged socio-economic circumstances, with less family science capital, and/or with home learning environments with less focus on science/ chemistry achievement.

In summary, students with higher levels of family science capital at Year 11 were statistically significantly more likely to report the following (**Table 12-2**):

- More positive overall aspirations towards chemistry (across A-Level studying, university studying, and careers);
- More positive specific aspirations towards studying A-Level chemistry;
- More positive specific aspirations towards studying chemistry at university;
- More positive specific aspirations towards a career in chemistry;
- More positive overall aspirations towards science (across A-Level studying, university studying, and careers);
- More positive specific aspirations towards studying A-Level science;
- More positive specific aspirations towards studying science at university;
- More positive specific aspirations towards a career in science;

Table 12-1: The relationship between family science capital at Year 11and books at home

Category	Information	0-10 Books	11-25 books	26-100 books	101-200 books	201-500 books	500+ books
Low family science capital	Number	401	286	311	96	54	48
	Percentage	33.5%	23.9%	26.0%	8.0%	4.5%	4.0%
	Percentage (grouped)	83.4%			16.6%		
High family science capital	Number	178	213	268	129	72	48
	Percentage	19.6%	23.5%	29.5%	14.2%	7.9%	5.3%
	Percentage (grouped)	72.6%			27.4%		

Notes: Results from both cohorts combined. Family science context/capital reflects students agreeing/disagreeing that someone in the family has a science-related job, a science-related qualification, and/or likes to talk about scientific facts, theories, or news items and how these relate to our lives. Low family science capital reflected average disagreement (less than 2.5 on the 1-4 scale); high family science capital reflected average agreement (equal or greater than 2.5 on the 1-4 scale).

- More positive home learning environments in chemistry (home support for achievement in chemistry and encouragement to continue with chemistry studies);
- More likely to take part in extra-curricular science activities;
- More likely to say they are exposed to teaching with hands-on activities;
- More likely to say they are exposed to teaching that shows the application of science;
- More likely to say they are exposed to teaching that has interaction, debate, and/or discussion;
- More likely to say their teacher encouraged them to study chemistry after GCSEs;
- Higher interest/enjoyment in chemistry;
- Higher perceived value of chemistry;
- Higher personal value of chemistry;
- More competitive in their learning;
- Higher self-confidence in their chemistry abilities;
- More confident they could do well at GCSE science;
- More confident they could do well at chemistry A-Level.

Table 12-2: Students' responses at Year 11 by family science context/capital at Year 11

Indicator (1-4 scales unless otherwise shown)	Low family science capital		High family science capital		Difference	
	M	SD	M	SD	D	Sig. (p)
Aspirations towards chemistry (overall)	1.65	.74	2.10	.90	**.552**	**<.001**
Aspirations towards chemistry: A-Level studying	1.70	.88	2.20	1.05	**.521**	**<.001**
Aspirations towards chemistry: university studying	1.56	.71	1.96	.91	**.493**	**<.001**
Aspirations towards chemistry: careers	1.69	.80	2.13	.95	**.516**	**<.001**
Aspirations towards science (overall)	1.94	.90	2.48	.98	**.575**	**<.001**
Aspirations towards science: A-Level studying	1.97	1.04	2.53	1.10	**.522**	**<.001**
Aspirations towards science: university studying	1.81	.92	2.33	1.06	**.529**	**<.001**
Aspirations towards science: careers	2.03	.99	2.57	1.03	**.535**	**<.001**
Family science capital/connection	1.70	.52	3.16	.45	**2.987**	**<.001**
Value of chemistry to society	2.54	.74	3.02	.60	**.710**	**<.001**
Home support for science/chemistry achievement	1.99	.69	2.80	.69	**1.169**	**<.001**
Extra-curricular engagement with science/chemistry	1.51	.57	1.97	.78	**.698**	**<.001**
Teaching/learning experiences: practical/experimental	2.05	.65	2.34	.73	**.412**	**<.001**
Teaching/learning experiences: relevance/applications	2.44	.86	2.85	.77	**.491**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	2.49	.68	2.78	.65	**.434**	**<.001**
Encouragement to study science/chemistry: from teachers	2.04	.86	2.67	.85	**.732**	**<.001**
Interest in chemistry	2.36	.76	2.75	.73	**.525**	**<.001**
Personal value of chemistry	1.95	.70	2.38	.78	**.584**	**<.001**
'I want to be one of the best students in my class'	2.84	.84	3.18	.80	**.416**	**<.001**
Perceived utility of chemistry	2.33	.65	2.72	.69	**.582**	**<.001**
Self-confidence in chemistry	2.01	.65	2.39	.70	**.577**	**<.001**
Grades: Expected GCSE science/chemistry grade (0-9)	4.41	1.76	5.13	1.76	**.407**	**<.001**
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	3.58	1.69	4.24	1.62	**.399**	**<.001**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups. Family science context/capital reflects students agreeing/disagreeing that someone in the family has a science-related job, a science-related qualification, and/or likes to talk about scientific facts, theories, or news items and how these relate to our lives. Low family science capital reflected average disagreement (less than 2.5 on the 1-4 scale); high family science capital reflected average agreement (equal or greater than 2.5 on the 1-4 scale). Current and GCSE grades are shown on a 0-9 scale (0=U, 1=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9); expected A-Level grades are shown on a 1-7 scale (1=U, 2=E, 3=D, 4=C, 5=B, 6=A, 7=A*).

Socio-economic status and students' perceptions and attitudes towards chemistry

The predictive modelling indicated that students from less advantaged socio-economic backgrounds were predicted to report lower chemistry and science aspirations than other students. Further analysis was applied to consider whether students from less advantaged backgrounds differed from those from more advantaged backgrounds in other ways (**Table 12-3**). At Year 11, students from family backgrounds with more advantaged socio-economic circumstances were not only more likely to report higher chemistry aspirations, but also higher levels of perceived value, interest/enjoyment, more engagement with extra-curricular science activities, positive perceptions of science teaching, and more positive self-confidence in their abilities. Students from more advantaged socio-economic backgrounds were statistically significantly more likely to have or exhibit the following (**Table 12-3**):

- More positive overall aspirations towards chemistry (across A-Level studying, university studying, and careers);
- More positive specific aspirations towards studying A-Level chemistry;
- More positive specific aspirations towards studying chemistry at university;
- More positive specific aspirations towards a career in chemistry;
- More positive overall aspirations towards science (across A-Level studying, university studying, and careers);
- More positive specific aspirations towards studying A-Level science;
- More positive specific aspirations towards studying science at university;
- More positive specific aspirations towards a career in science;
- More positive home learning environments (home support for achievement in chemistry and encouragement to study chemistry post-16);
- More likely to take part in extra-curricular science activities;
- More likely to say they experience teaching that has hands-on activities;
- More likely to say they experience teaching that shows the application of science;
- More likely to say they are exposed to teaching that has interaction;
- More likely to say their teacher encouraged them to study chemistry post-16;
- Higher interest/enjoyment in chemistry;
- Higher perceived value of chemistry;
- Higher personal value of chemistry;
- Greater competitiveness in their learning;
- Higher self-confidence in their chemistry abilities;
- More confident they could do well at GCSE science;
- More confident they could do well at chemistry A-Level.

Table 12-3: Students' responses at Year 11 by books at home

Predictors	Books: 0-10		Books: 11-25		Books: 26-100		Books: 101-200		Books: 201-500		Books: 500+		Overall difference	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	Eta^2	Sig. (p)
Aspirations towards chemistry (overall)	1.71	.74	1.88	.80	1.82	.84	1.90	.84	1.95	.96	2.17	1.11	**.016**	**<.001**
Aspirations towards chemistry: A-Level studying	1.77	.85	1.92	.94	1.89	1.00	1.96	1.00	2.10	1.17	2.27	1.23	**.014**	**<.001**
Aspirations towards chemistry: university studying	1.63	.73	1.78	.80	1.71	.81	1.77	.80	1.77	.92	2.03	1.12	**.012**	**<.001**
Aspirations towards chemistry: careers	1.73	.81	1.93	.84	1.86	.88	1.94	.88	1.99	.98	2.23	1.18	**.017**	**<.001**
Aspirations towards science (overall)	1.94	.86	2.22	.93	2.20	.95	2.30	1.02	2.36	1.13	2.38	1.15	**.023**	**<.001**
Aspirations towards science: A-Level studying	1.96	.98	2.22	1.06	2.26	1.09	2.31	1.14	2.47	1.24	2.49	1.26	**.022**	**<.001**
Aspirations towards science: university studying	1.83	.89	2.09	.99	2.04	1.01	2.16	1.05	2.20	1.17	2.25	1.18	**.018**	**<.001**
Aspirations towards science: careers	2.03	.96	2.33	1.00	2.29	1.02	2.40	1.07	2.42	1.15	2.43	1.21	**.020**	**<.001**
Family science capital/ connection	2.10	.83	2.33	.85	2.39	.86	2.60	.88	2.62	.82	2.47	1.01	**.038**	**<.001**
Value of chemistry to society	2.55	.72	2.73	.66	2.86	.65	2.91	.74	2.92	.74	2.81	.93	**.036**	**<.001**
Home support for science/chemistry achievement	2.14	.77	2.39	.75	2.36	.77	2.54	.83	2.56	.79	2.48	1.01	**.030**	**<.001**
Extra-curricular engagement with science/chemistry	1.53	.65	1.75	.67	1.73	.68	1.84	.69	1.85	.77	2.00	1.01	**.033**	**<.001**
Teaching/learning experiences: practical/ experimental	2.11	.70	2.23	.68	2.17	.68	2.19	.70	2.27	.68	2.22	.91	**.005**	**.027**
Teaching/learning experiences: relevance/ applications	2.51	.86	2.66	.82	2.68	.79	2.69	.86	2.62	.84	2.52	1.04	**.008**	**.003**
Teaching/learning experiences: interaction/ debate/discussion	2.59	.69	2.68	.62	2.61	.68	2.63	.61	2.59	.69	2.52	.93	.004	.103
Encouragement to study science/chemistry: from teachers	2.11	.85	2.37	.89	2.35	.90	2.41	.93	2.55	.93	2.52	1.09	**.022**	**<.001**
Interest in chemistry	2.35	.79	2.60	.71	2.54	.75	2.61	.75	2.58	.74	2.59	.95	**.018**	**<.001**
Personal value of chemistry	1.96	.73	2.20	.72	2.14	.74	2.23	.75	2.23	.77	2.30	1.00	**.021**	**<.001**
'I want to be one of the best students in my class'	2.83	.84	2.99	.80	3.06	.78	3.07	.83	3.16	.85	3.14	.97	**.017**	**<.001**
Perceived utility of chemistry	2.34	.66	2.57	.64	2.51	.66	2.56	.70	2.61	.72	2.57	.92	**.019**	**<.001**
Self-confidence in chemistry	2.07	.68	2.21	.66	2.19	.66	2.20	.68	2.21	.75	2.41	.96	**.013**	**<.001**
Grades: Expected GCSE science/chemistry grade (0-9)	3.95	1.63	4.55	1.66	4.98	1.65	5.24	1.74	5.41	1.84	5.53	2.45	**.085**	**<.001**
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	3.44	1.65	3.87	1.57	4.01	1.64	4.19	1.62	4.06	1.91	4.24	2.16	**.026**	**<.001**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean), together with the overall magnitude ('Eta2'; Eta squared) and significance ('Sig. (p)'; p-values) of the differences across groups. Eta squared reflects the proportion of variance that can be attributed to the difference across all of the groups. Current and GCSE grades are shown on a 0-9 scale (0=U, 1=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9); expected A-Level grades are shown on a 1-7 scale (1=U, 2=E, 3=D, 4=C, 5=B, 6=A, 7=A*).

Intersections between gender and aspirations

Social inequalities such as socio-economic circumstances, gender, family science capital/context, and home learning environments can facilitate or limit students' aspirations. Nevertheless, intersectionality implies that different students have different experiences and challenges, and some students nevertheless aspire towards science/chemistry. Further analysis specifically focused on girls with aspirations to study A-Level chemistry, and found that they formed a distinct group who had similar attitudes and perceptions towards chemistry they formed a distinct group who had attitudes and perceptions towards chemistry that were similar to those of high-aspiring boys. They also expressed more positive responses, and also expressed more positive responses than boys (and girls) who did not aspire to study A-Level chemistry (**Table 12-4** and **Table 12-5**). However, there was one key difference: high-aspiring girls still expressed lower self-confidence in their own abilities (compared to high-aspiring boys), despite their similar other attitudes and perceptions surrounding chemistry.

Both high-aspiring boys and girls were equally likely to report that (**Table 12-4** and **Table 12-5**):

- They were exposed to teaching that enabled them to take part in interaction and debate;
- They were exposed to teaching that enabled them to take part in investigations;
- They were exposed to teaching that explained the wider applications of science;
- They had more positive perceptions of their chemistry teacher;
- They had a more positive home learning environment in chemistry where they were encouraged to do well in chemistry and to continue with chemistry post-16;
- They were more likely to engage in science extra-curricular activities;
- They had higher levels of science capital;
- Their teachers were more likely to encourage them to continue with chemistry post-16;
- Their friends were more likely to encourage them to continue with chemistry post-16;
- Their parents and teachers conveyed the value and utility of science and parents were interested in science;
- They had competitive personalities, where they had high ambitions and wanted to do better than others;
- They were more positive in their own confidence and beliefs in their abilities in their GCSE and A-Level grades;
- They had higher levels of extrinsic motivation (perceived utility of chemistry);
- They had higher levels of intrinsic motivation (interest/value of chemistry);
- They had higher levels of the value of science in society;
- They had high higher levels of the personal value of science;
- They would like to study science at A-Level, university, or for a career;
- They would like to study chemistry at university, or have a career in chemistry.

However, despite these girls and boys reporting similar levels of confidence regarding their expected GCSE and A-Level grades, high-aspiring girls were less likely to report that they were good at chemistry and were able to do well in chemistry. These findings support the qualitative work where high-ability girls were questioning their ability in chemistry despite being high attainers. Lower self-confidence, particularly in the context of 'science/chemistry requiring natural ability' discourses, may limit some girls from aligning their own identities within science/chemistry.

Table 12-4: Students' responses at Year 11 by gender by A-Level chemistry aspiration groups

Predictors	Boys aspiring towards chemistry A-Level		Girls aspiring towards chemistry A-Level		Boys not aspiring towards chemistry A-Level		Girls not aspiring towards chemistry A-Level	
	M	SD	M	SD	M	SD	M	SD
Programme (Comparison=0, Chemistry for All=1)	.83	.37	.90	.30	.83	.38	.83	.37
Cohort (Younger=0, Older=1)	.38	.49	.40	.49	.46	.50	.44	.50
Gender (Girls=0, Boys=1)	1.00	.00	.00	.00	1.00	.00	.00	.00
School: Total number of pupils	1205.91	576.23	1038.51	596.79	1171.33	497.77	1096.62	540.40
School: Percentage of girls	40.75	12.55	60.97	25.71	40.40	15.07	54.88	21.15
School: Percentage of EAL	21.84	20.41	34.38	22.76	16.35	18.19	24.05	22.93
School: Percentage of FSM	27.01	12.74	26.24	11.36	24.89	12.33	25.63	12.31
School: Percentage of SEN	17.15	6.01	14.72	7.27	16.62	6.18	15.02	6.62
Teaching/learning experiences: interaction/debate/discussion	2.92	.69	2.81	.64	2.55	.67	2.54	.66
Teaching/learning experiences: practical/experimental	2.58	.80	2.45	.72	2.05	.66	2.10	.65
Teaching/learning experiences: relevance/applications	3.02	.77	2.98	.77	2.55	.85	2.47	.82
Perceptions of teachers	3.17	.65	3.11	.67	2.89	.72	2.88	.71
Books at home	2.86	1.54	2.80	1.42	2.42	1.29	2.58	1.39
Family science (science-related job, qualifications, talks science)	2.73	.84	2.75	.87	2.18	.83	2.23	.85
Home support for science/chemistry achievement	2.85	.71	2.94	.68	2.15	.76	2.19	.74
Extra-curricular engagement with science/chemistry	2.25	.84	2.16	.79	1.59	.62	1.52	.56
Encouragement/shared extra-curricular engagement	2.30	.98	2.26	.91	1.84	.84	1.91	.83
Encouragement to continue: parents	3.09	.81	3.26	.70	2.04	.90	2.08	.89
Encouragement to continue: teacher	3.10	.69	2.99	.78	2.15	.84	2.04	.83
Encouragement to continue: friends	2.94	.81	2.98	.79	1.87	.79	1.87	.77
Parents/teachers conveying the value of science/chemistry	2.99	.68	3.09	.61	2.25	.76	2.23	.73
Achievement motivation	3.51	.50	3.46	.57	3.28	.57	3.22	.55
Grades: Science grade this year (0-9)	5.44	1.93	5.14	1.97	4.08	1.79	3.93	1.54
Grades: Expected GCSE science/ chemistry grade (0-9)	5.97	1.86	5.64	1.96	4.49	1.68	4.21	1.53
Grades: Expected grade if A-Level chemistry were to be taken (1-7)	5.09	1.49	4.87	1.44	3.76	1.63	3.28	1.55
Perceived utility of chemistry	3.19	.60	3.26	.52	2.31	.57	2.24	.56
Interest in chemistry	3.10	.66	3.08	.61	2.38	.73	2.31	.72
Self-confidence in chemistry	2.81	.67	2.57	.62	2.12	.65	1.92	.60
Value of chemistry to society	3.20	.63	3.21	.56	2.66	.72	2.55	.67
Personal value of chemistry	2.92	.73	2.86	.65	1.95	.65	1.87	.61
Aspirations towards chemistry (overall: A-Level, university, and careers)	3.03	.63	3.05	.54	1.49	.50	1.49	.51

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD'; the extent of dispersion around the mean) per group. Current and GCSE grades are shown on a 0-9 scale (0=U, 1=1, 2=2, 3=3, 4=4, 5=5, 6=6, 7=7, 8=8, 9=9); expected A-Level grades are shown on a 1-7 scale (1=U, 2=E, 3=D, 4=C, 5=B, 6=A, 7=A*).

