Routledge
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Research Papers in Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rred20

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To cite this article: Becky Francis, Morag Henderson, Spela Godec, Emma Watson, Louise Archer & Julie Moote (26 Nov 2023): An exploration of the impact of science stratification in the English school curriculum: the relationship between 'Double' and 'Triple' Science pathways and pupils' further study of science, Research Papers in Education, DOI: 10.1080/02671522.2023.2283417

To link to this article: https://doi.org/10.1080/02671522.2023.2283417

Published online: 26 Nov 2023.

RESEARCH PAPERS IN EDUCATION
https://doi.org/10.1080/02671522.2023.2283417

An exploration of the impact of science stratification in the English school curriculum: the relationship between 'Double' and 'Triple' Science pathways and pupils' further study of science

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ABSTRACT

Supply of students to 'the science pipeline' remains an important imperative for economic policy, and for individual life chances. In England, Science courses from age 14–16 have been divided into 'Double' and (extended) 'Triple' Science. This article draws on data from 6,053 students to investigate the effects of science course designation on progress to further science study and qualifications, as well as exploring the representation of students according to variables such as gender, ethnicity and social background. It finds that the study of Triple Science at age 16 is associated with future science study. Holding other variables constant, including attainment, those students that took Triple rather than Double Science are significantly more likely to pursue A Level Science (post 16/age 16–18), and to study Science at degree level. Hence Triple Science is significantly associated with an increase in undergraduate participation in science; however, for Double Science (the majority route), the likelihood of future participation is significantly diminished. The findings are analysed in relation to efficacy and social justice, arguing for further research to distil the explanation for these trends, and for reflection on access to Triple Science.

ARTICLE HISTORY
Received 3 March 2023
Accepted 2 November 2023

KEYWORDS
Science education; access; Triple science; combined science; attainment; social justice

Background

The science curriculum frequently garners the attention of education policymakers (Smith 2010), principally due to the perceived importance of science education to supply the 'pipeline' of science careers (Skrentny and Lewis 2021) – important in turn for the economy (HM 2011; Smith 2010). In England and in many other parts of the world, a well-qualified, numerically sufficient science workforce is seen as vital for national economic competitiveness; and governments have accordingly invested in supporting participation in science, technology, engineering and maths (STEM) education to supply this pipeline

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(see e.g. DfE 2015b; Hill, Corbett, and Rose 2010; HM 2011). Hence the scope and quality of science education preoccupies education policymakers, as does its uptake.

The resultant drive for prioritisation of resource for science in the school curriculum also precipitates other challenges for education policymakers. The extent of science knowledge and content that is expected for successful progression along the 'STEM pipeline' sits in some tension with adequate room for other subjects in a broad and balanced secondary school curriculum.[1] Additionally, there is recognition that not all young people wish, or have the capacity, to pursue science post-16; and for these pupils, the depth and extent of science content demanded for successful progression to further and higher study of science may be less appropriate (Browne 2019). Consequently, the questions of how much science curriculum content is offered to all pupils during compulsory education, and which pupils (if any) receive additional content, have also been longstanding points of policy debate (see e.g. CBI 2015; Gibb 2015; Mortuza 2018).

These dilemmas are compounded by resource issues. In England, the supply of qualified science teachers has been a longstanding problem. Physics and maths teachers have been in perennial shortage (Adams 2022;Worth and Galvis 2022), and even generous Government bursaries have not succeeded in meeting the demand for Physics teachers (Martin 2022; Walker 2022): indeed in 2022 the recruitment of Physics teachers was more than 80% below the Government target (Adams 2022; Worth and Faulkner-Ellis 2022). And while the supply of Chemistry and – especially – Biology teachers is typically less challenging, there are presently supply challenges across these and other subject areas (Martin 2022). Hence, especially in areas of social disadvantage, many schools struggle to recruit suitably qualified teachers to staff a comprehensive science curriculum (Allen and Sims 2017, 2018).

These challenges notwithstanding, the English policy consensus on the importance of the school science curriculum is longstanding. This interest has driven two contemporary policy innovations aimed at improving the quality of the science curriculum and outcomes for learning by the end of mandatory schooling at age 16, when pupils take their GCSE (General Certificate in Secondary Education) exams.[2] The first and most recent was the programme of work to ensure parity in relative levels of challenge across the three science GCSEs (Biology, Chemistry and Physics), and across different exam boards (see DfE 2015b; Ofqual 2015). The second, longer-standing policy innovation was the introduction and development of Triple and Combined (Double) Science pathways and qualifications, and it is this topic that comprises the focus of this article.

In England, the National Curriculum includes the study of science as a core subject for all pupils, to the age of 16. Prior to 2006, there had been a diverse array of different science GCSEs, and alternative qualification routes (see Archer et al. 2017). Motivated by the aforementioned concern to support the science pipeline, the 2006 curriculum reforms introduced an entitlement to take 'Triple Science' from 2008, for higher attaining students. Although not an official course title, 'Triple Science' is a term applied ubiquitously to the study of Biology, Chemistry and Physics as separate subjects at GCSE, i.e. counting as three GCSEs. In short, this introduced a 'higher track' for GCSE science study, with extended curriculum for each of the core sciences.

Those students not taking Triple Science mainly take 'Double Science' (sometimes also known as 'Combined Science'). While Triple Science refers to a combination of three individual GCSE qualifications in the single sciences of

Biology, Chemistry and Physics, students studying for Double Award Science ('Double Science'), are also required to study a combination of all three sciences. However, in the case of Double Science the breadth of curriculum content is reduced in comparison Triple Science, and the course is counted as the equivalent of two GCSEs (hence the 'double' refers to the number of resulting qualifications, rather than the number of science subjects studied).

Following the introduction of the Triple Science route, there was initially a steady growth in the numbers and proportion of students submitted for Triple Science. For instance, there was a marked growth since 2006, when 5.6% of the cohort took Triple Science, to academic year 2013/14 when approximately 26% of all students taking science took Triple Science (DfE 2014). However, this appears now to have plateaued, with the same proportion (26%) taking Triple Science in 2021/22 (DfE 2022).

This growth in Triple Science entry has been outpaced by an acceleration in the proportions of students taking the dual award, such that in 2021/22 68% of all GCSE entrants took Double Science (DfE 2022).

The expansion of Triple Science entries since 2006 has been supported by strong advocacy from successive British governments, industry and many science education policy organisations (see e.g. CBI 2015; Harrison 2009; House of Commons Science & Technology Committee 2023). And, attainment and progression data suggest that students taking Triple Science tend to perform well. For example, Ofsted's (2013) analysis concludes that the proportion of students making the expected three levels of progress, and the proportion gaining high grades, is significantly higher in the separate sciences than in the case for combined science (Ofsted 2013, Para 68). Likewise, the Confederation of British Industry (CBI 2015) dre on DfE data to show that three quarters of Triple Science pupils achieving the highest grades progress to A Level[3] science subjects, while only 59% of Double Science pupils achieving the highest grades progress to A Level science subjects CBI (2015). De Philippis' (2021) recent investigation of the relative impact of additional curriculum time studying science at GCSE level (a key element of the Triple Science approach), looked at the impact on half a million students, and found that taking five more hours per week of science classes 'considerably' increases the likelihood of undertaking a STEM degree. Given their interest in supplying the science pipeline, the CBI has drawn on such evidence to call for all young people who attain 'good grades' in science at age 14 to be automatically enrolled for Triple Science (CBI 2015). Of course, it is important to mediate such views with critical awareness that science attainment and 'career pipelines' do not comprise a straightforward relationship (Moote and Archer 2018), and that science learning is beneficial beyond the needs of the economy (Roth and Calabrese Barton 2004). Nevertheless, access to science careers is a social justice issue given the benefits to individuals concerned from higher remuneration in this sector (Masterson 2021). As the DfE (2021), point out, 'achieving two or more A Levels in STEM subjects adds more than 7.8% to earnings, when compared to just gaining GCSE level qualifications.' These various benefits raise in turn the question of social justice in access to Triple Science: how, and to whom, this opportunity is made available.

Access to Triple Science

Study of science at school is typically characterised as important but difficult (Archer et al. 2017; Mortuza 2018). And as noted above, it is recognised that studying the three science subjects individually squeezes other curriculum subjects – potentially of more interest to some students – within finite curriculum time. Moreover, supply of sufficient subject-specialist science teachers has proved a perennial challenge. Hence the maintenance of a 'choice' of Double or Triple Science courses – the latter to provide specialist coverage for those students with sufficient 'ability' or interest, and Double Science as a more holistic option for those lower attaining/less interested pupils. However, this presents equity issues over access to prestige Triple Science provision, and the potential consequences of inclusion or exclusion. Triple Science was introduced in the 2006 reforms as an entitlement for higher attaining students (defined at that time as those achieving level 6 at Key Stage 3); see Fairbrother and Dillon 2008). Archer et al. (2017) observe that, in the interim, the entry criteria for Triple Science have become less clearly defined, and there is also considerable variation in practice between schools. Nevertheless, they note that the practices of delineation tend to remain bound by conceptions of 'ability' (see also Mortuza 2018). And crucially, that it is not usually *pupils* that have the ultimate choice in respect to opting for Double or Triple Science; but rather, the designation is often made by the school (often on the basis of the attainment set or stream in which a pupil has been placed) (see also Hamlyn et al. 2020; Spielman 2018). Hamlyn et al. (2020) found that 20% of participants who did not do Triple Science said they would have liked to study it if the option had been available to them. Moreover, the Wellcome Science Education Tracker 2019 (Hamlyn et al. 2020) highlights that some schools do not offer Triple Science at all.

Indeed, prior studies have shown that a range of other variables appear to characterise patterns of uptake of Triple Science, suggesting that issues of allocation and access can precipitate inequities. Homer, Ryder, and Donnelly (2013) show that students who are eligible for free school meals (FSM) are under-represented on Triple Science courses. Exploring this pattern further, Allen (2015) scrutinised the GCSE outcomes for students who were in the 10% of highest achievers at the end of primary schooling. She found that, of these high attaining students, pupils who had received free school meals (FSM) were significantly less likely to be taking Triple Science at GCSE compared to their more affluent peers. Burgess and Thomson (2019) also found significant socio-economic gaps in attainment among those taking Triple Science. In contrast, prior gender differences in uptake have diminished and now disappeared over time: while more boys than girls took Triple Science GCSEs prior to 2014 (DfE 2014), the gender gap narrowed over the intervening period and DfE figures show it has now closed (DfE 2022).