Table 12-5: Students' responses at Year 11 by gender by A-Level chemistry aspiration groups (differences across groups)

Indicator	Boys aspiring towards chemistry A-Level		Boys aspiring towards chemistry A-Level		Boys aspiring towards chemistry A-Level		Girls aspiring towards chemistry A-Level		Girls aspiring towards chemistry A-Level		Boys not aspiring towards chemistry A-Level	
	Girls aspiring towards chemistry A-Level		Boys not aspiring towards chemistry A-Level		Girls not aspiring towards chemistry A-Level		Boys not aspiring towards chemistry A-Level		Girls not aspiring towards chemistry A-Levele		Girls not aspiring towards chemistry A-Level	
	D	Sig. (p)	D	Sig. (p)	D	Sig. (p)	D	Sig. (p)	D	Sig. (p)	D	Sig. (p)
Programme (Comparison=0, Chemistry for All=1)	.212	.138	.014	1.000	.008	1.000	**.213**	**.015**	**.193**	**.040**	.022	1.000
Cohort (Younger=0, Older=1)	.042	1.000	.152	.163	.115	.564	.110	.658	.074	1.000	.037	1.000
Gender (Girls=0, Boys=1)	-	-	-	-	-	-	-	-	-	-	-	-
School: Total number of pupils	**.285**	**.002**	.067	1.000	**.199**	**.018**	**.255**	**.002**	.105	.696	**.144**	**.015**
School: Percentage of girls	**1.002**	**<.001**	.024	1.000	**.722**	**<.001**	**1.142**	**<.001**	**.274**	**<.001**	**.787**	**<.001**
School: Percentage of EAL	**.581**	**<.001**	**.293**	**.001**	.099	.741	**.934**	**<.001**	**.451**	**<.001**	**.372**	**<.001**
School: Percentage of FSM	.065	1.000	.171	.071	.111	.606	.111	.677	.050	1.000	.060	1.000
School: Percentage of SEN	**.365**	**<.001**	.086	1.000	**.328**	**<.001**	**.295**	**<.001**	.045	1.000	**.250**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	.172	.283	**.554**	**<.001**	**.575**	**<.001**	**.391**	**<.001**	**.411**	**<.001**	.017	1.000
Teaching/learning experiences: practical/ experimental	.179	.126	**.760**	**<.001**	**.709**	**<.001**	**.580**	**<.001**	**.524**	**<.001**	.068	1.000
Teaching/learning experiences: relevance/ applications	.045	1.000	**.565**	**<.001**	**.679**	**<.001**	**.525**	**<.001**	**.638**	**<.001**	.094	.268
Perceptions of teachers	.089	1.000	**.391**	**<.001**	**.413**	**<.001**	**.304**	**<.001**	**.325**	**<.001**	.019	1.000
Books at home	.041	1.000	**.330**	**<.001**	**.201**	**.016**	**.291**	**<.001**	.161	.111	.120	.073
Family science (science-related job, qualifications, talks science)	.028	1.000	**.653**	**<.001**	**.584**	**<.001**	**.677**	**<.001**	**.609**	**<.001**	.054	1.000
Home support for science/chemistry achievement	.127	1.000	**.932**	**<.001**	**.905**	**<.001**	**1.060**	**<.001**	**1.035**	**<.001**	.047	1.000
Extra-curricular engagement with science/ chemistry	.105	.869	**.976**	**<.001**	**1.157**	**<.001**	**.868**	**<.001**	**1.044**	**<.001**	.116	.219
Encouragement/shared extra-curricular engagement	.040	1.000	**.526**	**<.001**	**.452**	**<.001**	**.493**	**<.001**	**.416**	**<.001**	.083	.664
Encouragement to continue: parents	.216	.207	**1.204**	**<.001**	**1.160**	**<.001**	**1.430**	**<.001**	**1.384**	**<.001**	.048	1.000
Encouragement to continue: teacher	.143	.932	**1.175**	**<.001**	**1.322**	**<.001**	**1.021**	**<.001**	**1.164**	**<.001**	.127	.056
Encouragement to continue: friends	.039	1.000	**1.357**	**<.001**	**1.382**	**<.001**	**1.404**	**<.001**	**1.430**	**<.001**	.002	1.000
Parents/teachers conveying the value of science/chemistry	.149	.840	**1.004**	**<.001**	**1.061**	**<.001**	**1.156**	**<.001**	**1.219**	**<.001**	.023	1.000
Achievement motivation	.105	1.000	**.424**	**<.001**	**.549**	**<.001**	**.313**	**<.001**	**.432**	**<.001**	.111	.092
Grades: Science grade this year	.156	.280	**.744**	**<.001**	**.918**	**<.001**	**.575**	**<.001**	**.729**	**<.001**	.089	.439
Grades: Expected GCSE science/chemistry grade	.171	.149	**.858**	**<.001**	**1.090**	**<.001**	**.659**	**<.001**	**.873**	**<.001**	**.175**	**.003**
Grades: Expected grade if A-Level chemistry were to be taken	.150	.638	**.830**	**<.001**	**1.180**	**<.001**	**.697**	**<.001**	**1.044**	**<.001**	**.305**	**<.001**
Perceived utility of chemistry	.118	1.000	**1.534**	**<.001**	**1.677**	**<.001**	**1.702**	**<.001**	**1.851**	**<.001**	**.126**	**.040**
Interest in chemistry	.040	1.000	**1.018**	**<.001**	**1.118**	**<.001**	**.997**	**<.001**	**1.098**	**<.001**	.088	.320
Self-confidence in chemistry	**.372**	**<.001**	**1.048**	**<.001**	**1.454**	**<.001**	**.695**	**<.001**	**1.083**	**<.001**	**.329**	**<.001**
Value of chemistry to society	.024	1.000	**.774**	**<.001**	**.981**	**<.001**	**.811**	**<.001**	**1.023**	**<.001**	**.156**	**.008**
Personal value of chemistry	.093	1.000	**1.457**	**<.001**	**1.647**	**<.001**	**1.397**	**<.001**	**1.591**	**<.001**	.123	.059
Aspirations towards science/chemistry (overall)	.034	1.000	**2.909**	**<.001**	**2.868**	**<.001**	**3.087**	**<.001**	**3.039**	**<.001**	.002	1.000

Notes: Results from both cohorts combined. The table shows the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups.

12.1.1. Case studies of students

At Year 11, differences in aspirations between the most disadvantaged students and the most advantaged students were explained by differences in the students' various views. Students who were from socio-economically disadvantaged backgrounds expressed the lowest aspirations in chemistry (when controlling for gender, socio-economic status, and the percentage of students in their school with English as a second or additional language). However, the magnitude of social disadvantage was reduced at Year 11 when we controlled for engagement in extra-curricular science activities. We found similar types of effects for science outcomes. The most interesting point is that the influence of socio-economic disadvantage was eliminated between the most disadvantaged group and the most advantaged group for all four chemistry outcomes (although there were still some differences between some of the other categories of disadvantage). The qualitative analysis further explores why and/or how students' views link with their aspirations, and especially considers how the Chemistry for All programme may have supported students and their aspirations and attitudes.

The qualitative findings indicate that although some students from less advantaged socio-economic backgrounds were not sure about continuing with science or chemistry at the start of the study, by Year 11 some students had developed stronger chemistry (and science) identities, where the impact of the Chemistry for All programme played a large part, and some had indeed chosen to take chemistry A-Level. Four case studies of students, who represent under-represented groups in chemistry (female, ethnic minority, low socio-economic status), help to explore and illustrate these areas. These cases also help illustrate how factors highlighted through the quantitative analysis (such as extra-curricular engagement, perceived utility/extrinsic motivation, interest/enjoyment, and self-confidence) relate to students' aspirations.

Four case study students who are from each of the three under-represented groups: disadvantaged socio-economic circumstances, female, and ethnic minority

Despite the challenges around social inequalities, some girls from less advantaged socio-economic and/or ethnic minority backgrounds decided on remaining in chemistry after their GCSEs, and aspects of support could be attributable to the Chemistry for All programme. Here we discuss four case study students from various under-represented groups (less advantaged socio-economic circumstances, female, and from ethnic minority backgrounds) and also highlight case studies of their peers who are from advantaged socio-economic backgrounds. These girls showed high motivation towards achievement in general (and/or competitiveness), conveyed high general aspirations, and, in particular, enjoyed chemistry. The Chemistry for All programme helped them align the idea of their future selves with chemistry, particularly when the benefits of non-compulsory science/chemistry qualifications were conveyed by the programme. Below are brief pen portraits of these girls who we discuss within our narrative to substantiate key points about what it is that helps keep students within the chemistry trajectory.

Tara, British female (mixed-race Black Caribbean and White heritage), strong chemistry identity, average socio-economic circumstances, but high science capital

Tara has a very strong chemistry identity. She reports that she has natural ability in the subject; her perceptions of her natural ability are what drives her to continue with non-compulsory chemistry studies. She has a high personal value and perceived utility value of chemistry. She is a high-ability student from a mixed-race background and her parents are semi-skilled professionals. She is from a low science capital background although has an older sibling who has become a nurse and a father who encourages her to continue with chemistry. She wants a career either in chemistry research or as a doctor. She indicates that it was the Chemistry for All programme which helped her to make the decision about continuing with science at university.

Maryam, British Muslim female (of Bangladeshi heritage), medium chemistry identity, disadvantaged socio-economic circumstances, but high science capital

Maryam is a British-born Muslim female of Bangladeshi heritage in disadvantaged socio-economic circumstances who has chosen to continue with chemistry A-Level but her identification with chemistry, although not weak, is not firm either. She has high ability in each of the sciences and although she enjoys elements of chemistry in Year 11, she also finds it difficult. She does not have a high personal value of chemistry although does have a high utility value of chemistry. The core reason why she chose chemistry at A-Level was because of its benefits for her future career (extrinsic motivation): "it's really relevant to what I want to do at university". However, she chose economics and psychology because they were interesting rather than because of their value in facilitating future careers. She spoke highly of her brother who motivated her and encouraged her in continuing with chemistry and biology for her future career.

Sairah, British female (of Pakistani heritage), strong chemistry identity, disadvantaged to average socio-economic circumstances, and low family science capital

Sairah is a second/third generation migrant; her mother is a migrant from Pakistan. Her father works in sales. She is high attaining, with science aspirations, choosing chemistry, biology, mathematics, and Spanish at Year 12. She would like to study chemistry at university.

Whilst much of her narrative is distinctive for an ethnic minority female, she still displays less confidence in her own ability in doing well at chemistry. She has two role models, older sisters who have studied medicine, and her family, in general, push science as a career. She has attended chemistry clubs arranged by other providers in addition to the Chemistry for All activities.

However, she has not fully aligned herself with chemistry; when asked what she would do as a career, she says:

"I'm not too sure, to be honest. I might be hoping to be in some sort of employment, but I'm not really sure what job I want to do in the future right now". When she is further asked to think about her future she reports "that my future career will be within science", but is still unable to firmly position herself within chemistry. However, she was able to attribute her choice in moving into a chemistry trajectory after GCSEs because of Chemistry for All: "because of the programme, I'm more likely to want to go into chemistry. I think it gave me a deeper knowledge into it. I think it did somewhat help influence my decision to carry on with it".

Low science capital, medium chemistry identity, low-medium socio-economic status

Sri Lankan female, low family science capital, high ability, medium chemistry identity

Arooj is a young woman with high abilities who could continue with chemistry, and initially decided to do chemistry at A-Level but changed her mind because the classroom teaching at her school did not engage her. Rather than recognise that the problem related to the teaching, she reported that she felt that she was not good enough for chemistry. She does not feel that she has natural ability in chemistry, which she feels is needed to succeed. Nevertheless, despite thinking she is not good enough, she does enjoy chemistry. She indicates that the Chemistry for All programme helped her to think about science/chemistry post-16:

"Well, it definitely made me want to take chemistry and something with science more".

Additional key case study students from advantaged backgrounds

John, British male (of White heritage), strong chemistry identity, advantaged socio-economic circumstances, and high family science capital

John, of White British background, comes from a family with high family science capital; both of his parents work in the sciences with a professional and advantaged background. He aligns himself with the position of being clever at a subject that is understood to be hard: "Chemistry is one of my strong subjects, I feel like I get on reasonably well, I can kind of understand the content fairly well. And yeah, I think pretty decently." He says he "would definitely like to study science at university … something in either chemistry or physics". He was able to attribute his choice in moving into the physical sciences after GCSEs to Chemistry for All:

"So I think because before the programme, I didn't really have much of an idea in terms of what I wanted, university itself was like, in terms of science, it kind of helped show me that it was actually kind of a good route to take kind of in terms of science. Help me kind of science A-Levels because then I could pursue university later."

Priya, British female (of Indian heritage), medium chemistry identity, advantaged socio-economic circumstances, low family science capital

Priya is from a middle-class family; her parents are professionals, and typically, for students of Indian heritage, there is an emphasis from the family on entering the medical profession. She does not have a high personal value of chemistry although does have a high extrinsic/utility value of chemistry. She is of average ability, plans to continue with chemistry because her mother has told her to do medicine.

She likes practical work but is more interested in biology and does not see herself as being a chemist. Nevertheless, she says the Chemistry for All programme reinforced the idea that she should continue with chemistry. Unlike other students, she does not feel that the Chemistry for All programme helped her gain more knowledge about the careers and courses that are available with a post-16 chemistry qualification, but she did say that chemistry is now "much more enjoyable".

Adam, migrant male (now naturalised British of Muslim heritage), weak chemistry identity, high socio-economic circumstances, high family science capital

Despite being a high-ability student, Adam has a weak chemistry identity, reports finding it difficult and complicated, and does not like chemistry. Nevertheless, he finds mathematics easy, despite the two subjects being somewhat interlinked. He talks about requiring a mathematics qualification to be an architect, but says that he has no need for chemistry. Despite having high family science capital, he is nevertheless less connected with chemistry. His identity appears to be strongly focused towards mathematics, a subject he enjoys. He recognised positive points about the Chemistry for All programme, but he said that these were not enough to turn him away from his chosen career.

Mark, British White male, strong chemistry identity, advantaged socio-economic circumstances, and high science capital

Mark is from a more socio-economically advantaged family and has high ability in chemistry. He has a supportive network around him, where he discusses his choices with his family and teachers. He aspires to continue with chemistry because he enjoys it, identifies well with it, and can see its relevance to society. His brother is doing a chemistry degree. He indicates that it was the Chemistry for All programme that showed him that chemistry could be a path for him and was very positive about the opportunities the programme provided with respect to practical work and increasing his awareness of what could be done with a post-16 qualification.

12.2. Chemistry for All can boost extrinsic motivation and the perceived utility of chemistry

One theme that was prevalent amongst the interviewees was the recognition of the utility value of chemistry qualifications (being valued as facilitating careers, jobs, and future opportunities in general), essentially with chemistry qualifications being perceived as a 'door opener'. The predictive modelling of the students' questionnaire responses revealed that perceived utility value was the single most important predictor of students' overall aspirations towards chemistry (across A-Level and university studying, and towards careers) and for the pursuit of any one of these specific pathways. The path analysis further highlighted that students who received the Chemistry for All programme were predicted to express higher perceived utility value of chemistry than comparison students, when accounting for their personal characteristics, circumstances, and other views. The interviews allowed a more open-ended exploration of students' views about chemistry, and illustrate and clarify: the importance of students having awareness about careers and courses available with a post-16 qualification, how this awareness (extrinsic motivation) fits in with other important chemistry attitudes and social disadvantage, and what role the Chemistry for All programme played in developing students' chemistry aspirations. The analysis of the interview narratives found that, by the end of the Chemistry for All programme, there was a firm and clear link between choosing A-Level chemistry and recognising that chemistry qualifications can provide opportunities later in life.

Chemistry as a 'door opener' underpins constructions of chemistry qualifications as having distinct and clear available opportunities, which are unique to chemistry and/or the sciences in general. Maryam had indicated that she chose to continue with chemistry because:

"It's really relevant to what I want to do at university. You need those subjects to get into the course I want to do, and I just find them really interesting, as well."

Almost all interviewees were aware that undertaking a post-16 chemistry qualification would be of benefit. Those who had attended Chemistry for All events that specifically provided information about careers were able to become more enthused about chemistry and make more informed decisions:

"It [the Chemistry for All programme] introduced many apprenticeship options, all of the different university courses, so it did really open that up … with the programme we were taught about apprenticeships, and I hadn't really considered that before but it, obviously, made me realise that it is a good option." (Maryam)

"Well, I understood there's a lot more you can do with science than just medicine, like there's way more fields that it applies to. Like forensics … it made me interested in a lot of fields, like the way they applied chemistry, a lot of things. I suppose it did make me in a sense want to take it in university at the time."

Arooj chemistry student, British Muslim female of Sri Lankan heritage, disadvantaged socio-economic circumstances, low family science capital

Recognising the links between enhanced future opportunities and chemistry qualifications emerged as students progressed through secondary school:

"There are a couple of times when I changed my mind in career decisions halfway through Year 12. Because, in the beginning, I was wanting to do medicine and then I think I changed to wildlife conservation. Even with those sorts of backgrounds, I think chemistry is still something I will use. Because I have to know about content to be able to translate for people in areas of the medical field and stuff."