While these questions of agency and patterns of participation relate to *within*-school decisions over which pupils access Triple Science, there are also questions about access to Triple Science *between* schools. DfE data from 2012 shows that 84% of state schools offered Triple Science GCSE at the time, but analysis from the OPSN (2015) suggested that there is significant between-school variation on offers of Triple Science, with students located in deprived neighbourhoods being substantially less likely to attend schools that offer the route. In more deprived areas, such as parts of the North-East, over a third of secondary schools did not offer Triple Science, compared to some more affluent areas of the South-East wherein all schools offered Triple Science. The OPSN (2015) analysis found that in four of the six Local Authorities wherein more than one third of schools did not offer Triple Science, fewer than 15% of students took Triple Science – predominantly areas with higher levels of deprivation (trends supported by Wellcome Tracker findings [Hamlyn et al. 2020]).

Hence the existing literature suggests that social background (as indicated by the FSM measure) and school attended (influenced by whether or not that school is located in an areas of relative deprivation) inflect allocation to Triple or Double Science courses. These findings beg questions of inequality of access to a premium resource; with potential implications for social in/justice.

Nancy Fraser (1997) delineates two elements of social justice: distributive and recognitive justice. Distributive justice is concerned with issues of economic inequality and disadvantage, e.g. the distribution of material goods, and the control of resources. Recognition, on the other hand, concerns symbolic or cultural inequality, where particular social groups are relatively privileged or devalued within a cultural hegemony. This perspective has been applied to educational practices such as attainment grouping, or 'tracking' (see e.g. Francis, Taylor, and Tereshchenko 2020). This application is especially pertinent because, as noted above, rather than being in the immediate control of the individual pupil, allocation to Triple or Double Science courses is often related to prior attainment; and in these cases, comprises a form of attainment grouping or 'tracking'. Indeed, in many schools, allocation to Triple Science is directly related to being in the top attainment set or stream. Francis et al (2020a) argue that the extensive evidence on attainment grouping and social inequality demonstrates elements of both distributive and recognitive injustice.[4] As some of us have highlighted previously (Francis et al. 2017; Francis, Taylor, and Tereshchenko 2020), it is pupils from socially disadvantaged groups, and from certain minority ethnic groups, who are over-represented in low attainment groups and hence most likely to be subject to these inequities of distribution; a double-disadvantage.

A similar application of Fraserian social justice theory can be extended to the case of designation to Triple and Double Science routes. Our own prior findings illustrate how selective practices around Triple Science create and perpetuate social inequalities, and how the offer of Triple Science as 'for the clever' may additionally precipitate problems for the science 'pipeline' (Archer et al. 2017).

Of course, it has been argued that Combined (Double) Science for all would be adequate (Koenig 2019). In this case, the above demographic trend in uptake may be less consequential. Likewise, if prior attainment is a stronger predictor than course type, this finding would divert concerns from course type to pupil progress. However, were it to be shown to be the case that, as suggested by the CBI back in 2014, study of Triple Science *itself* supports further access to science, the matter of allocation and access to this course becomes a concern for social justice.

This article seeks to shed light on some of these questions concerning the salience or otherwise of GCSE science routes to the science pipeline. We draw on the large-scale ASPIRES[5] datasets to explore whether the pursuit of Triple or Double Science GCSEs impacts later take-up of science A Levels and/or science undergraduate study (overall, and specifically at prestigious Russell Group Universities). In so doing, we also seek to investigate whether or not access to Triple Science GCSE routes has a bearing on students' life chances. The following research questions are addressed:

(1) Is taking Triple Science associated with taking at least one science A level or at least one science and/or maths A Level?
(2) Is taking Triple Science associated with undertaking undergraduate study of science?
(3) Is taking Triple Science associated with pursuing undergraduate science study at a Russell Group university?

Data and methods

Data

The ASPIRES data comprises a longitudinal dataset which tracks young people's aspirations and behaviours in and out of STEM subjects throughout their educational careers. The present sweep of data was collected through a large-scale postal survey of young people in England by obtaining a sample of young people born between 1 September 1998 and 31 August 1999 who were registered on the Open Electoral Roll. A questionnaire exploring young peoples' aspirations and expectations and science attitudes (DeWitt et al. 2011) was revised, validated and piloted with 300 students before being administered to a sample of 21–22-year-olds in England. The data collection period started in May 2021 and was completed in August 2021. The survey had a 14.8% response rate. Following data cleaning (including the removal of duplicate and incomplete responses, responses completed in less than ten minutes and responses with more than 10 instances of providing the same response to all statements within a battery of questions), 7,635 of the 7,900 responses obtained remained in the sample for analysis. The study oversamples women, racially minoritised groups, young people from lower IMD quintiles and those in higher education. Due to these over-representations particularly those in Higher Education, there is also an over-representation of those studying triple science. The main variable of interest is participation in Double or Triple Science at GCSE, the qualification studied in Year 10 and Year 11 (age 14–16). This cohort would have sat their GCSEs in 2015 when the main GCSE routes were either core and additional science (Double Science award), or three separate sciences (Triple Science award). Participants were asked to report: Which science did you complete at GCSE? Please select one answer only. 1) Double science (e.g. 2 GCSEs, Core and Additional); 2) Triple science (e.g. 3 GCSEs, Core, Additional and Extra or Biology, Chemistry, Physics); 3) Applied science (e.g. 1 GCSE); 4) I did not take GCSE science or; 5) Don't know.

The main dependent variables of interest of this paper, and drawn from the survey responses, are:

- Taking one or more science A Levels (science A level defined as Chemistry, Biology and Physics; indicative of pursuit of a science course at A level)
- Taking two or more sciences at A Level (indicative of pursuit of a science course at A level, and facilitating study of science at undergraduate level – as admissions

requirements for most undergraduate science courses demand at least two science A Levels from applicants, or a science subject plus maths)

- Taking one or more science and maths at A Level (maths A level defined as Maths and Statistics, Pure Maths, Further Maths; indicative of pursuit of a science course at A level, and facilitating study of science at undergraduate level)
- Taking an undergraduate science degree[6] (indicative of pursuit of a science course at undergraduate level, and facilitating a STEM career)
- Taking an undergraduate science degree at a Russell Group university (indicative of pursuit of a prestigious science course at undergraduate level, and facilitating a STEM career).

With regard to the latter measure, UK Higher Education is heterogeneous and hierarchical, and associations of institutional prestige (or a lack thereof) are shown to resonate with employers (Jackson 2009). There is a positive relationship between attendance of the most selective universities and future employment outcomes (Britton et al. 2020; Chetty, Friedman, and Rockoff 2014; Sutton 2021). The majority of highly selective British Higher Education Institutions are members of the Russell Group[7]; a club of 24 UK universities described as 'world-class, research-intensive universities' (see Russell Group 2022). These institutions contribute strongly to UK scientific output: there are 165 higher education institutions in the UK (Universities UK 2022), yet the 24 Russell Group member institutions produce more than two-thirds of the world-leading research from UK universities (Russell Group 2022). Given the selective nature of these institutions and the potential positive career impact of undertaking study at a Russell Group university, it seemed relevant to explore whether there is a relationship between taking Triple Science at GCSE, and study of science at a Russell Group university. Especially given De Philippis' (2021) recent finding that additional study of science at GCSE increases probability of attending a Russell Group institution.

Control variables

We included the following control variables in all logistic regression models to better isolate the size of association between GCSE Science type on the outcomes of interest:

- Gender was captured by asking 'Which of the following BEST describes how you identify?', with the response categories including: 'Man', 'Woman', 'Non-binary', and 'Other' and 'Prefer not to say'. Men were the reference category used in the modelling and non-binary and other genders were combined. Here and for all variables below, those responding 'Prefer not to say' and anyone who skipped the questions were grouped into a category labelled 'Unknown'.
- Ethnicity was captured by asking 'Which of these BEST describes how you identify?', with possible response including: 'Black'; 'Asian'; 'White', 'Chinese or East Asian', 'Middle Eastern'; 'Other (including mixed and multiple ethnic groups)' and 'Prefer not to say'. This variable was coded to four categories: 'Black'; 'Asian'; 'White', 'Other' and 'Unknown', where 'Other' included Chinese or East Asian, Middle Eastern and Other ethnicities. Five categories were created to White, Black, Asian, Other and Unknown. White was set as the reference category.

- Index of Multiple Deprivation (IMD) was determined by the participants postcode (where they are registered on the Open Electoral Register and the invitation letter was sent to). The IMD values were grouped into quintiles based on national thresholds (IMD1 represents the least privileged quintile of people), and was treated as a continuous variable.
- Parental education was determined by asking 'Did any of your parents/guardians go to university?' with possible response including 'Yes', 'No' and 'I don't know'. The responses were grouped into 'at least one parent having attended University' or not. Neither parent having a degree was set as the reference category.
- Parental occupation was determined by the following question: 'Think about one of your parent/guardians and their job. Which of these phrases BEST describes the MAIN job that they do currently?', with options including: 'Professional occupation (e.g. doctor, architect, teacher, lawyer, dentist, accountant, director, nurse, graphic and media designers, IT professional, project manager)' and 'Sales and customer service occupation (e.g. sales representative, shopkeeper, shop owner, sales supervisor)'. The responses were grouped into 'at least one parent having high status job' or not, where high status job comprised professional occupations; corporate manager, director or senior official; or senior government or public sector worker. The reference category was set to neither parent having a high status job.
- Highest GCSE Science Grade and Highest GCSE Maths Grade was captured by asking 'What was the highest grade you achieved in science at GCSE?' (and equivalent for maths). The responses were coded into 'A*-B' and 'C and Lower', with 'A*-B' being the reference category.
- Type of school attended at age 14-16 asked respondents to select between the following: 'Comprehensive state school', 'Academically Selective State School (e.g. Grammar School)', 'Independent/private school' and 'Other', with 'Comprehensive state school' being set as the reference category.

We also included A Level grades and A level subject choice in some of the models predicting university attendance as sensitivity checks.

- A level grades were obtained by asking 'How many of the following qualifications did you get? A*-B'. Participants were able to type in the number of A*-B grades received and this was treated as a continuous variable.
- Having done at least one or at least two science A Levels, or having done at least one science and one maths A Levels.

Method

The dependent variables of interest are binary, therefore we ran multivariable logistic regression analyses and report the computed average marginal effects (AMEs), which can be interpreted as percentage point differences. For example, a 0.16 result means that the variable has 16% point difference compared to the reference group. The full list of dependent variables and descriptive statistics is included in Table 1.