Aliyah, chemistry student, ethnic minority female, average socio-economic circumstances, low family science capital

During GCSE studies (Year 10 and Year 11), students were directly asked whether there had been any impact of the Chemistry for All programme on their knowledge about careers and courses that might be facilitated by a post-16 chemistry qualification. It became apparent that the programme indeed played a key role in helping to create these connections. The examples here of chemistry as a 'door opener', from a range of students from disadvantaged backgrounds, help demonstrate the efficacy of the Chemistry for All programme in enabling a shared understanding about the benefits of a post-16 chemistry qualification. Positively reaching and supporting less advantaged students appeared to help students to align their future selves with chemistry, which might not have been otherwise possible. Students were also asked if the Chemistry for All programme had an impact on how they saw themselves in the future and whether this involved chemistry:

"I would love to do some sort of research job, hopefully making a new medicine, or a doctor, and have a research project as well … Just learning where you go to from school and what you can achieve has really pushed me to take chemistry in particular because it's just something that's so broad. I keep saying it because it's going to anything that you want to really with chemistry. That is something I have been looking into as well." (Tara)

Many students were able to appreciate the value of having a post-16 chemistry qualification. The Chemistry for All programme appeared to be effective in supporting this by providing targeted talks and assemblies on the different routes students could take to pursue a post-16 qualification and which qualifications could lead to different types of careers:

"It [the Chemistry for All programme] showed me that there is a much wider range beyond the 16 level and that university can be very exciting indeed." (Mark)

Additionally, trips to outside organisations, chemistry after-school clubs, and demonstrations and experiments provided as part of the Chemistry for All programme helped to create connections between students' identities and chemistry. For example, the Chemistry for All programme sparked the interest of Fatimah (who had disadvantaged socio-economic circumstances, a single parent, and an ethnic minority background) regarding what her future in chemistry could involve:

"I'm more aware of them [careers and courses in chemistry] because I researched into some of them as well, what I wanted to do … Like dentists, I researched into that, but then it wasn't quite on my thing." (Fatimah)

Again, Arooj, who had disadvantaged socio-economic circumstances, benefitted from the Chemistry for All programme as she was able to appreciate the benefits of a post-16 chemistry qualification, specifically because of the activities she was involved in:

"I mean, it [the Chemistry for All programme] made me interested in a lot of fields, like the way they [Chemistry for All activity providers] applied chemistry, a lot of things. I suppose it did make me in a sense want to take it in university." (Arooj)

Teachers at Arooj and Fatimah's school felt that more students could benefit from Chemistry for All but, given that they had made attendance of some of these events optional (in particular, the after-school club), from their perspective, there was a low student turnout. Nonetheless, they felt the activities were very beneficial:

"I think the project is superbly well resourced. I think the delivery that we've had over both years has been excellent. The issue that we had as a school is sort of student response to that, because, despite the quality, it is a bit hit and miss. And it's difficult to put a reason behind why that might be." (Teacher)

Many aspects of life might facilitate or constrain students' engagement with optional activities or events. For example, one student within this school indicated that she was unable to attend the after-school clubs as she had to collect her younger sibling from school and babysit whilst her mother worked. Various social inequalities may impact students in a range of ways; clearly, this school did not pick up (which isn't unusual) that there could have been some students who might have liked and benefited from attending after-school clubs, but were unable to do so because of personal circumstances. This is how social inequalities can lead to further widening of any initial differences in participation and/or trajectories towards or away from science, given that different circumstances can entail missed opportunities. Quantitative analysis conducted on students who came from families from high family science capital, versus those from low family science capital indicates some profound differences in the way students responded to the Year 11 survey (as discussed above).

Students from backgrounds with high family science capital were more likely to be aware of the benefits of having a post-16 chemistry qualification (as also shown through the differences in students' average questionnaire responses reported earlier), more positive about pursuing a post-16 qualification and more likely to appreciate, from the Chemistry for All activities, the value of post-16 chemistry qualifications, which concurs with the findings in the qualitative work.

"I think it brought a very good subject, and like I said before, it could be a base to a lot of different subjects and a lot of different career paths. So, I think it's a good option." (A student who almost chose chemistry)

12.3. Natural ability and non-compulsory choices: boys' and girls' constructions of chemistry identity and its relationship with choices

Another discourse that was prevalent within the students' interview narratives was 'natural talent/ cleverness'. Many students felt that only those who were naturally good at chemistry with little effort are the ones who could legitimately remain in the chemistry pipeline:

"Some people are lucky; it comes naturally and they just understand the subject really well but others have to put more effort into understanding it. I think that people who continue with chemistry are very good at it. I think you have to be very smart to continue with the subject in higher education as it's quite complicated. Personally, I don't think I'm very good at chemistry. It wasn't my strong subject because it was difficult at times and I didn't click with the subject as well as I hoped to have." (Low science capital, high-ability ethnic minority female)

"I enjoy it and I wouldn't say it is easy [but he later says that he personally finds it easy, so may be implying that it is not easy for all] but I have an aptitude for it." (White male chemistry student, high family science capital, parents work in science)

The interview narratives revealed a gender-specific construction amongst girls, where chemistry was often felt to involve and require hard work for them (and perhaps not for others), and there was a sense that good grades were unattainable. For some girls, these views, together with their perceptions and experiences that chemistry required more effort than other subjects, discouraged them away from intending to continue studying chemistry. The narratives indicated that some girls internalised problems with learning chemistry, whereas some boys externalised the same problems. For example, whilst Arooj initially decided to continue with A-Level chemistry, she changed her decision at a later date and thought about dropping out of the subject at the end of Year 12. Her last interview indicated that she was conflicted about leaving chemistry but the notion around it being difficult and not being for her emerged within this interview a number of times. She was unable to have a positive chemistry identity because she (like some of the other ethnic minority girls in the sample) continued to compare herself to the notion of success in chemistry involving being 'naturally clever', even though she was a level 8 chemistry student:

"I felt like the whole specification was way too hard for me, like I couldn't really keep up with it in lessons … I find chemistry very hard … Wasn't my strong subject at all … I know people who continue with chemistry and are naturally good at it while there are others who simply work hard. Some people are lucky; it comes natural and they just understand the subject really well but others have to put more effort into understanding it." (Arooj)

Rather than questioning whether the classes were taught in an inclusive way, or how the teacher could support her in her learning, this student appeared to internalise the problems she was having – the problem, she concluded, was her and her lack of natural ability to understand the work without hard work. On the other hand, the boys with trajectories towards chemistry often aligned themselves with the notion that chemistry is hard for everyone but with persistent hard work they would be able to do well in it; boys did not appear to internalise issues around difficulty so often, or they self-identified with the notion of having a natural aptitude:

"I think, in general, it's not easy, but fairly straightforward. There are some concepts that are hard to grasp, but it's not extremely hard to the point where it's stressing me out and I don't know what to do about it. It's one of those subjects where I take my time doing. I think I can definitely reach my target grade, but if I work even harder, I can get better than that. This year I have been working consistently around B grades and A grades. Next year I could definitely do that well if I – maybe even better … if I continue doing chemistry over the next year and a half and I manage to do well in it, I think I should take a career in it." (A chemistry student, British Muslim male of Pakistani heritage)

Tara is a bit of an anomaly amongst the females as she has confidence in her own abilities, has a strong chemistry identity, and aligns herself with the group of students who have natural ability in chemistry; because of this she has decided to continue aspire towards with chemistry:

"Because at GCSE it was one of my favourite subjects, and I was really interested in it. It was something that I was naturally good at. I was like, 'Oh OK, I could build on this and hopefully learn as much as I can'."

However, despite liking chemistry and knowing that she was good at it, she was not sure about continuing with chemistry at university prior to taking the Chemistry for All programme. The decision to align her future self with chemistry arose because of the Chemistry for All programme:

"It was an idea [to continue with chemistry post-16] that I had because at GCSE, I did really like the sciences, but it wasn't something that I was confirmed and had a goal of doing. Now [since taking part in Chemistry for All], I am set on doing a science-based subject at university."

Boys who felt that they were not doing well in chemistry or related subjects distanced themselves from the issue. Rather than internalise the problem, they often externalised it:

"It hasn't gone as well as I would have liked it to this year, and I don't think it's worth the stress next year. I'd rather not stress myself out even more. These [mathematics, chemistry, and further mathematics] are more important. (White male, advantaged socio-economic circumstances)

Boys from families with higher family science capital were often the most confident in their abilities in chemistry, and often expressed firm decisions about continuing with the sciences at university. Both of John's parents worked within science-related fields and they encouraged him to continue with the sciences.

Given his existing family science capital, positive experiences of the Chemistry for All programme, and his realisation that a chemistry A-Level would bring more prospects, John was very confident in his ability and quite clear about his future path at university:

"Well, chemistry is one of my strong subjects, I feel like I get on reasonably well, I can kind of understand the content fairly well. And yeah, I think pretty decently … So, I think because before the programme, I didn't really have much of an idea in terms of what I wanted … in terms of science, it kind of helped show me that it was actually kind of a good route to take kind of in terms of science. Helped me kind of [decide to take] science A-Levels because then I could pursue university later." (John)

Luke is another example of a white middle-class boy who aligned himself with a part of the 'naturally clever' group of people who could continue with chemistry, and with his positive experience of the Chemistry for All programme, he was influenced to carry on:

"Well, through this programme it explained quite a lot about what studying at university and studying science at university was like and how it is quite a developing line of work, and how a lot of universities are looking for students now, so it has kind of given me more confidence in applying and that I could get in." (Luke, chemistry student, White male, advantaged socio-economic circumstances, high family science capital)

Adam is an interesting case because, despite coming from a middle-class family, with high levels of family science capital, and having the ability to continue with chemistry, he chose not to continue with chemistry. What we can gather from this particular case is that he enjoys mathematics and has a clear ambition to be an engineer, so he feels he has no need for chemistry. His father is an engineer who dabbles in science for fun:

"Because he's always out on the back garden and he likes experimenting with stuff. Because we have this little shed/hut place, and he likes mixing stuff together. He's kind of like a little crazy scientist, we'll say … He does engineering, but he likes messing around with other stuff."

He says his father has advised him that:

"Chemistry is really useful to have on like your CV if you want to get employed, it's really good to have just A, and plus if like stuff don't go to plan, you can always like go to B plan, and after you can go towards chemistry side if you want."

Adam also has a 'science geek' uncle who has done science-related fun things with him. Despite all this input, Adam reports chemistry is not for him.

12.4. Intrinsic interest, personal value, and encouragement from others

All of the interviewees who chose to continue with chemistry spoke about enjoying it and being interested in it:

"Yes, yeah. I enjoyed them both [chemistry and biology]; a lot of school I'd say I prefer chemistry, but I find both as

a subject very interesting. They're some of my favourite subjects, which is why I decided to keep them on A-Level … Yes. I enjoy learning about the content side of it, and then realizing that at practicals. And also, just generally, I think it's really interesting to be able to have an understanding of the physical phenomena around you and seeing how those ideas can be used in industry, I think is something that is really interesting to me … the science as a whole is kind of I want to go into and I'm kind of quite involved with – chemistry is one of the subjects in sciences I'm most interested in." (John)

"I love science as a whole because you find out lots of new things and you can just learn about everything that you could. And chemistry, I really greatly enjoy because you can have rules for certain things and it can apply to so much that you can have a set of rules and just apply it to a lot of things, and I really like that." (Tara)

Students who had the ability to continue with chemistry but who did not enjoy it or lacked any personal value of chemistry were less likely to continue with it once it was no longer compulsory. For Adam, this was the case even though he said positive things about the benefits of a post-16 qualification that he learnt about from the Chemistry for All programme:

"Yeah. You can get, like, you have more job opportunities."

He was still quite clear that chemistry was not for him:

"I just find it kind of boring."

What was apparent from these interviews is that students who appeared to enjoy chemistry, had a personal value of chemistry, and opted to study it further also came from backgrounds with positive home learning environments and/or family science capital:

"Yes, my dad, he wants it [the student to study chemistry]. If he could do his time over again, he would try so much harder in chemistry and physics because he like those two subjects in particular. So, yeah, he encourages me along to try my best." (Tara)

Another student, Lisa, had an older sister who was also supported and encouraged by their father to continue with chemistry and the sciences. Lisa's older sister had continued in the sciences and, in turn, supported her. Access to work experience provided by her sister had enabled Lisa to picture herself as a chemist, enhance her personal value of chemistry, and helped to align a positive identity with chemistry:

"Hopefully – I would love to do some sort of research job, hopefully making a new medicine, or a doctor, and have a research project as well. That is something I have been looking into as well … [these ideas came about because] my sister actually brought me to the hospital. I got to hang around with her for a few days, but it was really interesting. And she's doing a research project currently because she does love science and she didn't want to give it up. So, I think, the hospital have funded a research project for the senior doctors and she's part of the team have that. I have got to come in and have a look and be around that for a few days … I could [be a chemist], I do love chemistry and yes, I could [be a chemist]."

The Chemistry for All programme played a crucial part in building on the interest of students. Although Lisa had support from her family in being made aware about the careers available with a post-16 qualification, and a general interest in chemistry, the Chemistry for All programme helped to support this decision further:

"This programme just really helped me to build on the interest [in chemistry] and then learn and then hopefully learn more … when we did the programme, it went along with these that we were learning about in school, and because of that, we had a basic understanding already, and then it just built on that and obviously it was really interesting … Meeting the students (involved in the Chemistry for All activity provisions) and knowing what courses they have been doing has really widened the amount of courses I thought there was."

For other students, encouragement from teachers also helped to boost their engagement with chemistry:

"Well, I had a very good teacher … and she was very enthusiastic and also the lessons were always quite exciting, practical sometimes, sometimes theory, and it was just generally very engaging." (Mark)

Fatimah's aspirations to do triple science and to continue with the physical sciences at A-Level appear to be driven (in addition to other things) by positive self-confidence in these subjects; during her Year 10 and Year 11 interviews she also talked about her mother being an important influence. Her narrative demonstrates that her mother's belief in Fatimah helped to reinforce a positive identification with chemistry and Fatimah believing in her own chemistry ability. Her mother normalises for Fatimah that continuing with the hard sciences is the right decision to make because she is good at the sciences and in chemistry:

"She thinks I can do something in it because previously I've been getting good at science … She says she wants me to take chemistry further."

Fatimah's positive self-concept in chemistry was further reinforced by the Chemistry for All clubs and activities that she attended. There appears to be a link for her and for other Chemistry for All students between a positive chemistry self-concept, personal value of chemistry, and intrinsic motivation in chemistry:

"I didn't think I would be good at chemistry when I was younger, but over the years I started to realise chemistry could be for me. I found the chemistry clubs [Chemistry for All] really interesting, yeah, enjoyable. When we did stuff, I thought yeah I can do this and it's fun … my mum tells me I need to go the clubs after school, she says it will be good for me, for later maybe [meaning A-Level choices] and it's something interesting to do."

Fatimah also indicated that she received support from her teacher in her chemistry learning, in addition to what was learnt in the classroom. Fatimah was asked if she did anything else to help her with learning more about chemistry and she said:

"I revise at home, I take my teacher's help, so he helps a lot, and I pay attention in class."

It is quite clear from Fatimah that despite being from a single-parent family and being of ethnic minority status, she has high aspirations which appear to be linked to the copious amounts of support she is getting from her mother, her teacher and the Chemistry for All activities. Being a part of the Chemistry for All activities has helped with developing a chemistry identity, and continuing with chemistry has naturally become the expected path for her, both from her own expectations of herself and from those around her:

"It [the Chemistry for All programme] made me more interested, like I enjoyed doing the experiment, the more practical side of chemistry."

Many bright girls internalised issues around feeling that they were not good enough to continue with chemistry or that they felt that they were presently unable to do well in chemistry because of their own (perceived lack of) understanding. Nevertheless, there were some (but fewer) girls who identified positively with chemistry, thought they might do well in it, but again internalised any problems they had with chemistry. As the narrative from Sairah shows, she did not align herself with being able to do chemistry without problems, given that she still gets things 'mixed up' in the examinations. Her narrative also, in part, includes her thoughts on why she might not attain a higher grade:

"I think I get on quite well … sometimes it's quite tricky, but I'll try and make sure I end up understanding what I'm doing. I think I find it difficult, but it's not impossible … I think within the exams, I think I tend to get mixed up with the way a lot of the questions are worded, especially when it comes to calculating questions." (Sairah, Female British, chemistry student, of Pakistani heritage)

Whilst Sairah had a stronger chemistry identity than most other girls, she was still not confident enough to say without reservation that she could become a chemist:

"I'm not sure; I think I'd picture myself doing more lab-based work because that's what I enjoy. I'm not sure."

A particular issue for girls may involve feeling that there is no room for 'hard-working girls' to challenge or fit in with the socially-constructed conception of 'naturally clever' chemists and scientists. This issue of natural cleverness is something that we have come across in our work in physics and mathematics education, and it appears here within chemistry education. Some girls who took part in the Chemistry for All programme benefitted from understanding the wider value and benefits that may arise from studying chemistry (chemistry being a 'door opener' subject), although they still balanced their place within chemistry (and their abilities in chemistry) against beliefs that doing well in chemistry is only for those who are naturally clever without having to work hard at it. Girls may be accepting gendered patterns of participation in Chemistry; being able to remain in the chemistry pipeline is presumed to be about being able to attain and understand well without hard-work (in other words, succumbing to the notion of natural cleverness). Despite girls doing as well as boys, having similar initial trajectories towards A-Level chemistry courses, expressing similar enjoyment of chemistry, and expressing similar views about the Chemistry for All programme opening up their minds about careers in the chemical sciences, girls may be selling themselves short by removing themselves from the chemistry pipeline because they feel that they are not good enough and internalise any problems they have within the classroom. Arooj very much enjoyed chemistry both within her secondary school and within the Chemistry for All programme:

"I felt like the whole specification was way too hard for me, like I couldn't really keep up with it in lessons. And, because of that, I don't feel like it's something I want to study. It's not something I'd enjoy."

There appeared to be little or no realisation from females from disadvantaged backgrounds who might not ordinarily have continued with the chemistry pipeline that they had indeed bucked the trend and were exceptional, given their backgrounds, that if they were finding current chemistry lessons disengaging or difficult, the issue might be with the way content is delivered (or numerous other external aspects), rather than their own ability.

Nevertheless, a strong chemistry identity appeared to come from a range of influences, including those from the Chemistry for All programme. For example, a female student (of Pakistani heritage) in disadvantaged socio-economic circumstances talked about the people who delivered the Chemistry for All activities and events as being positive role models, who helped her engage with chemistry:

"They were really good; they brought the energy and they were really enthusiastic, so that made us enthusiastic, as well. And, because they were young – they were university students – we could really relate to them." (Maryam)

12.5. Chemistry identity and self-confidence beliefs

The issue about some girls not having a strong enough chemistry identity to remain in chemistry highlights that future work may benefit from supporting girls' confidence in their own abilities. For all girls, support and action to address the notion of natural ability in chemistry might help to keep more girls, particularly those from disadvantaged backgrounds, within the chemistry pipeline by removing the reference point of natural ability in chemistry.