The present study enables us to isolate the association between taking either Double or Triple Science at GCSE with science based educational trajectories. By

Table 1. Main variables of interest by Double or Triple Science.

	Double %	Triple %	(n)	N
Men	47.80	52.18	2,217	
Women	53.14	46.90	3,581	
Non-Binary and other genders	48.20	51.80	112	
Unknown	58.00	42.00	143	6,053
White	51.29	48.71	4,685	
Black	53.54	46.46	226	
Asian	49.75	50.25	601	
Other	49.57	50.43	464	
Unknown	61.04	38.96	77	6,053
Index of Multiple Deprivation Q1	55.67	44.33	1,410	
Index of Multiple Deprivation Q2	51.96	48.04	1,276	
Index of Multiple Deprivation Q3	48.61	51.39	1,191	
Index of Multiple Deprivation Q4	49.87	50.13	1,125	
Index of Multiple Deprivation Q5	48.72	51.28	1,051	6,053
Neither parent with degree	55.56	44.44	4,014	
At least one parent with degree	42.67	57.33	2,039	6,053
Neither parent with high status job	54.53	45.47	3,332	
At least one parent with high status job	47.15	52.85	2,721	6,053
A*-B Science GCSE	43.03	56.97	4,055	
C or below Science GCSE	67.82	32.18	1,998	6,053
A*-B Maths GCSE	39.86	60.14	3,605	
C or below Maths GCSE	67.93	32.07	2,448	6,053
State School	53.61	46.39	4,773	
Selective School	34.28	65.72	566	
Private School	37.47	62.53	395	6,053
Did not study for any A Levels	62.42	37.58	2,448	
Studied for A Levels	43.61	56.39	3,605	6,053
No Sciences at A Level	55.90	44.10	2,329	
At Least One Science A Level	21.16	78.84	1,276	3,605
Fewer than Two Sciences at A Level	49.14	50.86	2,965	
At Least Two Sciences at A Level	17.97	82.03	640	3,605
Not One Science & Maths A Level	50.54	49.46	2,865	
At Least One Science & Maths A Level	16.76	83.24	740	3,605
Did not attend university	57.84	42.16	3,062	
Attended University	44.43	55.57	2,991	6,053
Did not Study Science Degree	49.64	50.36	2,466	
Studied Science Degree	20.00	80.00	525	2,991
Science at non-Russell Group university	23.84	76.16	323	
Science at Russell Group University	13.86	86.14	202	525
Total	51.21	48.79	-	6,053

controlling for confounding variables including gender, ethnicity, parental occupation, parental education, area-level deprivation, GCSE attainment in science and maths and school type we can more accurately assess the magnitude of the association. We view our results as not truly causal, but rather as capturing conditional relationships between GCSE science type and subsequent educational science trajectories. We acknowledge that we may be overestimating the strength of association between science participation at GCSE and subsequent science participation as there may be endogenous effects involved in participation of either Double or Triple Science. These unobserved selection effects, such as teacher perception of student motivation and ability, are somewhat mitigated by the inclusion of attainment at GCSE: however, we note that a prior measure, rather than a concurrent measure, would be preferable for this purpose. An attainment measure prior to GCSE is not available in the data.

Descriptive analysis

Of our sample of 6,053 students, 48.8% studied Triple Science ($n = 2,953$), and 51.2% studied Double science ($n = 3,100$). These students constitute the sample under scrutiny in this article. A further 1,582 students from the original sample are excluded, as taking an applied science, not taking a GCSE science qualification at all, or having missing data. It is worth reiterating that our sample is skewed towards Triple Science: whereas the proportions taking Double and Triple Science are almost even in our sample, with only slightly more students taking Double Science, nationally of all students taking either double or Triple Science GCSE in 2015 (same year as the study cohort) was 71.3% taking Double Science, and 28.7% taking Triple (DfE 2022).

We investigate the sample at various stages on their post-16 educational trajectories, first at A Level, then at degree. To make sure our comparisons are sensible, we further broke down the sample to represent the young people who chose science or non-science qualifications, at each point of analysis. The sample sizes are included in Table 1.

Results

In terms of the demographic characteristics of the 6,053 students from the ASPIRES 3 sample that took Double or Triple Science GCSE, trends are in line with our expectations with the Triple Science sample showing relative social advantage across a range of measures. As shown in Table 1, 46.4% of state school students reported doing Triple Science; compared to 65.7% of (selective) grammar school students and 62.5% of private (fee-paying) school students. Likewise, 57.3% of pupils for whom at least one parent had attended university took Triple Science, compared to only 44.4% of those whose parents had not been to university. And, a higher proportion of those with at least one parent with a high-status occupation took Triple Science (52.9%) compared to Double science (47.1%). The proportion of those taking Triple Science by the Index of Multiple Deprivation (IMD) is also greater among the least deprived areas (51.3%) compared to the most deprived areas (44.3%).

Other key descriptive findings of interest include gender and ethnicity. We observe that a slightly higher proportion of boys (52.2%) rather than girls (46.9%) took Triple Science, showing a slight distinction from the national trend wherein the gender gap has closed (presently standing at 26% boys taking Triple Science, and 26.6% girls, DfE 2022). This may reflect that the respondents took their GCSE exams approximately six years before responding to our survey (and the gap has closed in the interim). We do not observe large differences by ethnic take-up in GCSE science, however we observe that students identifying with the 'Unknown' and Black categories have the smallest proportion of Triple Science take-up (39% and 46.5% respectively) and 'Other' and Asian the largest (50.4% and 50.2% respectively).