In order to unpack issues around ability and confidence within this evaluation, we took another slice of the data from the survey work to look at particular questions around students' confidence in their own chemistry ability (**Table 12-6**). At Year 11, girls were indeed less positive in their abilities than boys, and the gender differences within these questions were statistically significant. So, for example, boys were more able to identify with the notions that 'I am good at chemistry', 'I don't need help with chemistry', and 'I am able to learn quickly in chemistry'.

Factors associated with students' self-confidence in chemistry at Year 11

In order to further substantiate and contextualise some of the qualitative findings, multi-level predictive models were used to explore which factors associated with students' self-confidence beliefs as of Year 11 (**Table 12-7**). The analysis explored how potential influences of being surrounded by people who support and encourage students, and, who help to normalise that science is for them because of their scientific ability, may help them to build positive self-confidence in chemistry, regardless of socio-economic background.

The analysis revealed that, after controlling for socio-economic circumstances and levels of family science capital, self-confidence beliefs in chemistry at Year 11 were associated with students interest/enjoyment of chemistry, personal value of chemistry, being encouraged to continue with chemistry after GCSEs, experiencing practical/experimental work and debate/discussion in teaching/learning, engaging with extra-curricular science activities, and with family science capital/context, all considered as of Year 11 (**Table 12-7**).

Science extra-curricular activities: Positively associated with the Year 11 chemistry self-confidence beliefs.

Interest/enjoyment in chemistry: Positively associated with the Year 11 chemistry self-confidence beliefs.

Family science capital: Positively associated with the Year 11 chemistry self-confidence beliefs.

Home learning environment (encouragement to study chemistry post-16 from family): Positively associated with the Year 11 chemistry self-confidence beliefs.

Encouragement to study chemistry post-16 from teachers: Positively associated with the Year 11 chemistry self-confidence beliefs.

Teaching/learning experiences: Teaching that includes interaction with students and which involves practical experiments positively associated with the Year 11 chemistry self-confidence beliefs.

Personal approach in teaching: 'Higher agreement with 'My chemistry/science teacher is interested in me as a person', positively associated with the Year 11 chemistry self-confidence beliefs.

Socio-economic circumstances: Students with fewer books at home were predicted to express lower self-confidence in chemistry, accounting for the various other predictors.

Students' gender: Boys were predicted to express higher self-confidence in chemistry than girls, accounting for the various other predictors.

The impact of Chemistry for All on a chemistry identity

All of the interviewees who aspired to study non-compulsory chemistry at A-Levels and/or university cited that the Chemistry for All programme had a positive effect on their chemistry identity, and it was because of this that positive identity students aspired to study chemistry further. This was even the case for students who did not necessarily have a strong chemistry identity. For example, whilst one student embodied a less positive chemistry identity, she did find that attending the Chemistry for All activities helped her to think about doing chemistry further:

"I mean, it [the Chemistry for All activities] made me interested in a lot of fields, like the way they applied chemistry, a lot of things. I suppose it did make me in a sense want to take it in university at the time. I'm not really sure."

For another student who had a less positive chemistry identity prior to the Chemistry for All programme, the Chemistry for All activities opened up the possibility that chemistry could be for him and put him on the trajectory for studying non-compulsory chemistry:

"I was a little sceptical perhaps thinking it was interesting but perhaps far too difficult for someone like me, that was my initial thought … it showed me that if you have the right teaching staff and everything it can actually be open to everyone and very possible indeed" (Mark)

The Chemistry for All programme had an impact on Mark in a range of ways. He indicated that the programme had an effect on his ability to do well in chemistry:

"Well I suppose it's mostly down to the, it [the Chemistry for All programme] gives you a deeper understanding of those experiments and taking more time to go in depth about how and why these things are useful, slightly

Table 12-6: Year 11 self-confidence beliefs (items)

Questionnaire item	Girls		Boys		Difference	
	M	SD	M	SD	D	Sig. (p)
I am good at chemistry	2.30	.82	2.51	.86	**.251**	**<.001**
I do well in chemistry tests	2.30	.80	2.46	.85	**.191**	**<.001**
I don't need help with chemistry	1.89	.83	2.07	.87	**.206**	**<.001**
When I am doing chemistry, I always know what I am doing	1.94	.73	2.12	.79	**.235**	**<.001**
I do better in chemistry than most other students in my class	1.97	.84	2.21	.92	**.273**	**<.001**
I'm certain I can figure out how to do the most difficult chemistry tasks in classes	1.95	.82	2.21	.86	**.306**	**<.001**
I am able to learn chemistry quickly	2.12	.86	2.38	.88	**.298**	**<.001**

Notes: Results from both cohorts combined. The table shows the mean ('M'; the average) and standard deviation ('SD') per questionnaire item, together with the magnitude ('D'; Cohen's D) and significance ('Sig. (p)'; p-values) of the differences across groups.

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**
Programme (Comparison=0, Chemistry for All=1)	.021	.642	-.009	.839	-.010	.784	-.008	.774	-.006	.837
Cohort (Younger=0, Older=1)	-.026	.230	-.020	.328	-.016	.431	-.011	.552	-.012	.503
Gender (Girls=0, Boys=1)	**.164**	**<.001**	**.159**	**<.001**	**.138**	**<.001**	**.132**	**<.001**	**.121**	**<.001**
Books at home: 0-10 compared to 500+	**-.164**	**<.001**	**-.158**	**<.001**	**-.103**	**.013**	**-.095**	**.015**	**-.077**	**.034**
Books at home: 11-25 compared to 500+	**-.101**	**.016**	**-.115**	**.004**	**-.081**	**.041**	**-.093**	**.013**	**-.094**	**.007**
Books at home: 26-100 compared to 500+	**-.125**	**.004**	**-.126**	**.003**	**-.082**	**.047**	**-.095**	**.014**	**-.092**	**.011**
Books at home: 101-200 compared to 500+	**-.111**	**.001**	**-.110**	**.001**	**-.086**	**.007**	**-.088**	**.004**	**-.087**	**.002**
Books at home: 201-500 compared to 500+	**-.077**	**.008**	**-.075**	**.007**	**-.065**	**.018**	**-.081**	**.002**	**-.073**	**.003**
Family science (science-related job, qualifications, talks science)	**.276**	**<.001**	**.207**	**<.001**	**.149**	**<.001**	.039	.057	**.050**	**.010**
Perceptions of teachers: 'My chemistry/science teacher is interested in me as a person'	**.185**	**<.001**	**.098**	**<.001**	**.079**	**.001**	**.048**	**.039**	.034	.111
Perceptions of teachers: 'My chemistry/science teacher is good at explaining chemistry'	**.141**	**<.001**	**.054**	**.029**	**.050**	**.040**	.027	.232	-.018	.403
Teaching/learning experiences: practical/experimental			**.225**	**<.001**	**.180**	**<.001**	**.136**	**<.001**	**.063**	**.003**
Teaching/learning experiences: interaction/debate/discussion			**.141**	**<.001**	**.129**	**<.001**	**.108**	**<.001**	**.049**	**.030**
Extra-curricular engagement with science/chemistry					**.238**	**<.001**	**.136**	**<.001**	**.055**	**.006**
Encouragement to study science/chemistry: from family							**.177**	**<.001**	**.066**	**.005**
Encouragement to study science/chemistry: from teachers							**.228**	**<.001**	**.168**	**<.001**
Interest in chemistry									**.281**	**<.001**
Personal value of chemistry									**.177**	**<.001**
Explained variance	23.6%		30.9%		36.0%		44.5%		52.0%	
Unexplained variance (residual)	74.1%		67.2%		63.0%		54.9%		47.5%	
Unexplained variance (school)	2.2%		1.9%		1.0%		.6%		.5%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

◄ Table 12-7: Students' views at Year 11 predicting their Year 11 self-confidence in chemistry

outside what the standard like specification was for our grades and that helped in the exams because it was a slightly more novel context."

For Mark, the Chemistry for All programme also had a positive impact on his personal value of chemistry:

"It's [the Chemistry for All programme] shown me that it can be much more exciting than the textbooks make out, yes."

The Chemistry for All programme also had a positive impact on helping Mark realise what options were available to him with a post-16 chemistry qualification:

"I would say it has, yes, there's a variety of jobs that I'm aware of now which I wasn't before in the programme and I may well pursue those in the future, yes … Well, definitely helped with my GCSE grades because it was, it had a deeper understanding of the sciences and so then I got good grades so I was wanting to progress towards the scientific areas so it made a difference in that respect, yes."

Whilst these positive associations between the Chemistry for All programme and students' perceptions and identification with chemistry could lead to a choice to continue with chemistry, positive experiences did not necessarily entail positive chemistry aspirations for all students. For example, Priya had a less positive chemistry identity, despite coming from a family in advantaged socio-economic circumstances. Her family background did not, however, include having high science capital.

12.6. Chemistry for All shows the relevance of chemistry to everyday life through teaching about the wider applications of science and the impact on students' value of science to society

One important task that the Chemistry for All programme was able to do that schools were not able to do as well was to have practical experiments which could help link the relevance of chemistry to everyday life:

"I think kind of it was really interesting to me the practical side of it and so I found that I was really interested in doing that kind of thing in labs, at [the university], where we did the project, so I thought that kind of definitely made me more involved in the subjects. We had a practical while we were making thermochromic material. So, when you made it and then when you put you apply heat to it, it changed colour, and I thought that was really interesting. As well, we kind of made some suntan cream and Paracetamol, I thought that was really interesting because they were kind of effects that I saw in everyday life, but I didn't really understand what they were or how to make them and so those practicals I really enjoyed and I thought that was really helpful." (John)

Schools do not necessarily have extensive resources or facilities to conduct non-routine experiments. Additionally, it may be more difficult for schools to convey the wider applications of chemistry and its relevance to everyday life if they are unable to provide certain hands-on activities and/or practical experiments; nevertheless, practical work is not necessarily required in order to convey the wider relevance and applications of chemistry or science, and many teaching and learning approaches may be feasible. As one teacher put it:

"It would be impossible [to run the sort of experiments that Chemistry for All have conducted]. The amount of funding even for the chemicals, the equipment, for some of the practicals that have been done, we [the school] just haven't got the funds to be able to do that." (Teacher)

The interviews indicated that many students found that the practical elements of the Chemistry for All programme, which involve various demonstrations and university visits (and did not necessarily only involve practical laboratory work), helped them to see the relevance of chemistry to everyday life which in turn helped to boost students' personal value of chemistry and their intrinsic interest and enjoyment for chemistry:

"It was having a look around the university in all the different kind of labs and stuff, and having talks about what machines and what they do and what you can do with them and what you can find out. That was really interesting." (Mixed-race female)

Teachers also recognised and highlighted that the Chemistry for All programme raised students' interest and enjoyment in chemistry and the sciences, which in turn improved students' wider attitudes towards science at school.

"It's [Chemistry for All] encouraged them to join our STEM clubs and it's encouraged their enjoyment of the science lessons, yes." (Teacher)

One student highlighted that "I enjoy the practical's and the class work and everything" when asked why science was her favourite subject. When she was asked about the best parts about the Chemistry for All programme, she focused on how enjoyable the practicals were. Narrative notes from the researcher's observations illustrate how an event focused on careers in chemistry within the Chemistry for All programme ended with an experiment. This relatively small and additional activity helped to generate positive experiences for the students:

"Today rather than run just an afterschool club (which is optional every fortnight) the activity providers have conducted an activity available to all students who are at school within lesson time. The lesson was conducted in one of the school halls and it focused on careers in chemistry. Students were run through the different options and routes available to them and by the general discussions afterwards it appears that some students were not aware that a post-16 chemistry qualification could lead to a range of careers. From my observations I can't say for sure whether all students were enjoying and focused in on the lesson, I could tell that a fair few students were switching off part way through. However, at the end of the lesson the activity providers conducted an experiment, to show what would happen when certain chemicals are mixed together. Immediately I saw there was a change in the way students engaged with what was being taught to them, students appeared keen and interested. On their way out students were talking about the experiment and some tried to go over near the equipment, they were inquisitive and interested. Even I felt this was an exciting end to a potentially irrelevant topic to the vast majority of students who might have been thinking (prior to the event) chemistry is not for them. What was important about this particular lesson and activity was that it was mandatory and secondly it was a contained lesson which did not require prior knowledge or attendance to previous sessions to understand and fully benefit from what was being discussed." (Researcher's observation notes)

12.7. Value of chemistry/science to society

The value of chemistry to society covers chemistry being thought to improve people's living conditions, help understand the world, and being generally valuable to society. In order to gain further insights, students' views about the value of chemistry/science to society were considered in more detail.

Correlation analyses were conducted in order to ascertain what factors were linked with valuing science for society at Year 11 (**Table 12-8**). We investigated which indicators had the strongest associations with valuing science for society. The strongest associations at Year 11 were: perceived utility value ($R = .555$, $p < .001$), interest/enjoyment ($R = .555$, $p < .001$), and students' experiences of teaching that conveyed the wider application or relevance of science ($R = .546$, $p < .001$). Other associations were as follows:

- Number of books at home ($R = .161$, $p < .001$);
- Gender (identifying as a boy compared to as a girl: $R = .058$, $p < .001$);
- Family science capital ($R = .425$, $p < .001$);
- Exposure to teaching with hands-on activities ($R = .390$, $p < .001$);
- Exposure to teaching showing the wider applications of science ($R = .546$, $p < .001$);

- Exposure to teaching that enables interaction (R = .385, p < .001);
- Perceptions of the chemistry teacher (R = .382, p < .001);
- Extra-curricular engagement in science activities (R = .455, p < .001);
- Encouragement by chemistry teacher to study chemistry post-16 (R = .497, p < .001)
- Interest/enjoyment in chemistry (R = .556, p < .001);
- Being motivated to achieve better than anyone else / competitiveness (R = .301, p < .001);
- Perceived utility value of chemistry (R = .555, p < .001);
- Self-confidence in chemistry (R = .473, p < .001);
- Personal value of chemistry (R = .509, p < .001).

Similar magnitudes of association were seen for students at Year 9 (**Table 12-8**). The strongest associations at Year 9 were: extrinsic motivation (R = .599, p < .001), intrinsic motivation (R = .596, p < .001), and students being exposed to teaching which showed the wider application of science (R = .486, p < .001). Other associations were as follows:

- Number of books at home (R = .186, p < .001);
- Gender (identifying as a boy compared to as a girl: R = .066, p < .001);
- Family science capital (R = .374, p < .001);
- Exposure to teaching with hands-on activities (R = .312, p < .001);
- Exposure to teaching showing the wider applications of science (R = .486, p < .001);
- Exposure to teaching that enables interaction (R = .402, p < .001);
- Perceptions of the chemistry teacher (R = .430, p < .001);
- Extra-curricular engagement in science activities (R = .384, p < .001);
- Interest/enjoyment in chemistry (R = .596, p < .001);
- Being motivated to achieve better than anyone else/competitiveness (R = .345, p < .001);
- Perceived utility value in chemistry (R = .599, p < .001);
- Self-confidence in chemistry (R = .492, p < .001);
- Personal value of chemistry (R = .544, p < .001).

Indicator	Correlation between value of science/chemistry to society at Year 9 and students views at Year 9		Correlation between value of chemistry to society at Year 11 and students views at Year 11	
	R	Sig. (p)	R	Sig. (p)
School: Percentage of EAL	**.106**	**<.001**	.034	.112
Programme (Comparison=0, Chemistry for All=1)	-.011	.490	.013	.555
Cohort (Younger=0, Older=1)	-.027	.095	-.016	.453
Gender (Girls=0, Boys=1)	**.066**	**<.001**	**.058**	**.008**
Books at home	**.186**	**<.001**	**.161**	**<.001**
Family science (science-related job, qualifications, talks science)	**.374**	**<.001**	**.425**	**<.001**
Teaching/learning experiences: practical/experimental	**.312**	**<.001**	**.390**	**<.001**
Teaching/learning experiences: relevance/applications	**.486**	**<.001**	**.546**	**<.001**
Teaching/learning experiences: interaction/debate/discussion	**.402**	**<.001**	**.385**	**<.001**
Perceptions of teachers	**.430**	**<.001**	**.382**	**<.001**
Extra-curricular engagement with science/chemistry	**.384**	**<.001**	**.455**	**<.001**
Encouragement/shared extra-curricular engagement: from teachers	-	-	**.497**	**<.001**
Interest in science/chemistry	**.596**	**<.001**	**.556**	**<.001**
'I want to be one of the best students in my class'	**.345**	**<.001**	**.301**	**<.001**
Perceived utility of science/chemistry	**.599**	**<.001**	**.555**	**<.001**
Self-confidence in science/chemistry	**.492**	**<.001**	**.473**	**<.001**
Personal value of science/chemistry	**.544**	**<.001**	**.509**	**<.001**

Notes: Results from both cohorts combined. The table shows Pearson correlation coefficients (R values) and their significance ('Sig. (p)'; p-values).

◄ Table 12-8: Correlations between value of science/ chemistry to society at Year 9 and students' other views at Year 9, and between value of chemistry to society at Year 11 and students' other views at Year 11

Year 11 multi-variate analysis: Value of science to society

With these relationships outlined within the qualitative work and correlation analysis, a series of multi-level predictive models to explore what factors were the most important in explaining students' value of science for society were run at Year 11 (**Table 12-9**) and at Year 9 (**Table 12-10**). This analysis explored whether experiencing the wider applications/relevance of chemistry and/or science (as the Chemistry for All programme often did, and which the qualitative work indicated was important) indeed associated with students recognising the value of science to society. These models are different to the repeated measures analysis as they consider the questionnaire responses in a different way and they complement the knowledge generated by the repeated measures analysis. Multi-level predictive modelling essentially determined which factors independently explained variation in the students' reported value of science for society. Predictors were added in sequential steps: proportions of explained variance, deviance statistics, and chi-square likelihood ratio tests were used to consider how appropriate it was to use more complex models (i.e. whether complex models provided better fits than simpler models), together with examining the influence of individual predictors and their statistical significance.