When we look at the educational trajectories descriptively, we observe that a higher proportion of those taking Triple rather than Double Science at GCSE pursued any A Levels (56.4% compared to 43.6%). When we look more specifically at the subjects studied at A Level by GCSE science type, we see a similar pattern, that is, we observe a higher proportion of those taking at least one science, at least two sciences and at least one science and maths A Level if they took Triple (between 78.8% – 83.2%) rather than

Double Science at GCSE (between 21.2%-16.8%). A higher proportion of Triple Science students went on to study at university (55.6%) compared to Double Science students (44.4%). Of those students in our original GCSE sample that continued on to an undergraduate degree (n = 2,991), 17.6% went on to study a *science* undergraduate degree (n = 525). For those who went to university the degree subject studied and institution studied at is patterned by type of GCSE Science, that is, of those who pursued science study at university, 80% had taken Triple Science at GCSE, and 20% had taken Double Science. Lastly, a higher proportion of Science degree students at Russell Group had taken Triple Science (86.1%) compared Double Science (13.86%).

Is taking triple science associated with taking at least one science a level or at least one science and a maths a level?

In the multivariable regression analyses we are able to control for possible confounding characteristics to explore whether taking Triple Science is associated with taking science at A level compared to those who take Double Science, net of gender, ethnicity, etc. Our dependent variables of interest are taking at least one science A level; at least two science A levels and taking at least one Science and Maths at A Level. The results from the multinomial logistic regressions predicting different levels of science participation at A Level are shown in Table 2, Models 1–3.

As shown in Table 2, for those who continue to A Level study, taking Triple rather than Double Science is associated with a statistically significant higher probability of taking at least one Science A level (24% points higher: Model 1); at least two Science A Levels (14% point higher: Model 2); and at least one Science and Maths A Level (16% points higher: Model 3). These results are over and above GCSE attainment, socio-economic background, school type, gender and ethnicity.

There are other interesting findings to note: for example we observe some gender differences in line with previous expectations. We note that women are 5% points less likely than men and non-binary students are 15% points less likely than men to take at least one science at A Level (Model 1). We observe a similar trend in Model 3, with women being 9% points less likely and non-binary 13% points less likely to take at least one Science and Maths compared to men (Model 3).

For A Level Science trajectories (Table 2, Models 1–3), we see a pattern by ethnicity where Black, Asian and students from 'Other' ethnicities are statistically significantly more likely to take all A Level science trajectories examined compared to White students (Models 1–3).

As expected, due to common school criteria to progress onto A Level science courses, GCSE attainment strongly and significantly predicts Science A Level participation across the three of our outcomes (Table 2, Model 1–3).

We also see that for young people with at least one parent who attended university, there is positive association with having taken Science at A levels. However, we do not observe statistically significant differences by school type or parental occupation for these Science A Level choices.

(1) *Is taking Triple Science associated with undertaking undergraduate study of science?*

Table 2. Logistic regression predicting a Level Science participation, average marginal effects.

	Model 1		Model 2		Model 3	
	At Least One Science A Level		At Least Two Science A Levels		At Least One Science & Maths A Level	
	AME	SE	AME	SE	AME	SE
Ref: Double Science						
Triple Science	0.24***	(0.02)	0.14***	(0.01)	0.16***	(0.01)
Ref: Men						
Women	−0.05**	(0.02)	0.01	(0.01)	−0.09***	(0.01)
Non-Binary and other genders	−0.15**	(0.05)	−0.05	(0.04)	−0.13**	(0.04)
Unknown	−0.01	(0.07)	0.00	(0.06)	0.02	(0.06)
Ref: White						
Black	0.08*	(0.04)	0.13***	(0.04)	0.09*	(0.03)
Asian	0.11***	(0.02)	0.14***	(0.02)	0.13***	(0.02)
Other	0.07**	(0.03)	0.06**	(0.02)	0.09***	(0.02)
Unknown	−0.02	(0.07)	−0.02	(0.05)	−0.03	(0.05)
Index of Multiple Deprivation	−0.01*	(0.01)	−0.01+	(0.00)	−0.00	(0.00)
Ref: Neither parent with degree						
At least one parent with degree	0.07***	(0.02)	0.05***	(0.01)	0.07***	(0.01)
Ref: Neither parent with high status job						
At least one parent with high status job	−0.02	(0.02)	−0.02	(0.01)	−0.02	(0.01)
Ref: A*-B Science GCSE						
C or below Science GCSE	−0.19***	(0.02)	−0.10***	(0.02)	−0.11***	(0.02)
Ref: A*-B Maths GCSE						
C or below Maths GCSE	−0.23***	(0.02)	−0.14***	(0.01)	−0.17***	(0.01)
Ref: State School						
Selective School	−0.02	(0.02)	−0.02	(0.02)	0.00	(0.02)
Private School	0.02	(0.02)	0.01	(0.02)	0.01	(0.02)
Other Type of School	−0.07	(0.05)	0.01	(0.04)	−0.10**	(0.04)
Observations	3,605		3,605		3,605	
Log Likelihood	−1448.2424		−1610.9169		−1500.8102	
Pseudo R-squared	0.1409		0.2114		0.1799	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.10$.