At Year 11, in the first model only modelling students' background characteristics (**Table 12-9**, model 1), students' value of science for society was positively predicted by family science capital, socio-economic profile as measured by the number of books at home (students from the most advantaged backgrounds of having more than 500 books were more likely to value science for society), and gender (boys were more likely to value science for society).

Subsequently, the modelling also included teaching approaches (**Table 12-9,** model 2). Students' value of science for society was positively predicted by experiencing teaching that was hands-on (such as practical and experimental work) and by teaching that conveyed the wider applications/relevance of science.

Subsequently, students' valuing science for society was also positively predicted by their experiences of their chemistry teachers (**Table 12-9**, model 3) and by their engagement with extra-curricular activities (**Table 12-9**, model 4).

Ultimately, when also considering students' attitudes and beliefs (**Table 12-9**, model 6), students' valuing science for society was also positively predicted by experiencing teaching that conveyed the wider applications/relevance of science/chemistry, perceived utility of science, family science capital, engagement with extra-curricular science activities, interest/enjoyment of chemistry, perceptions of teachers, teachers encouraging students to study non-compulsory chemistry, and students being highly motivated to achieve.

This modelling supports some of the key findings from the qualitative work in that whilst social inequalities can have an influence on students' attitudes to science, the gap in views about chemistry can be reduced. The Chemistry for All programme has enabled students from disadvantaged backgrounds and/or from backgrounds that have lower levels of family science capital to have exposure and opportunities to engage in extra-curricular activities and/or acquire information about the relevance of science/chemistry to society. It appears what is most important is exposing students to teaching/learning that shows the wider applications of chemistry.

Table 12-9: Students' views at Year 11 predicting their Year 11 value of chemistry to society

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**
School: Percentage of EAL	.006	.855	-	-	-	-	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	.034	.431	-.007	.825	-.010	.751	-.009	.787	-.012	.711
Cohort (Younger=0, Older=1)	.005	.814	-.013	.497	-.020	.296	-.016	.384	-.002	.919
Gender (Girls=0, Boys=1)	**.078**	**<.001**	**.060**	**.001**	**.063**	**.001**	**.045**	**.012**	.033	.054
Books at home: 0-10 compared to 500+	**-.098**	**.029**	**-.094**	**.017**	**-.093**	**.018**	-.048	.215	-.018	.620
Books at home: 11-25 compared to 500+	-.033	.442	-.059	.114	-.055	.139	-.029	.426	-.023	.506
Books at home: 26-100 compared to 500+	.037	.407	.012	.755	.015	.705	.049	.200	.059	.105
Books at home: 101-200 compared to 500+	.021	.546	.011	.727	.013	.663	.025	.398	.033	.245
Books at home: 201-500 compared to 500+	.021	.480	.018	.491	.017	.512	.022	.389	.018	.475
Family science (science-related job, qualifications, talks science)	**.391**	**<.001**	**.237**	**<.001**	**.235**	**<.001**	**.185**	**<.001**	**.132**	**<.001**
Teaching/learning experiences: practical/experimental			**.102**	**<.001**	**.096**	**<.001**	**.069**	**.002**	.005	.804
Teaching/learning experiences: relevance/applications			**.387**	**<.001**	**.354**	**<.001**	**.321**	**<.001**	**.238**	**<.001**
Teaching/learning experiences: interaction/debate/discussion			.042	.074	-.003	.907	-.006	.789	-.036	.123
Perceptions of teachers					**.119**	**<.001**	**.105**	**<.001**	**.078**	**<.001**
Extra-curricular engagement with science/chemistry							**.214**	**<.001**	**.116**	**<.001**
Encouragement/shared extra-curricular engagement: from teachers									**.068**	**.002**
Interest in chemistry									**.095**	**<.001**
'I want to be one of the best students in my class'									**.051**	**.004**
Perceived utility of chemistry									**.221**	**<.001**
Self-confidence in chemistry									.045	.057
Personal value of chemistry									-.030	.309
Explained variance	19.9%		39.2%		39.8%		43.6%		49.9%	
Unexplained variance (residual)	78.4%		60.2%		59.3%		55.5%		49.2%	
Unexplained variance (school)	1.6%		.6%		.8%		.9%		.9%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

Year 9 multi-variate analysis: Value of science to society

Similar analysis was also undertaken to consider students' views in Year 9 (**Table 12-10**), mainly to examine whether there were any differences (which may have implications for future initiatives and activities). Whilst there were many similarities, there were two key differences. At Year 9, students' self-confidence in science positively predicted valuing science in society, whilst this was not clearly revealed in Year 11, once accounting for the various other predictors within the model. The second key difference was that experiencing teaching/learning that conveyed the wider applications/relevance of science had the strongest predictive association in Year 11, whereas the students' perceived utility of science had the strongest predictive association in Year 9.

Ultimately, in Year 9 (**Table 12-10**), students' valuing science/chemistry for society was also positively predicted by perceived utility of science/chemistry, teaching/learning that conveyed the wider applications/relevance of science/chemistry, interest/enjoyment in science, family science capital, perceptions of teachers, students' being motivated to achieve against their peers, engagement with extra-curricular activities, and self-confidence in science/chemistry.

Students' socio-economic profile as measured by the number of books at home was not significant in the final model, after accounting for the other predictors and measures, but was significant in interim stages of modelling (students from the most advantaged backgrounds of having more than 500 books were more likely to value science for society). Gender was initially associated with students' valuing science/chemistry for society (where boys were initially predicted to convey higher value than girls), but the subsequent stages of modelling suggested that this followed from boys and girls expressing different attitudes and beliefs (interest/enjoyment, perceived utility, self-confidence, and/or being motivated to achieve against their peers).

Table 12-10: Students' views at Year 9 predicting their Year 9 value of science/chemistry to society

Predictors	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)	β	Sig. (p)
Intercept	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**	**N/A**	**<.001**
School: Percentage of EAL	.089	.063	-	-	-	-	-	-	-	-
Programme (Comparison=0, Chemistry for All=1)	-.022	.663	-.073	.104	-.078	.095	-.068	.060	-.018	.529
Cohort (Younger=0, Older=1)	-	-	-	-	-	-	-	-	-	-
Gender (Girls=0, Boys=1)	**.123**	**<.001**	**.074**	**.001**	**.079**	**<.001**	**.048**	**.026**	.009	.661
Books at home: 0-10 compared to 500+	-.088	.104	**-.130**	**.008**	**-.121**	**.012**	**-.100**	**.033**	-.068	.110
Books at home: 11-25 compared to 500+	-.022	.664	-.075	.109	-.064	.167	-.043	.334	-.043	.289
Books at home: 26-100 compared to 500+	-.012	.829	-.074	.127	-.069	.148	-.041	.378	-.032	.442
Books at home: 101-200 compared to 500+	.044	.278	-.012	.745	-.009	.812	.003	.922	.001	.963
Books at home: 201-500 compared to 500+	.025	.482	-.015	.646	-.008	.801	-.001	.964	.007	.787
Family science (science-related job, qualifications, talks science)	**.310**	**<.001**	**.223**	**<.001**	**.210**	**<.001**	**.169**	**<.001**	**.092**	**<.001**
Teaching/learning experiences: practical/experimental			.022	.405	.010	.707	-.009	.729	-.035	.129
Teaching/learning experiences: relevance/applications			**.284**	**<.001**	**.228**	**<.001**	**.218**	**<.001**	**.153**	**<.001**
Teaching/learning experiences: interaction/debate/discussion			**.135**	**<.001**	**.074**	**.009**	**.059**	**.035**	-.024	.354
Perceptions of teachers					**.177**	**<.001**	**.159**	**<.001**	**.079**	**.001**
Extra-curricular engagement with science/chemistry							**.182**	**<.001**	**.066**	**.004**
Interest in chemistry									**.152**	**<.001**
'I want to be one of the best students in my class'									**.073**	**.001**
Perceived utility of science/chemistry									**.276**	**<.001**
Self-confidence in science/chemistry									**.054**	**.033**
Personal value of science/chemistry									.024	.462
Explained variance	23.9%		38.0%		39.6%		44.8%		56.1%	
Unexplained variance (residual)	72.1%		59.2%		57.3%		53.8%		43.0%	
Unexplained variance (school)	4.0%		2.8%		3.1%		1.4%		.8%	

Notes: Results from both cohorts combined. The table shows the standardised predictive coefficient ('β') and significance ('Sig. (p)'; p-values) per predictor.

13

Discussion

13. Discussion

The research and evaluation programme aimed to reveal the impact of the Chemistry for All programme, and to gain wider insights into students' progression towards science/chemistry, which could inform practices and policies within science/chemistry education.

13.1. Students' changing attitudes and aspirations

Students within schools that did and did not receive the Chemistry for All programme tended to express similar views at the start of the research programme. Initially, at Year 8 (age 12/13), students tended to convey positive views for: science/chemistry being valued as facilitating careers, jobs, and future opportunities in general (perceived utility value of science/chemistry); science/chemistry being thought to improve people's living conditions, help understand the world, and be generally valuable to society (value of science/chemistry to society); liking their teacher and perceiving that their teacher is fair, good at explaining science, and believes that all students can learn (perceptions of teachers); enjoying doing science/chemistry, finding it interesting, and looking forward to lessons (interest/enjoyment in science/chemistry); experiences of teaching/learning encompassing having opportunities to explain ideas and opinions, experiencing and engaging in a range of practical activities, and that teachers use science to help understand the world outside school; perceiving encouragement to continue with science/chemistry from their family; and perceiving that their family provides help, wants to talk about science work, and wants them to be successful in science (home support for science/chemistry achievement). Students expressed neutral views (around the middle of the disagreement to agreement scale) for: aspirations toward science/chemistry studying and careers (which encompassed intentions to study science/chemistry at A-Level, at university, and that they would like a job that includes science/chemistry); and feeling that they are good at and do well in science/chemistry (self-confidence in science/chemistry).

Students' views became less positive over time, but the changes tended to be smaller for students within schools that received the Chemistry for All programme. At Year 11 (age 15/16), students tended to convey: positive views regarding the value of chemistry to society and perceptions of their teachers; neutral views regarding utility value of chemistry, interest/enjoyment in chemistry, and experiences of teaching/learning; and negative views regarding their self-confidence in chemistry, perceived encouragement to continue with science/chemistry, and aspirations toward chemistry studying and careers. Students in schools that received the Chemistry for All programme conveyed higher views at Year 11 than students within comparison schools for: perceptions of teachers, teaching and learning experiences, aspirations toward chemistry, perceived utility of chemistry, extra-curricular engagement with science/chemistry, and interest/enjoyment in chemistry. These findings can be inferred to reflect the impact of the Chemistry for All programme, as well as potentially reflecting aspects of the programme itself, where students could engage with many extra-curricular activities and events, including science/chemistry clubs, practical demonstrations and workshops, and various other activities.

Changes in views from Year 8 to Year 11 tended to be smaller for students with greater engagement with the Chemistry for All programme (those who were recorded as attending at least one, and/or more than one, optional activity/event). Students with greater engagement with the programme showed slightly declining views but maintained positive perceived utility of chemistry, interest in chemistry, value of chemistry to society, and perceptions of teachers, all as of Year 11. Other patterns of changes over time also involved gender differences in views (including for science/chemistry aspirations) arising and/or increasing for students in schools that did not experience the Chemistry for All programme (with boys tending to express higher views than girls), while gender differences were not present or were smaller in magnitude for students in schools that received the Chemistry for All programme; nevertheless, this was only apparent within the younger cohort of students.

At Year 11, students tended to express disagreement towards continuing to studying and/or following a career in chemistry, although students in schools that received the Chemistry for All programme tended to convey slightly higher views than students in comparison schools. For example, at Year 11, for students in comparison schools, 18.3% of the younger cohort and 19.0% of the older cohort agreed or strongly agreed that they intended to continue to study chemistry at an A-Level or equivalent; for students in schools that received the Chemistry for All programme, 25.8% of the younger cohort and 20.4% of the older cohort agreed or strongly agreed that they intended to continue to study chemistry at an A-Level or equivalent. For students with greater engagement with the Chemistry for All programme (those who were recorded as attending more than one optional activity/event), 32.1% of the younger cohort and 26.9% of the older cohort agreed or strongly agreed that they intended to continue to study chemistry at an A-Level or equivalent. Similarly, again at Year 11, for students in comparison schools, 13.2% of the younger cohort and 15.2% of the older cohort agreed or strongly agreed that they would like a job that involves chemistry. For all students in schools that received the Chemistry for All programme, 24.5% of the younger cohort and 20.0% of the older cohort agreed or strongly agreed that they would like a job that involves chemistry. For students with greater engagement with the Chemistry for All programme, 32.1% of the younger cohort and 27.6% of the older cohort agreed or strongly agreed that they would like a job that involves chemistry. By way of comparison, in considering nationally representative samples across England, 18.6% of children aged 15 in 2006 and 29.7% of children aged 15 in 2015 expressed science-related career aspirations that encompassed all fields including chemistry (Sheldrake, Mujtaba, & Reiss, 2017a).

Students within schools that received the Chemistry for All programme, compared to comparison students, also had more positive views about the (self-perceived and self-reported) benefits arising from additional activities and events that they experienced or otherwise encountered at their schools. Specifically, more students within schools that received the Chemistry for All programme believed that activities/events increased their science/chemistry self-confidence, interest in science/chemistry, and knowledge about science/chemistry progressions, careers, and their associated benefits. At Year 11, the largest differences involved students in schools that received the Chemistry for All programme expressing higher perceptions that activities/events increased their knowledge about the careers available with a chemistry qualification and made them aware that anyone can be a scientist/chemist.

These various findings from the Chemistry for All programme offer important insights and a positive message: some students can be supported to maintain positive views across secondary education. Although students' views became less positive over time, those who received the Chemistry for All programme often expressed slightly more positive views than comparison students. Students' views becoming less positive over time is not necessarily unusual or unique to science/chemistry; older students have generally expressed less positive views than younger students across many academic subjects and other areas of life (Bennett & Hogarth, 2009; Eccles, Wigfield, Harold, & Blumenfeld, 1993; Fredricks & Eccles, 2002; Höft, Bernholt, Blankenburg, & Winberg, 2019; Wang, Chow, Degol, & Eccles, 2017), including for their interest in chemistry (Bennett & Hogarth, 2009; Cheung, 2009; Höft, Bernholt, Blankenburg, & Winberg, 2019). Prior research across English has also highlighted that gender differences in aspirations appear to increase because more boys move towards science and more girls move away from science during secondary school (Sheldrake, Mujtaba, & Reiss, 2017b; Sheldrake, 2018). The findings from the Chemistry for All programme affirm that action to mitigate against such trends can be possible, which may ultimately help increase accessibility and diversity within science and chemistry. From a wider perspective, many scientists have conveyed that their interests in science developed during secondary school, which affirms the importance of this time (Maltese & Tai, 2010; Maltese, Melki, & Wiebke, 2014; Venville, Rennie, Hanbury, & Longnecker, 2013). Across England, many adults have agreed that science learnt in school has been useful to their everyday lives (51% agreed, while 33% disagreed, and the remainder were neutral; Castell, et al., 2014), although fewer adults agreed that chemistry learnt in school has been useful to their everyday lives (31% agreed, while 44% disagreed; TNS BMRB, 2015). Encouragingly, few adults have agreed that school put them off science (23% agreed, while 63% disagreed; Castell, et al., 2014) or chemistry (24% agreed, while 49% disagreed; TNS BMRB, 2015). It may be beneficial to continue to highlight that change is possible and/or that providing support can help achieve benefits. Otherwise, assumptions or stereotypes about people needing to have early and/or consistent interests, aspirations, and orientations towards science may implicitly entail that others who gain interests during education might be seen as less valid, and potentially ensure that science and chemistry continue to be less accessible to many.

The various findings from the Chemistry for All programme highlight that the provision of diverse and long-lasting programmes of activities and events can be beneficial. Many other programmes and interventions have aimed to foster students' interests and/or aspirations towards science, with varying results but some successes (van den Hurk, Meelissen, & van Langen, 2019). Some earlier interventions also focused on students' attitudes towards science (Rosenzweig & Wigfield, 2016); for example, emphasising the relevance of science and explaining the experiences and work of scientists has helped to increase students' interest in science (Bernacki, Nokes-Malach, Richey, & Belenky, 2016; Hong & Lin-Siegler, 2012; Hulleman & Harackiewicz, 2009). Similarly, promoting the relevance and utility of science for students and parents has associated with higher science interest and attainment for students, and with students selecting courses in science (Harackiewicz, Rozek, Hulleman, & Hyde, 2012; Rozek, Hyde, Svoboda, Hulleman, & Harackiewicz, 2015). Specific interventions to promote chemical sciences as a beneficial career, to raise students' aspirations, and to promote links between educational and other organisations, have resulted in higher interest and career aspirations in students, but had greatest impact for those with existing aspirations (Lord, Straw, Springate, Harland, & Hart, 2008; Lord, Straw, Hart, Springate, & Harland, 2009). The findings from Chemistry for All were somewhat similar, with greater benefits being observed for those who specifically attended optional activities/events, who tended to express positive initial views. This implicitly highlights the continuing need to focus on accessibility and inclusion.

13.2. Insights into students' attitudes and views

Likes and dislikes

Considering students in schools that did and did not receive the Chemistry for All programme, many students conveyed that they liked experimental/practical work in science/chemistry, although this was less prevalent as students grew older. Some students appreciated their teachers, and highlighting this became more prevalent as students grew older. Students also liked: learning new things; learning many things and/or a variety of things; and learning about relevant things (including learning about the world and/or how things work). Students disliked having to write extensively (including have to write about experimental/practical work), although this was less prevalent as students grew older. As students grew older, they increasingly highlighted dislikes following from: material being considered to be difficult, complex, and/or hard to understand;

equations, formulae, and symbols; and that teaching/learning involved memorisation/remembering.