(2) *Is taking Triple Science associated with pursuing undergraduate science study at a Russell Group university?*

We now turn to the question of whether those students who took Triple Science are significantly more likely to undertake undergraduate study of science than those that took Double Science at GCSE. Given the potential positive career impact of undertaking study at a Russell Group university, and the selective nature of these institutions, we also sought to explore whether there is a relationship between taking Triple Science at GCSE, and access to undergraduate science study at a Russell Group university comparing to those who studied science at a non-Russell Group university.

Of those students in our original GCSE sample that continued on to an undergraduate degree ($n = 2{,}991$), 17.6% went on to study a *science* undergraduate degree ($n = 525$). Among these latter we found that 38.5% ($n = 202$) did so at a Russell Group university.

The results of the multinomial logistic regression analyses predicting science undergraduate degree participation are shown in Table 3. In Model 1, we see that taking Triple Science rather than Double is associated with 14% point higher probability of studying for a science degree subject, this result is statistically significant (Model 1). We also see a positive association between taking Triple Science and studying for a science degree at Russell Group rather than studying science elsewhere, however this result is not

Table 3. Logistic regression predicting degree Science participation, average marginal effects.

	Model 1		Model 2	
	Studied Science Degree		Studied Science Degree At Russell Group Uni	
	AME	SE	AME	SE
Ref: Double Science				
Triple Science	0.14***	(0.01)	0.06	(0.05)
Ref: Man				
Woman	−0.04*	(0.01)	−0.02	(0.04)
Non-Binary and other genders	−0.10*	(0.04)	0.06	(0.19)
Unknown	−0.05	(0.06)	0.23	(0.22)
Ref: White				
Black	0.09**	(0.04)	0.11	(0.08)
Asian	0.10***	(0.02)	0.04	(0.05)
Other	0.11***	(0.03)	0.12*	(0.06)
Unknown	−0.00	(0.06)	0.01	(0.20)
Index of Multiple Deprivation	−0.02**	(0.01)	0.04*	(0.02)
Ref: Neither parent with degree				
At least one parent with degree	0.05**	(0.02)	0.07	(0.05)
Ref: Neither parent with high status job				
At least one parent with high status job	−0.03+	(0.02)	0.00	(0.05)
Ref: A*-B Science GCSE				
C or below Science GCSE	−0.09***	(0.02)	−0.22*	(0.10)
Ref: A*-B Maths GCSE				
C or below Maths GCSE	−0.10***	(0.02)	−0.25***	(0.07)
Ref: State School				
Selective School	−0.02	(0.02)	0.21**	(0.07)
Private School	−0.01	(0.02)	0.25***	(0.07)
Other Type of School	0.00	(0.05)	−0.14	(0.12)
Observations	2,991		525	
Log Likelihood	−1228.6514		−313.0627	
Pseudo R-squared	0.1157		0.1051	

Standard errors in parentheses. Average Marginal Effects computed from Logistic Regression Analyses.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.10$.

statistically significant. These results take into account GCSE science and maths attainment, socio-economic background, school type, gender and ethnicity. As a sensitivity check we include A level attainment and A level subject choice in the models (shown in Table S1) and the results for Triple/Double Science hold for participation in Science degrees (Model 1, 3, and 5), albeit they are attenuated slightly.

Women are significantly (4% points) less likely than men to study Science degrees (Table 3, Model 1). Ethnicity reveals some interesting patterns with respect to degree participation: we find that Black students are 9% points more likely than White students to undertake a science undergraduate degree; Asian students are 10% points more likely and 'Other' (including mixed heritage) students are 11% points more likely to take science degrees (Table 3, Model 1). These patterns do not hold consistently when looking at those studying for science degrees and comparing institution type (Table 3, Model 2); however, we see that for Black and 'Other' heritage students, they are respectively 11% points and 12% points more likely than White students to study a science degree at a Russell Group university. Asian heritage students are 4% points more likely to do so.

Prior attainment is a strong and significant predictor of degree participation (Table 3, Model 1) and Russell Group participation (Table 3, Model 2). Interestingly, there are no statistically significant differences by school type on science participation at university (Table 3, Model 1), but we observe that there is a strong private school and selective school advantage for studying science at a Russell Group university compared with studying science at a non-Russell Group university (Table 3, Model 2). More specifically, we see that those who attend a private school are 25% points more likely to study science at a research-intensive university than comprehensive school students, and those who attend a selective school are 21% points more likely than comprehensive school students. These findings are robust to additional controls, shown in Table S1.

Discussion

We have shown that the study of Triple Science at GCSE is closely associated with future science study. Holding other variables constant, including attainment, those students that took Triple rather than Double Science are significantly more likely to pursue A Level Science (including more likely to take the two or more science and/or maths A Levels indicative of access requirements for study of undergraduate science), and to study Science at degree level. In this sense, we can say that Triple Science is significantly associated with an increase in undergraduate participation in science, a key necessary factor in supply to the STEM pipeline. However, for Double Science (the majority route), the reverse is true.

Our bivariate analysis highlights the trends from our data: Of those students that studied one or more science A level, 79% had studied Triple Science, and 21% Double Science. Of those students taking *two* or more science A levels (a common entry requirement for undergraduate science study), 82% had studied Triple Science, compared to only 18% Double Science. And of those who studied Science at university, 80% had studied Triple Science, compared to 20% who had taken Double Science. Finally, of those students who studied science at a Russell Group university, 86% had studied Triple Science, and 14% Double Science.