These findings help affirm and extend prior research, which has similarly highlighted that students have often appreciated experimental/practical work (Hamlyn, et al., 2020; Hamlyn, Matthews, & Shanahan, 2017; National Foundation for Educational Research, 2011). For example, prior research has highlighted that secondary school students (and their teachers) suggested that, in order to make chemistry more meaningful and interesting, more laboratory and practical work, and connecting chemistry education to everyday life situations, may be beneficial (Broman, Ekborg, & Johnels, 2011). The findings also affirm existing research that has highlighted that some students perceived chemistry as difficult, found challenges in meeting expectations, and found symbols, formulae, and language to be less accessible (Rüschenpöhler & Markic, 2020).

Practical work is often favoured and/or applied within science education because it is assumed to reflect the empirical nature of science, to help foster and support interest and enjoyment, and to improve students' understanding. The findings presented here help affirm some intuitions or assumptions behind the wider approaches for the Chemistry for All programme, which often involved practical experiments, demonstrations, and lectures that aimed to be enjoyable and inspirational for younger students, while events for older students often had other foci or approaches (such as helping revision and understanding for examinations). From a wider perspective, it may be challenging to ensure that curriculum content, pedagogies, and further aspects of teaching and learning can be refined, optimised, and/or otherwise balanced to best support students' learning and progression within science. For example, qualification reforms have meant that students in England are required to undertake a minimum number of practical activities in science at GCSE and at A-Level, and students are assessed on their knowledge, skills, and understanding of practical work in science at GCSE and at A-Level (Department for Education, 2020c; Ofqual, 2019). The findings presented here highlighted that, although many students liked experimental/practical activities, highlighting this became less prevalent as students grew older; concurrently, students increasingly found science/chemistry to be difficult, complex, and/or hard to understand. Compulsory assessment of practical activities may present particular challenges for complex areas of science and/or chemistry, and it may be beneficial to consult and engage with students regarding changes to educational policies.

Implications of aspects of teaching/learning

Analysis across students in schools that did and did not receive the Chemistry for All programme revealed that students' reports of their teacher using science/chemistry to help them understand the world outside school positively predicted their aspirations towards science/chemistry, their interest/enjoyment in science/chemistry, their perceived utility value of science/chemistry, their self-confidence in science/chemistry, and their perceived value of science/chemistry to society. Students reports of more frequently attending a science/chemistry club was also an important positive predictor of their views. Doing practical experiments and having the chance to explain ideas were also important positive predictors of interest/enjoyment of science/chemistry.

These areas offer potential avenues to help foster students' attitudes and beliefs, regardless of schools applying formalised programmes of activities/events. Additionally, the Chemistry for All programme provided science/chemistry clubs and likely involved (to some extent) debates, discussions, and chances for students to explain their ideas and views (whether formally or informally as part of the various activities/events). These findings may suggest how some programme benefits reach students. Previous research in England has also revealed that providing science clubs and also ambassadors (volunteers from science-related fields who visit schools to give career talks, provide advice, and deliver demonstrations) has resulted in students reporting higher interest in science, interest in studying science further, and aspirations towards science careers, compared to other students (Straw & Macleod, 2015).

13.3. Insights into students' aspirations

Predictive modelling and path analysis revealed the independent associations between aspects of students' home life, educational contexts, and attitudes and beliefs relating to science/chemistry, and their studying and career aspirations for science/chemistry. Some aspects of the Chemistry for All programme may have fostered students' interest, such as through experimental demonstrations and/or practical work, for example, or may have fostered students' perceived utility value of science/chemistry, such as through careers lectures within schools. Students' attitudes and beliefs can closely associate, and also associate with their aspirations and identities. Essentially, there may be many direct and/or indirect influences on students' aspirations towards science/chemistry.

Path analysis

Path analysis revealed that many aspects of life have direct and/or indirect associations with students' aspirations. Combining direct and indirect predictive associations, students' chemistry aspirations at Year 11 (encompassing A-Level, university, and career intentions) most strongly associated with their utility value of chemistry, personal value of chemistry, expected grades if A-Level chemistry were to be taken, encouragement to continue studying science/chemistry (from friends and from parents), extra-curricular engagement with science/chemistry, and teaching/learning experiences of practical/experimental work.

Many aspects of life, such as extra-curricular engagement, associate with students' personal attitudes and beliefs related to science/chemistry, which then associate with their aspirations. Because of the potential for indirect associations, many aspects of life may be more important than they might initially appear. These findings also suggest how some Chemistry for All programme benefits might reach students. Various extra-curricular activities, experiences of teaching/learning, and other aspects of life associate with students' attitudes and beliefs, which associate with their studying and career aspirations. Programme activities/events may be experienced positively and/or foster students' perceived utility of chemistry through greater awareness of the benefits of science/chemistry studying and careers, which may then associate with studying and career aspirations.

The students' perceived utility value of chemistry and personal value of chemistry were important independent predictors of students' aspirations for studying and careers in science/chemistry. Perceived utility value considers science/chemistry being valued as inherently supporting particular careers (such as agreeing that 'Making an effort in science/chemistry is worth it because it will help me in the work that I want to do later on' and/or 'I think science/chemistry will help me in the job I want to do in the future'). Perceived utility value of science and also interest in science/chemistry have often associated with students' aspirations towards science-related studying and careers (Bøe & Henriksen, 2015; Mujtaba & Reiss, 2014; Regan & DeWitt, 2015; Sheldrake, 2016). Students have often recognised that chemistry can be necessary or helpful for further careers, especially in medicine, health, and pharmacy (Springate, Harland, Lord, & Wilkin, 2008). Personal value considers science as a valued and inherent aspect of someone's identity (such as agreeing that 'Science/chemistry is important to me personally' and/or 'Thinking scientifically is an important part of who I am'). Personal value is an important aspect of motivational theories (Eccles, 2009), and has been found to positively associate with students' aspirations towards science-related studies and careers (Sheldrake, 2016).

Predictive modelling

Further cross-sectional analysis between Year 8 and Year 11 revealed numerous insights.

- Cross-sectional analysis indicated that students with increasing perceived utility value of science/chemistry (including increasingly more positive views about the benefits of chemistry/science qualifications) between Year 8 and Year 11 were more likely to express positive aspirations at Year 11. Changes in interest/enjoyment and self-confidence did not have the same effect. Fostering utility value may be most effective within programmes and initiatives.
- Increasing engagement in extra-curricular activities between Year 8 and Year 11 was not associated with students' aspirations at Year 11. This suggests that increasing participation in extra-curricular activities over time is not required for raising aspirations; some engagement each year may be sufficient and/or beneficial. Additionally, engagement with extra-curricular activities as of Year 11 had more impact on aspirations as of Year 11 than engagement with extra-curricular activities as of Year 8. This suggests that continuing to provide opportunities across secondary school remains beneficial.
- Helping students to develop a positive identity with science by ensuring they are confident in their abilities and learning of science (self-confidence beliefs at Year 8 and at Year 11) positively associated with their aspirations at Year 11.
- Receiving the Chemistry for All programme (compared to comparison schools) positively associated with students' chemistry aspirations (but not science aspirations), over and above their attitudes, beliefs, and other aspects of life. This is understandable, as the programme focused on chemistry rather than general science.
- Students who reported a positive home learning environment for science/chemistry were predicted to express higher aspirations, accounting for their attitudes, beliefs, and other aspects of life.
- Students who reported having more family science capital (family members having science-related qualifications, jobs, and/or interest in talking about science) were predicted to express higher aspirations, accounting for their attitudes, beliefs, and other aspects of life.
- Any impact of socio-economic circumstances was mediated by students' attitudes and beliefs. Essentially, regardless of background, someone with higher perceived utility, interest/enjoyment, and/or self-confidence could express positive aspirations.

13.4. Intersectionality between social disadvantage, gender, and ethnic background

There are a range of factors which associate with students' chemistry aspirations, which often have interrelated connections. For example, students with families with higher levels of science capital (family members having science-related qualifications, jobs, and/or interest in talking about science) were also more likely to have more advantaged socio-economic circumstances; both of these aspects of life were found to link with aspirations in various ways.

- Students' generally recognised the importance and value of science, but were generally less positive about non-compulsory science/

chemistry studying and careers. This disparity was even more prominent across students with different levels of socio-economic circumstances and family science capital.

- Social inequalities linked with differences in aspirations, as well as differences in perceived experiences of chemistry/science education. Some students may be more prepared and supported to appreciate and learn about sciences within school, given home learning environments that may broadly support and/or encourage learning for science/chemistry.
- Students from family backgrounds with higher science capital expressed higher science/chemistry aspirations, perceived utility of science/chemistry, self-confidence beliefs, and other attitudes, as well as more positive perceptions of science teaching, and were more likely to engage in extra-curricular activities.
- Students from family backgrounds with more advantaged socio-economic circumstances expressed higher science/chemistry aspirations, perceived utility of science/chemistry, self-confidence beliefs, interest/enjoyment, and other science attitudes, as well as more positive perceptions of science teaching, and were more likely to engage in extra-curricular science activities.

Chemistry as a 'door-opener' discourse

One theme that was prevalent from the students' interview narratives was recognition of the use and utility of chemistry qualifications (as facilitating careers, jobs, and future opportunities in general), essentially with chemistry qualifications being a potential 'door opener'.

- Students from under-represented groups (such as girls, those from ethnic minority backgrounds, and/or those with less advantaged socio-economic circumstances) who had attended Chemistry for All events specifically covering the topic of careers, were able to become more enthused about non-compulsory chemistry courses and make more informed decisions about continuing with chemistry.
- The Chemistry for All programme helped students, especially those from under-represented groups, to become aware of and understand the connections between non-compulsory chemistry qualifications and the careers and courses that subsequently become available.
- The Chemistry for All programme was able to support girls, those from ethnic minority backgrounds, and/or those with less advantaged socio-economic circumstances to align their future selves with chemistry.
- The quantitative results revealed that perceived utility value (science/chemistry being useful and valued for facilitating careers, jobs, and future opportunities in general) followed by personal value of chemistry (chemistry being a valued and inherent aspect of identity) were the strongest predictors of students' aspirations. The qualitative results indicated that the two measures could intersect, and with implications to students' wider trajectories. Specifically, if students could not easily consider chemistry to be an inherent aspect of their identity, but recognised the utility of chemistry, they could consider chemistry A-Level as an avenue towards other professions such as medicine rather than chemistry. Holding a personal value of chemistry may be especially important to continue within chemistry.

Natural ability and non-compulsory choices

Another prevalent theme from the students' interview narratives involved 'natural talent and/or cleverness': only students who were perceived to be naturally good at chemistry with little effort were perceived to be the ones who could legitimately remain within chemistry. These beliefs could help to reinforce some students' decisions to remain in non-compulsory chemistry education, especially those from families with supportive home-learning environments for science, with higher levels of family science capital, and/or more advantaged socio-economic circumstances. However, the perceptions and discourse around 'natural ability' could discourage some other students from chemistry.

- There was a gender-specific construction among young women where chemistry was associated with requiring hard work and/or requiring natural ability, which could lead to some young women deciding not to study non-compulsory chemistry. Essentially, attaining a positive chemistry identity could be difficult for young women if they continued to compare themselves with the notion of being successful in chemistry as meaning being 'naturally clever'.
- Some young women internalised problems with their chemistry learning, linking increasing difficulties and lower confidence with feeling that chemistry required natural ability. Some young men externalised any problems, where increasing difficulties did not necessarily reflect anything about themselves (and/or through identifying with the notion that they held a natural aptitude) and that matters could still be achievable with persistence, which could help protect their chemistry identities.
- Some young women (from other under-represented backgrounds) were able to align their future selves with chemistry, because of the Chemistry for All programme. Various inspirational and enjoyable experiences were cited, together with their increasing

understanding of careers, and through seeing the people who helped to deliver some of the Chemistry for All activities and events (such as university students who were seen as relatable role-models). Some young women also reported becoming more confident in chemistry because of Chemistry for All activities.

- Young men from families with higher levels of family science capital and/or more advantaged socio-economic circumstances were nevertheless the most confident in their abilities in chemistry, and more likely to make firm decisions about continuing with the sciences at university.

Further programmes and initiatives that help to break down the notion of natural ability in chemistry may help to keep more young women, particularly those from disadvantaged backgrounds, within trajectories towards chemistry.

Confidence in chemistry

Girls and boys with aspirations towards studying A-Level chemistry reported similar views about their expected GCSE and A-Level grades, similar attitudes to chemistry, and similar perceptions of their chemistry education. However, girls with aspirations towards studying A-Level were less likely to express that they were good at chemistry and were able to do well in chemistry, compared to boys with aspirations towards studying A-Level. Within their interview narratives, some girls questioned their abilities in chemistry, despite having high attainment. Lower confidence in their own abilities, particularly in the context of natural ability discourses, may ensure that girls find it harder to align their own identities with chemistry.

Further analysis considered how students' self-confidence beliefs might be supported and/or fostered. Students' self-confidence beliefs positively associated with the following, in addition to boys tending to express higher self-confidence than girls:

- Higher interest/enjoyment in chemistry;
- Higher personal value of chemistry;
- More encouragement to continue studying chemistry after GCSEs;
- More experiences of practical/ experimental work and debate/discussion in teaching/learning;
- More engagement with extra-curricular activities;
- Higher levels of family science capital;
- More advantaged socio-economic circumstances (numbers of books at home).

Relevance of chemistry and science to everyday life and society

Beliefs about the value of chemistry to society encompass chemistry being thought to improve people's living conditions, help understand the world, and to be generally valuable to society. Students' interview narratives conveyed that they found that the practical elements of the Chemistry for All programme helped them to see the relevance of chemistry to everyday life, which, in turn, helped to foster their personal value of chemistry and their interest/ enjoyment of chemistry. Students' questionnaire responses revealed that their beliefs about the value of chemistry to society were positively associated with experiencing teaching/learning that conveyed the wider applications and relevance of science, perceived utility of science, participation in extra-curricular activities, perceptions of teachers, interest/ enjoyment of chemistry, teachers encouraging them to study chemistry after GCSEs, and being motivated towards higher achievement through competitiveness. Additionally, boys expressed more positive perceptions about the value of science to society than girls; students with higher levels of family science capital were also more likely to value science for society.

13.5. Wider implications

Much attention has focused on increasing the numbers of students studying science-related subjects at school and university so that they could then follow science-related careers (Royal Society of Chemistry, 2014; Royal Society, 2014). The Chemistry for All programme highlights that some benefits to students' views, including to their studying and career aspirations, are achievable through the provision of diverse and long-lasting programmes of activities and events. This broadly affirms the benefit of providing and maintaining support so that studies and careers in chemistry can be considered to be feasible and achievable. Wider research in England affirms the benefit of support: some students can and do maintain or even gain connections to science during secondary school, and it remains important to ensure that this can be possible for everyone (Sheldrake & Mujtaba, 2019; Sheldrake, 2018). Nevertheless, students' home and school circumstances, and wider aspects of society, also remain relevant; any one programme such as Chemistry for All cannot feasibly or realistically impact all of these areas. In addition to supporting students, the fields of education and science may also benefit from changes to increase accessibility and so that more pathways into studying and careers become available.

Students can be supported and benefits are possible

The Chemistry for All programme highlights that some benefits are achievable. Emerging research in England has also highlighted that some students can and do maintain (or may even gain) connections to science during secondary school (Sheldrake & Mujtaba, 2019; Sheldrake, 2018). It remains important to recognise that students may not necessarily lack aspirations, interest, and/or positive views; students are also not at fault if they do not choose science/chemistry studying or career avenues. The underlying issue may involve providing and maintaining support so that science/chemistry studying and careers can be consistently considered to be feasible and achievable, while removing any avoidable barriers so that free and informed choices can be made. From a wider perspective, much attention has focused on increasing the numbers of students studying science-related subjects, so that they could then follow science-related careers (Royal Society of Chemistry, 2014; Royal Society, 2014). Concurrently, the fields of education and science could also change to increase accessibility.

What should future interventions focus on?

Pervasive inequalities continue to impact students' attitudes, possible access to extra-curricular activities, how students experience their learning, and access to support and encouragement to continue with non-compulsory chemistry. Starting interventions early may be helpful, and maintaining provision across secondary education is likely to be beneficial and maximise potential accessibility. The main areas that future interventions may benefit from focusing on are: wider aspects of life and role models; increasing awareness of the benefits of careers and courses; providing programmes that facilitate engagement from all students, conducted during regular teaching and learning time; and building chemistry identities and addressing discourses of 'natural ability' being the only legitimate path to chemistry careers. This may require further support for schools to help with engagement and delivery, and to reduce burdens on schools and teachers. In order to keep schools engaged with a support programme, particularly one that spans more than a year, commitment is required from school leadership to help support teachers and the overall delivery.

Future programmes could increase accessibility through working with schools to integrate activities and events within the science curriculum. Teachers encouraging students to continue with non-compulsory chemistry was a significant predictor of students' aspirations. Future interventions could use continuing professional development to help teachers understand the importance of their interactions with students and the issues around breaking down the discourse of natural ability.

Wider aspects of life and role models

The findings broadly highlighted the relevance of many aspects of life that may be outside of the scope of programmes such as Chemistry for All. For example, encouragement to continue studying chemistry from friends, parents, and teachers each had independent and positive overall associations with students' aspirations (encompassing direct and indirect associations). This highlights the inherent challenge of supporting students who experience diverse influences across many aspects of life.

Nevertheless, programmes and initiatives can still help mitigate challenges and/or provide benefits. For example, family members, teachers, and/or wider media can provide role models. The students' interview narratives revealed that some young women highlighted that the Chemistry for All delivery teams (including university students who visited schools) helped make chemistry feel more accessible, through providing visible and more relatable people to act as and/or become role models.

Increasing awareness of the benefits of careers and courses

Perceived utility value / extrinsic motivation in chemistry encompasses science/chemistry being valued as inherently supporting particular careers, as well as careers and wider benefits in general. Increasing utility value between Year 8 and Year 11 associated with higher aspirations for studying and careers, in chemistry and science in general. Future programmes may benefit from focusing on perceptions of utility / extrinsic motivation in chemistry. The students' interview narratives also revealed that raising ethnic minority girls' awareness about the benefits of a non-compulsory qualifications helped to combat some of the issues around their confidence and the dominant discourse of 'natural ability' in chemistry.

Facilitating engagement

Students with greater engagement with the Chemistry for All programme showed the greatest benefits. Nevertheless, students with greater engagement with the Chemistry for All programme may have selected themselves, and often (but not always) also tended to express more positive initial views at Year 8 than the comparison students. Students may not have wanted and/or been able to attend optional activities for various reasons.

Previous interventions to promote chemistry resulted in higher interest and career aspirations in students, and had the greatest impact for those with existing aspirations (Lord, Straw, Springate, Harland, & Hart, 2008; Lord, Straw, Hart, Springate, & Harland, 2009). The findings from Chemistry for All were somewhat similar: benefits were observed, on average, across all students within the schools that received the Chemistry for All programme, compared to comparison students; within the Chemistry for All programme, those who attended more optional activities/events reported the most positive views (and also tended to express positive initial views). This implicitly highlights the continuing need to focus on accessibility and inclusion, even (and perhaps especially) within wider programmes.

Integrating programmes of support within regular teaching/learning (and/or other actions to mitigate inaccessibly) may help ensure that benefits can reach all students. Teachers may benefit from further support and development to implement any additional activities. Engaging with school leadership may also help facilitate and ensure lasting and holistic changes within schools.

Chemistry identities and tackling discourses of natural ability

Personal value considers science/chemistry as a valued and inherent aspect of someone's identity. Becoming a 'science person' may involve reconciling various expectations or beliefs about who someone is and what someone can do against who 'science people' are thought to be and what they are thought to do (Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007). Challenges may arise when someone may not see themselves as good at science, for example, and/or when they are not recognised by others (Calabrese Barton, et al., 2013; Tan, Calabrese Barton, Kang, & O'Neill, 2013). Various social and cultural expectations may also influence what people consider to be appropriate for themselves, and/or 'people like me', which can influence their educational choices (Archer, et al., 2010).

Many expectations and/or stereotypes may be relevant, and may need to be addressed, in order to help create more accessible images and ideals of science and/or the people who do science. For example, it may be beneficial to address assumptions of 'natural ability' being necessary for participation and/or identities. Different students may face different challenges around these areas; the interview narratives revealed how some young men externalised problems or challenges with chemistry learning, for example, while some young women internalised issues and perceived that they were not good enough in chemistry. Discourses of ability, effort, and difficulty could potentially be addressed within school teaching and learning, as well as through wider messages.

13.6. Recommendations

In order to increase the number of students who continue with chemistry post-16 and increase the numbers from under-represented groups, policy and practice needs to address a number of issues.

- Careers advice and information about the range of courses and qualifications available with a post-16 chemistry qualification should be made available in early secondary school; this will help more students realise that there are a range of paths that they can take.
- Students' perceived utility value/extrinsic motivation in science will help to keep students in the science pipeline. Nevertheless, perceived utility value alone may not be sufficient to keep students within chemistry, particularly if chemistry is used as a stepping stone into medicine and other careers, and building students' personal value in chemistry may be beneficial.
- Inequalities within chemistry education may persist because students' personal circumstances can impact how students perceive their chemistry/science education and also play a key role in how students develop a chemistry identity and future aspirations. If there is no acceptance that students' personal circumstances can be barriers or facilitators of aspirations and identification, then school pedagogy and other aspects of education cannot be altered to help mitigate such issues. The Chemistry for All programme has shown that targeting students from disadvantaged backgrounds can indeed draw students into the chemistry pipeline and strengthen their identification with chemistry.
- Changing school practices and helping to tackle dominant representations of chemistry both amongst teachers and students is a long-term strategy that practitioners and policymakers may need to consider.
- The Chemistry for All programme was geared towards reducing the aspirations gap between socio-economic groups, which appeared to be achieved. However, issues around gender were still apparent; specifically, girls and boys believed that having natural ability was the only legitimate pathway into chemistry, which helped create a particular barrier for some girls.
- In order to raise the number of students from under-represented groups continuing towards chemistry, more needs to be done to target and tailor funding, resources, and support for under-represented groups. A 'one-size-fits-all' approach will not necessarily work, particularly when addressing social inequalities that arise from students' personal circumstances.
- Students from disadvantaged backgrounds are less likely to have family science capital and/or a home learning environment which focuses on chemistry achievement, which can limit students' self-confidence. Opportunities to get involved in extra-curricular activities would help students, particularly if they are able to make connections with role models and feel that chemistry can be for 'people like me'.
- More needs to be done to change how chemistry is presented and portrayed. Regular teaching will always struggle to engage certain student groups if dominant representations of chemistry are not challenged within the classroom itself. Examples of successful people in chemistry who have 'worked hard' rather than rely on 'natural cleverness' will help to make chemistry feel more appealing and approachable to a range of students.
- Schools can be gatekeepers of who can continue to study post-16 chemistry. Schools could be encouraged to reflect on and/or lower the entrance grades into post-16 chemistry so that they are equivalent to other subjects, for example, rather than being higher.
- Experiencing practicals and experimentals linked with students' aspirations. Schools may benefit from more resources and support to deliver such experiences, including opportunities for partnerships with universities and industries.

We recommend that specific organisations help to increase chemistry participation in a number of ways.

Government, awarding bodies, professional organisations, and others involved in determining education policy

- Avoid chemistry being seen as a difficult subject only suitable for 'naturally clever' students.
- Provide examples in curricula of successful people in chemistry who have 'worked hard' rather than rely on 'natural cleverness'.
- Ensure a diversity of people (including across age, ethnicity, gender and other aspects of people's identities, characteristics, and circumstances) are portrayed as contributing to chemistry and working in it and with it.
- Facilitate partnerships between schools and organisations (including universities, professional bodies, and industries) that can complement what schools do for students' learning of and engagement with chemistry.

Schools

- Help students to see the relevance of chemistry, not just to possible careers in medicine but to society more generally.
- Help students to see the relevance of chemistry to themselves, both in terms of possible jobs and in terms of general understanding.
- Ensure students understand the fundamentals of the subject so that they can maintain their confidence in their chemistry ability.
- Keep students engaged with chemistry so that they retain interest and motivation.
- Do not give students the impression that some students are 'naturally good at chemistry' or 'naturally clever'; rather, communicate the benefits of working steadily with persistence and enthusiasm.
- Encourage all students to think about the possibility of continuing with non-compulsory chemistry studies.
- Do not have higher grade requirements for non-compulsory studies in chemistry than for other subjects.
- From early in secondary school, provide careers advice and information about the range of courses and qualifications available with chemistry qualifications.
- Ensure girls receive at least as much encouragement as boys.
- Especially among younger students, ensure there is sufficient practical work in chemistry.
- Keep memorisation to a minimum.
- Only get students to write where there is a clear need.
- Where there are optional events or activities, such as out-of-school visits or chemistry/science clubs, ensure that all students are able to access these.
- Give students and their chemistry teachers the opportunity to build good, professional relationships that sometimes last for more than a single year.
- Provide a small number of high-quality extra-curricular engagements with chemistry, rather than large numbers of lower-quality ones.
- Provide careers events where knowledgeable people are positive about chemistry, as these can attract students who might otherwise not continue with it.

University/outreach providers

- Help give students access to high-quality practical work in chemistry and to see the diversity of people who work with and in chemistry.
- Work with teachers in a way that does not require them to miss classes.
- Build relationships with local schools in ways that do not rely on the enthusiasm of just one or two teachers in a school.
- Take active steps to ensure that your provision is not predominantly taken up by more advantaged students, such as students with families that encourage them to attend optional events, and students who can attend events held off school premises.

Funders

- It is better to target funding on a relatively small number of schools over a period of several to many years than to target a larger number of schools for just one or two years.
- Keep schools engaged, particularly senior management, and reduce the demands made on their time.

Parents

- Be positive about the worth of learning chemistry.
- Encourage your child to value learning about chemistry and participating in extra-curricular chemistry activities.
- Communicate to your child that everyone can succeed at learning chemistry.
- Communicate to your child that chemistry benefits all of us in society.

Media

- Communicate how chemistry benefits society.
- Promote the view that chemistry is a diverse profession, both with regards to what it entails and to who undertakes it.

14

References

14. References

Abrahams, I., & Reiss, M. (2012). Practical Work: Its Effectiveness in Primary and Secondary Schools in England. *Journal of Research in Science Teaching, 49*(8), 1035-1055. doi:10.1002/tea.21036

Allen, K., Kern, M., Vella-Brodrick, D., Hattie, J., & Waters, L. (2018). What Schools Need to Know About Fostering School Belonging: a Meta-analysis. *Educational Psychology Review*, 30(1), 1-34. doi:10.1007/s10648-016-9389-8

Archambault, I., Eccles, J., & Vida, M. (2010). Ability Self-Concepts and Subjective Value in Literacy: Joint Trajectories From Grades 1 Through 12. *Journal of Educational Psychology*, 102(4), 804-816. doi:10.1037/a0021075

Archer, L., & DeWitt, J. (2017). *Understanding young people's science aspirations: How students form ideas about 'becoming a scientist'*. Abingdon: Routledge.

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching, 52*(7), 922-948. doi:10.1002/tea.21227

Archer, L., DeWitt, J., & Osborne, J. (2015). Is Science for Us? Black Students' and Parents' Views of Science and Science Careers. *Science Education, 99*(2), 199-237. doi:10.1002/sce.21146

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education, 94*(4), 617-639. doi:10.1002/sce.20399

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science Aspirations, Capital, and Family Habitus: How Families Shape Children's Engagement and Identification With Science. *American Educational Research Journal, 49*(5), 881-908. doi:10.3102/0002831211433290

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013a). 'Not girly, not sexy, not glamorous': primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society, 21*(1), 171-194. doi:10.1080/14681366.2012.748676

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Wong, B., & Willis. (2013b). ASPIRES: *Young people's science and career aspirations, age 10-14*. London: King's College London.

Archer, L., Moote, J., & MacLeod, E. (2020). Learning that Physics is 'Not for Me': Pedagogic Work and the Cultivation of Habitus among Advanced Level Physics Students. *Journal of the Learning Sciences*, 1-38. doi:10.1080/10508406.2019.1707679

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (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. *American Educational Research Journal, 54*(1), 88-126. doi:10.3102/0002831216678379

Archer, L., Moote, J., MacLeod, E., Francis, B., & DeWitt, J. (2020). ASPIRES 2: *Young people's science and career aspirations, age 10-19*. London: UCL Institute of Education.

Archer, L., Nomikou, E., Mau, A., King, H., Godec, S., DeWitt, J., & Dawson, E. (2019). Can the subaltern 'speak' science? An intersectional analysis of performances of 'talking science through muscular intellect' by 'subaltern' students in UK urban secondary science classrooms. *Cultural Studies of Science Education, 14*(3), 723-751. doi:10.1007/s11422-018-9870-4

Aschbacher, P., Li, E., & Roth, E. (2010). Is Science Me? High School Students' Identities, Participation and Aspirations in Science, Engineering, and Medicine. *Journal of Research in Science Teaching, 47*(5), 564-582. doi:10.1002/tea.20353

Aslam, F., Adefila, A., & Bagiya, Y. (2018). STEM outreach activities: an approach to teachers' professional development. *Journal of Education for Teaching, 44*(1), 58-70. doi:10.1080/02607476.2018.1422618

Bandura, A. (1986). *Social foundations of thought and action: a social cognitive theory*. Englewood Cliffs, New Jersey: Prentice-Hall.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*(9), 1175-1184. doi:10.1037/0003-066X.44.9.1175

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: Freeman.

Bennett, J., & Hogarth, S. (2009). Would You Want to Talk to a Scientist at a Party? High school students' attitudes to school science and to science. *International Journal of Science Education, 31*(14), 1975-1998. doi:10.1080/09500690802425581

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education, 91*(3), 347-370. doi:10.1002/sce.20186

Bernacki, M., Nokes-Malach, T., Richey, J. E., & Belenky, D. (2016). Science diaries: a brief writing intervention to improve motivation to learn science. *Educational Psychology, 36*(1), 26-46. doi:10.1080/01443410.2014.895293

Blenkinsop, S., McCrone, T., Wade, P., & Morris, M. (2006). *How do young people make choices at 14 and 16? DfES Research Report 773*. Nottingham: Department for Education and Skills.

Bøe, M. V., & Henriksen, E. K. (2015). Expectancy-Value Perspectives on Choice of Science and Technology Education in Late-Modern Societies. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding Student Participation and Choice in Science and Technology Education* (pp. 17-29). Dordrecht: Springer. doi:10.1007/978-94-007-7793-4_2

Bøe, M., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: young people's achievement-related choices in late-modern societies. *Studies in Science Education, 47*(1), 37-72. doi:10.1080/03057267.2011.549621

Bong, M., & Skaalvik, E. (2003). Academic Self-Concept and Self-Efficacy: How Different Are They Really? *Educational Psychology Review, 15(*1), 1-40. doi:10.1023/A:1021302408382

Bonnette, R., Crowley, K., & Schunn, C. (2019). Falling in love and staying in love with science: ongoing informal science experiences support fascination for all children. *International Journal of Science Education, 41*(12), 1626-1643. doi:10.1080/09500693.2019.1623431

British Academy. (2015). *Count us in: Quantitative skills for a new generation*. London: British Academy.

Broman, K., & Parchmann, I. (2014). Students' application of chemical concepts when solving chemistry problems in different contexts. *Chemistry Education Research and Practice, 15*(4), 516-529. doi:10.1039/C4RP00051J

Broman, K., Ekborg, M., & Johnels, D. (2011). Chemistry in crisis? Perspectives on teaching and learning chemistry in Swedish upper secondary schools. *Nordic Studies in Science Education, 7*(1), 43-60.

Buschor, C. B., Berweger, S., Frei, A. K., & Kappler, C. (2014). Majoring in STEM—What Accounts for Women's Career Decision Making? A Mixed Methods Study. *The Journal of Educational Research, 107*(3), 167-176. doi:10.1080/00220671.2013.788989

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a Future in Science: Tracing Middle School Girls' Identity Work Over Time and Space. *American Educational Research Journal, 50*(1), 37-75. doi:10.3102/0002831212458142

Carlone, H., & Johnson, A. (2007). Understanding the Science Experiences of Successful Women of Color: Science Identity as an Analytic Lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218. doi:10.1002/tea.20237

Castell, S., Charlton, A., Clemence, M., Pettigrew, N., Pope, S., Quigley, A., . . . Silman, T. (2014). *Public Attitudes to Science 2014*. London: Ipsos MORI.

Cavagnetto, A. (2010). Argument to Foster Scientific Literacy: A Review of Argument Interventions in K–12 Science Contexts. *Review of Educational Research, 80*(3), 336-371. doi:10.3102/0034654310376953

Cheung, D. (2009). Students' Attitudes Toward Chemistry Lessons: The Interaction Effect between Grade Level and Gender. *Research in Science Education, 39*, 75-91. doi:10.1007/s11165-007-9075-4

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, New Jersey: Lawrence Earlbaum Associates.

Dabney, K., Tai, R., Almarode, J., Miller-Friedmann, J., Sonnert, G., Sadler, P., & Hazari, Z. (2012). Out-of-School Time Science Activities and Their Association with Career Interest in STEM. *International Journal of Science Education, Part B: Communication and Public Engagement, 2*(1), 63-79. doi:10.1080/21548455.2011.629455

De Fraine, B., Van Damme, J., & Onghena, P. (2007). A longitudinal analysis of gender differences in academic self-concept and language achievement: A multivariate multilevel latent growth approach. *Contemporary Educational Psychology, 32*(1), 132-150. doi:10.1016/j.cedpsych.2006.10.005

Department for Education. (2011). *Maths and science education: the supply of high achievers at A level. Research Report DFE-RR079*. London: Department for Education.

Department for Education. (2014). *The national curriculum in England: Framework document*. London: Department for Education. Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-framework-for-key-stages-1-to-4

Department for Education. (2020a). *Find and compare schools in England*. Retrieved from https://www.compare-school-performance.service.gov.uk/download-data

Department for Education. (2020b). *Get information about schools.* Retrieved from https://get-information-schools.service.gov.uk/Downloads

Department for Education. (2020c). *Secondary accountability measures: Guide for maintained secondary schools, academies and free schools*. London: Department for Education.

DeWitt, J., Archer, L., & Mau, A. (2016). Dimensions of science capital: exploring its potential for understanding students' science participation. *International Journal of Science Education, 38*, 2431-2449. doi:10.1080/09500693.2016.1248520

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related Aspirations Across the Primary–Secondary Divide: Evidence from two surveys in England. *International Journal of Science Education, 36*(10), 1609-1629. doi:10.1080/09500693.2013.871659

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: the science aspirations-careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education, 9*(2), 243-271. doi:10.1007/s10763-010-9245-0

EACEA. (2011). *Science Education in Europe: National Policies, Practices and Research*. Brussels: European Commission. doi:10.2797/7170

Eccles, J. (2009). Who Am I and What Am I Going to Do With My Life? Personal and Collective Identities as Motivators of Action. *Educational Psychologist, 44*(2), 78-89. doi:10.1080/00461520902832368

Eccles, J., Wigfield, A., Harold, R., & Blumenfeld, P. (1993). Age and Gender Differences in Children's Self- and Task Perceptions during Elementary School. *Child Development, 64*(3), 830-847. doi:10.1111/j.1467-8624.1993.tb02946.x

Elias, P., Jones, P., & McWhinnie, S. (2006). *Representation of Ethnic Groups in Chemistry and Physics*. London: The Royal Society of Chemistry and the Institute of Physics.

EngineeringUK. (2018). *Engineering UK 2018: The state of engineering*. London: EngineeringUK.

Erduran, S., & Jiménez-Aleixandre, M. P. (Eds.). (2007). *Argumentation in Science Education: Perspectives from Classroom-Based Research*. Dordrecht/London: Springer. doi:10.1007/978-1-4020-6670-2

Fredricks, J., & Eccles, J. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology, 38*(4), 519-533. doi:10.1037/0012-1649.38.4.519

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research, 74*(1), 59-109. doi:10.3102/00346543074001059

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. (2012). Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching: A Meta-Analysis. *Review of Educational Research, 82*(3), 300-329. doi:10.3102/0034654312457206

Gatsby. (2018). *Key Indicators in STEM Education*. London: The Gatsby Charitable Foundation.

Gatsby Charitable Foundation. (2017). *Good Practical Science*. London: Gatsby Charitable Foundation.

Godec, S., King, H., & Archer, L. (2017). *The Science Capital Teaching Approach: engaging students with science, promoting social justice*. London: University College London.

Hamlyn, B., Hanson, T., Malam, S., Man, C., Smith, K., & Williams, L. (2020). *Young people's views on science education: Science Education Tracker 2019: Wave 2*. London: Wellcome Trust.

Hamlyn, R., Matthews, P., & Shanahan, M. (2017). *Young people's views on science education: Science Education Tracker Research Report February 2017*. London: Wellcome Trust.

Harackiewicz, J., Rozek, C., Hulleman, C., & Hyde, J. (2012). Helping Parents to Motivate Adolescents in Mathematics and Science: An Experimental Test of a Utility-Value Intervention. *Psychological Science, 23*(8), 898-906. doi:10.1177/0956797611435530

Hodson, D. (1993). Re-thinking Old Ways: Towards A More Critical Approach To Practical Work In School Science. *Studies in Science Education, 22*(1), 85-142. doi:10.1080/03057269308560022

Höft, L., Bernholt, S., Blankenburg, J., & Winberg, M. (2019). Knowing more about things you care less about: Cross-sectional analysis of the opposing trend and interplay between conceptual understanding and interest in secondary school chemistry. *Journal of Research in Science Teaching, 56*(2), 184-210. doi:10.1002/tea.21475

Holmegaard, H. T. (2015). Performing a Choice-Narrative: A qualitative study of the patterns in STEM students' higher education choices. *International Journal of Science Education, 37*(9), 1454-1477. doi:10.1080/09500693.2015.1042940

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2014). To Choose or Not to Choose Science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education, 36*(2), 186-215. doi:10.1080/09500693.2012.749362

Holmegaard, H. T., Ulriksen, L., & Madsen, L. M. (2014). The Process of Choosing What to Study: A Longitudinal Study of Upper Secondary Students' Identity Work When Choosing Higher Education. *Scandinavian Journal of Educational Research, 58*(1), 21-40. doi:10.1080/00313831.2012.696212

Holmegaard, H. T., Ulriksen, L., & Madsen, L. M. (2015). A Narrative Approach to Understand Students' Identities and Choices. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding Student Participation and Choice in Science and Technology Education* (pp. 31-42). Dordrecht: Springer. doi:10.1007/978-94-007-7793-4_3

Homer, M., Ryder, J., & Banner, I. (2014). Measuring determinants of post-compulsory participation in science: a comparative study using national data. *British Educational Research Journal, 40*(4), 610-636. doi:10.1002/berj.3106

Hong, H.-Y., & Lin-Siegler, X. (2012). How Learning About Scientists' Struggles Influences Students' Interest and Learning in Physics. *Journal of Educational Psychology, 104*(2), 469-484. doi:10.1037/a0026224

Hox, J., Moerbeek, M., & van de Schoot, R. (2018). *Multilevel Analysis: Techniques and Applications* (3rd ed.). Abingdon: Routledge.

Hulleman, C., & Harackiewicz, J. (2009). Promoting Interest and Performance in High School Science Classes. *Science, 326*(5958), 1410-1412. doi:10.1126/science.1177067

Institute of Physics. (2012). *The Importance of Physics to the UK Economy*. London: Institute of Physics.

Institute of Physics. (2013). *Closing Doors: Exploring gender and subject choice in schools*. London: Institute of Physics.

Institute of Physics. (2014). *Raising Aspirations in Physics: A review of research into barriers to STEM participation for students from disadvantaged backgrounds.* London: Institute of Physics.

Institute of Physics. (2015). *Opening Doors: A guide to good practice in countering gender stereotyping in schools*. London: Institute of Physics.

Institute of Physics, Royal Astronomical Society, & Royal Society of Chemistry. (2019). *Exploring the workplace for LGBT+ physical scientists*. London: Institute of Physics, Royal Astronomical Society, & Royal Society of Chemistry.

Jacobs, J., Lanza, S., Osgood, D. W., Eccles, J., & Wigfield, A. (2002). Changes in Children's Self-Competence and Values: Gender and Domain Differences across Grades One through Twelve. *Child Development, 73*(2), 509-527. doi:10.1111/1467-8624.00421

Jenkins, E., & Nelson, N. (2005). Important but not for me: students' attitudes towards secondary school science in England. *Research in Science and Technological Education, 23*(1), 41-57. doi:10.1080/02635140500068435

Lord, P., Straw, S., Hart, R., Springate, I., & Harland, J. (2009). *Evaluation of Chemistry for our Future: Extension Phase Report*. Slough: National Foundation for Educational Research.

Lord, P., Straw, S., Springate, I., Harland, J., & Hart, R. (2008). *Evaluation of Chemistry for Our Future: Report on the first year of the evaluation (2007 – 2008)*. Slough: National Foundation for Educational Research.

Lykkegaard, E., & Ulriksen, L. (2019). In and out of the STEM pipeline – a longitudinal study of a misleading metaphor. *International Journal of Science Education, 41*(12), 1600-1625. doi:10.1080/09500693.2019.1622054

Maltese, A., & Tai, R. (2010). Eyeballs in the Fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685. doi:10.1080/09500690902792385

Maltese, A., Melki, C., & Wiebke, H. (2014). The Nature of Experiences Responsible for the Generation and Maintenance of Interest in STEM. *Science Education, 98*(6), 937-962. doi:10.1002/sce.21132

Marsh, H. (1989). Age and sex effects in multiple dimensions of self-concept: preadolescence to early childhood. *Journal of Educational Psychology, 81*(3), 417-430. doi:10.1037/0022-0663.81.3.417

Martin, M., Mullis, I., & Hooper, M. (Eds.). (2016). *Methods and Procedures in TIMSS 2015*. Chestnut Hill, Massachusetts: TIMSS & PIRLS International Study Center / International Association for the Evaluation of Educational Achievement.

Mellors-Bourne, R., Connor, H., & Jackson, C. (2011). *STEM Graduates in Non-STEM Jobs*. London: Department for Business, Innovation and Skills.

Millar, R. (1998). Rhetoric and reality: What practical work in science is really for. In J. Wellington (Ed.), *Practical work in school science. Which way now?* (pp. 16-31). London: Routledge.

Minner, D., Levy, A. J., & Century, J. (2010). Inquiry-Based Science Instruction—What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002. *Journal of Research in Science Teaching, 47(*4), 474-496. doi:10.1002/tea.20347

Mujtaba, T., & Reiss, M. J. (2013). Inequality in Experiences of Physics Education: Secondary School Girls' and Boys' Perceptions of their Physics Education and Intentions to Continue with Physics After the Age of 16. *International Journal of Science Education, 35*(11), 1824-1845. doi:10.1080/09500693.2012.762699

Mujtaba, T., & Reiss, M. J. (2014). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15-year-old students' aspirations to study physics in post-compulsory English schools. *International Journal of Science and Mathematics Education, 12*(2), 371-393. doi:10.1007/s10763-013-9404-1

Mujtaba, T., & Reiss, M. J. (2016). "I Fall Asleep in Class … But Physics Is Fascinating": The Use of Large-Scale Longitudinal Data to Explore the Educational Experiences of Aspiring Girls in Mathematics and Physics. *Canadian Journal of Science, Mathematics and Technology Education, 16*(4), 313-330. doi:10.1080/14926156.2016.1235743

Mujtaba, T., Sheldrake, R., Reiss, M. J., & Simon, S. (2018). Students' science attitudes, beliefs, and context: associations with science and chemistry aspirations. *International Journal of Science Education, 40*(6), 644-667. doi:10.1080/09500693.2018.1433896

Mullis, I., & Martin, M. (Eds.). (2017). *TIMSS 2019 Assessment Framework*. Chestnut Hill, Massachusetts: TIMSS & PIRLS International Study Center / International Association for the Evaluation of Educational Achievement.

Murphy, C., & Beggs, J. (2003). Children's perceptions of school science. *School Science Review, 84*(308), 109-116.

National Audit Office. (2018). *Delivering STEM (science, technology, engineering and mathematics) skills for the economy*. London: National Audit Office.

National Foundation for Educational Research. (2011). *Exploring young people's views on science education*. London: Wellcome Trust.

OECD. (2007). *PISA 2006 Science Competencies for Tomorrow's World. Volume 1: Analysis*. Paris: OECD Publishing. doi:10.1787/9789264040014-en

OECD. (2015). *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence*. Paris: OECD Publishing. doi:10.1787/9789264229945-en

OECD. (2017). *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving, revised edition*. Paris: OECD Publishing. doi:10.1787/9789264281820-en

OECD. (2019). *PISA 2018 Assessment and Analytical Framework*. Paris: OECD Publishing. doi:10.1787/b25efab8-en

Ofqual. (2019). *Ofqual postcards: GCSE, AS and A level reforms*. Retrieved from https://www.gov.uk/government/publications/your-qualification-our-regulation-gcse-as-and-a-level-reforms

Ogunde, J., Overton, T., Thompson, C., Mewis, R., & Boniface, S. (2017). Beyond graduation: motivations and career aspirations of undergraduate chemistry students. *Chemistry Education Research and Practice, 18(*3), 457-471. doi:10.1039/c6rp00248j

Oliver, M., Woods-McConney, A., Maor, D., & McConney, A. (2017). Female senior secondary physics students' engagement in science: a qualitative study of constructive influences. *International Journal of STEM Education, 4*(4), 1-15. doi:10.1186/s40594-017-0060-9

Potvin, P., & Hasni, A. (2014). Analysis of the Decline in Interest Towards School Science and Technology from Grades 5 Through 11. *Journal of Science Education and Technology, 23*(6), 784-802. doi:10.1007/s10956-014-9512-x

Rahman, M. T., & Lewis, S. (2019). Evaluating the evidence base for evidence-based instructional practices in chemistry through meta-analysis. *Journal of Research in Science Teaching*, 1-29. doi:10.1002/tea.21610

Regan, E., & Childs, P. (2003). An investigation of Irish students' attitudes to chemistry: the promotion of chemistry in schools project. *Chemistry Education Research and Practice, 4*(1), 45-53. doi:10.1039/B2RP90036J

Regan, E., & DeWitt, J. (2015). Attitudes, Interest and Factors Influencing STEM Enrolment Behaviour: An Overview of Relevant Literature. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding Student Participation and Choice in Science and Technology Education* (pp. 63-88). Dordrecht: Springer. doi:10.1007/978-94-007-7793-4_5

Rhodes, J., Roffman, J., Reddy, R., & Fredriksen, K. (2004). Changes in self-esteem during the middle school years: a latent growth curve study of individual and contextual influences. *Journal of School Psychology, 42*(3), 243-261. doi:10.1016/j.jsp.2004.04.001

Rosenzweig, E., & Wigfield, A. (2016). STEM Motivation Interventions for Adolescents: A Promising Start, but Further to Go. *Educational Psychologist, 51*(2), 146-163. doi:10.1080/00461520.2016.1154792

Royal Society. (2008). *Science and mathematics education, 14–19: A 'state of the nation' report on the participation and attainment of 14–19 year olds in science and mathematics in the UK, 1996–2007*. London: The Royal Society.

Royal Society. (2010). *Science and mathematics education, 5–14. A 'state of the nation' report*. 2010: The Royal Society.

Royal Society. (2014). *Vision for science and mathematics education*. London: The Royal Society.

Royal Society of Chemistry. (2014). *Inspiring, engaging and expert: the formula for world-class science and chemistry education*. London: Royal Society of Chemistry.

Royal Society of Chemistry. (2018). *Diversity landscape of the chemical sciences: A report by the Royal Society of Chemistry*. London: Royal Society of Chemistry.

Royal Society of Chemistry. (2019). *Science Horizons: Leading-edge science for sustainable prosperity over the next 10-15 years*. London: Royal Society of Chemistry.

Rozek, C., Hyde, J., Svoboda, R., Hulleman, C., & Harackiewicz, J. (2015). Gender Differences in the Effects of a Utility-Value Intervention to Help Parents Motivate Adolescents in Mathematics and Science. *Journal of Educational Psychology, 107*(1), 195-206. doi:10.1037/a0036981

Rüschenpöhler, L., & Markic, S. (2020). Secondary school students' acquisition of science capital in the field of chemistry. *Chemistry Education Research and Practice, 21*(1), 220-236. doi:10.1039/C9RP00127A

Savelsbergh, E., Prins, G., Rietbergen, C., Fechner, S., Vaessen, B., Draijer, J., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review, 19*, 158-172. doi:10.1016/j.edurev.2016.07.003

Schroeder, C., Scott, T., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A Meta-Analysis of National Research: Effects of Teaching Strategies on Student Achievement in Science in the United States. *Journal of Research in Science Teaching, 44*(10), 1436-1460. doi:10.1002/tea.20212

Sheldrake, R. (2016). Students' intentions towards studying science at upper-secondary school: the differential effects of under-confidence and over-confidence. *International Journal of Science Education, 38*(8), 1256-1277. doi:10.1080/09500693.2016.1186854

Sheldrake, R. (2018). Changes in Children's Science-Related Career Aspirations from Age 11 to Age 14. *Research in Science Education*, 1-30. doi:10.1007/s11165-018-9739-2

Sheldrake, R., & Mujtaba, T. (2019). Children's Aspirations Towards Science-related Careers. *Canadian Journal of Science, Mathematics and Technology Education*, 1-20. doi:10.1007/s42330-019-00070-w

Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2017a). Science teaching and students' attitudes and aspirations: The importance of conveying the applications and relevance of science. *International Journal of Educational Research, 82*, 167-183. doi:10.1016/j.ijer.2017.08.002

Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2017b). Students' Changing Attitudes and Aspirations Towards Physics During Secondary School. *Research in Science Education*, 1-26. doi:10.1007/s11165-017-9676-5

Silver, A., & Rushton, B. (2008). Primary-school children's attitudes towards science, engineering and technology and their images of scientists and engineers. *Education 3–13*, 36(1), 51-67. doi:10.1080/03004270701576786

Snijders, T., & Bosker, R. (2012). *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling* (2nd ed.). London: SAGE Publications.

Springate, I., Harland, J., Lord, P., & Wilkin, A. (2008). *Why choose physics and chemistry? The influences on physics and chemistry subject choices of BME students.* London: The Institute of Physics and the Royal Society of Chemistry.

Straw, S., & Macleod, S. (2015). *Evaluation of STEMNET's operations and impacts 2011-2015: Summary report*. Slough: National Foundation for Educational Research.

Tan, E., Calabrese Barton, A., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities-in-practice in science. *Journal of Research in Science Teaching, 50*(10), 1143-1179. doi:10.1002/tea.21123

TNS BMRB. (2015). *Public attitudes to chemistry: research report*. London: Royal Society of Chemistry.

Tripney, J., Newman, M., Bangpan, M., Niza, C., MacKintosh, M., & Sinclair, J. (2010). *Factors Influencing Young People (Aged 14-19) in Education about STEM Subject Choices: A systematic review of the UK literature*. London: Wellcome Trust.

Turner, S., & Ireson, G. (2010). Fifteen pupils' positive approach to primary school science: when does it decline? *Educational Studies, 36(*2), 119-141. doi:10.1080/03055690903148662

Upadyaya, K., & Salmela-Aro, K. (2013). Development of School Engagement in Association With Academic Success and Well-Being in Varying Social Contexts: A Review of Empirical Research. *European Psychologist, 18*(2), 136-147. doi:10.1027/1016-9040/a000143

Vaino, K., Holbrook, J., & Rannikmäe, M. (2012). Stimulating students' intrinsic motivation for learning chemistry through the use of context-based learning modules. *Chemistry Education Research and Practice, 13*(4), 410-419. doi:10.1039/C2RP20045G

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education, 41*(2), 150-164. doi:10.1080/09500693.2018.1540897

Venville, G., Rennie, L., Hanbury, C., & Longnecker, N. (2013). Scientists Reflect on Why They Chose to Study Science. *Research in Science Education, 43*(6), 2207-2233. doi:10.1007/s11165-013-9352-3

Wang, M.-T., & Eccles, J. (2012). Social Support Matters: Longitudinal Effects of Social Support on Three Dimensions of School Engagement From Middle to High School. *Child Development, 83*(3), 877-895. doi:10.1111/j.1467-8624.2012.01745.x

Wang, M.-T., Chow, A., Degol, J., & Eccles, J. (2017). Does Everyone's Motivational Beliefs about Physical Science Decline in Secondary School?: Heterogeneity of Adolescents' Achievement Motivation Trajectories in Physics and Chemistry. *Journal of Youth and Adolescence, 46*(8), 1821-1838. doi:10.1007/s10964-016-0620-1

Wigfield, A., & Eccles, J. (2000). Expectancy–Value Theory of Achievement Motivation. *Contemporary Educational Psychology, 25*(1), 68-81. doi:10.1006/ceps.1999.1015

WISE. (2014). *"Not for people like me?" Under-represented groups in science, technology and engineering*. Bradford: WISE.

Wong, B. (2015). Careers "From" but not "in" science: Why are aspirations to be a scientist challenging for minority ethnic students? *Journal of Research in Science Teaching, 52*(7), 979-1002. doi:10.1002/tea.21231

Professor Shirley Simon has produced a separate analysis of students in one region (analysis is available as Supplemental Material) which shows how one group of students experienced and responded to their intervention over the span of the project.

Thomas Graham House
Science Park, Milton Road
Cambridge CB4 0WF, UK
T +44 (0)1223 420066

Burlington House
Piccadilly, London
W1J 0BA, UK
T +44 (0)20 7437 8656

International offices
Beijing, China
Shanghai, China
Berlin, Germany
Bangalore, India
Tokyo, Japan
Philadelphia, USA
Washington, USA

www.rsc.org/new-perspectives

@RoyalSocietyofChemistry

@RoySocChem

@roysocchem

@wwwRSCorg

linkedin.com/company/roysocchem

Registered charity number: 207890
© Royal Society of Chemistry 2020