The contrast in proportions of students that took Triple Science GCSE reflected at each level of study of science, with those that took Double Science at GCSE, is stark. In comparison with those taking Triple Science, very small proportions of students taking Double Science GCSE subsequently progress on with science at A level and then at undergraduate level. This latter should be of concern to those seeking to bolster STEM participation and supply to STEM careers, given that Triple Science GCSE remains a minority route. It also presents concerns about equity in access, from a social justice perspective.

Before discussing the implications of our findings, it is worth re-stating limitations of our methods and analysis, including the deliberate oversampling of HE students meaning the proportion of Triple science route students is higher in our sample than the national average. Another limitation of the present analysis is that we use observational data which limits the extent we can make causal inference from the relationships explored. Whilst we try our best to account for selection into Double or Triple science and include robust specifications in our models, we cannot be certain we are dealing with the unobserved appropriately.

Our findings raise two immediate questions. This first concerns the explanation for the identified trends. The second relates to social justice, given the relationship between access to (selective) study of Triple Science and further science study progression.

So, why might study of Triple Science be facilitating science progression? The evidence suggests a range of plausible explanations. Firstly, it may be that Triple Science provides the best preparation for science progress, by providing the elaborated knowledge and understanding necessary to secure students' adequate self-efficacy and achievement for progression. The Triple Science curriculum allows extended study of the three sciences, including both greater breadth and depth of content (DfE 2015a). It is also the case that the 'jump' between GCSE and A Level study is perceived as especially wide for Science subjects (see e.g. Paine 2020; Newton et al. 2017[8]). If this perceived gap has veracity, then it might be mitigated via the extended study of individual science subjects facilitated by Triple Science GCSEs, potentially supporting progression to A Level.

Further potential explanations relate to the selective nature of Triple Science, which may mean the course harnesses superior resources, and/or precipitates particular responses in those included and excluded. Regarding resources, it is well established that quality of teaching is the in-school factor with greatest impact on pupil progress (Hattie 2008; Hanushek 2011; Burgess 2019; Opper 2019), and it might be that subject-specialist science teachers – themselves a scarce resource, as noted previously – are attracted to deliver the more developed, specialist provision that Triple Science teaching facilitates; and/or are attracted to teaching the high attaining students. Or, that they are allocated to these classes because Triple Science students are prioritised by the school. Research on tracking in the United States has shown how top 'academic track' classes tend to be provided higher quality teachers (see e.g. Gameron and Mare 1989; Gameron and Nystrand 1994).

The other potential explanation relating to selection concerns self-fulfilling prophecy, and the impact of labelling that 'Triple' and 'Double' Science attributions confer within a selective landscape. It seems plausible that – especially in cases where students are actively allocated to Double or Triple Science routes rather than choosing them themselves – these labels impact students' self-perception and identification with science or otherwise, resulting in a self-fulfilling prophecy wherein students taking Double Science see future science study as 'not for me' (DeWitt, Archer, and Moote 2018). There is extensive research evidence concerning the impact of tracking by attainment on pupil self-confidence (see e.g. Francis et al. 2020), and given that science GCSE course allocation is usually selective, the cases appear applicable. Finally, even where science GCSE course choices are freely made by the student, it may be that those who take Triple Science are more motivated in science, and it is this that explains their better progress, rather than matters of curricula or pedagogy.

It may be that these various factors all have a bearing, perhaps mediated by school policy. Further research would be necessary to explore this. The implications of our findings concerning impact of GCSE science route for pupils' future engagement with science suggests that this research is urgent. In effect, our findings suggest that the act of allocation of a pupil to Double Science GCSE immediately renders it unlikely that they will pursue science post-GCSE. This is an issue for both distributive justice and recognitive justice (Fraser 1997). In terms of *distributive* justice, given that science careers are comparatively well-renumerated (DfE 2021), this apparent cauterisation of pupils' access to future science study and careers at an early age via allocation to the Double Science route has implications for economic distribution in the future, and for distribution of resources and access opportunities in the pupils' present.

Meanwhile, the hypothesis concerning labelling and self-fulfilling prophecy evokes the proposition that students' identities and expectations are impacted by placement in Double or Triple Science courses respectively; a potential case of recognitive injustice (see Fraser 1997). However, without further research investigation, this remains speculation. What we do see is certain patterns of representation in course allocation. In our findings, boys and young men are slightly over-represented in Triple Science and then at A level and undergraduate level. It is worth noting the time lag in our data, and that, while these findings show there remains work to be done to encourage girls' engagement with STEM, nevertheless the relatively small gender gaps illustrate the progress in this regard over time. In contrast, there are larger gaps for social background, as indicated variously by 'first in family', parental education, parental occupation and IMD measures. Given that minority ethnic students are not under-represented among Triple Science students overall,[9] and have increased odds compared to their White peers to proceed to science A level and science undergraduate study, it seems that – at least at face value – the primary issue in inequality of access to science preparation concerns the under-representation of socio-economically disadvantaged students. This highlights the issues of distributive justice raised by our findings on the benefits of participating in Triple Science GCSE – and the implications for those that do not.

We thus call for further research to unpick the various explanations for the 'Triple Science advantage'. This seems especially imperative before taking steps to make radical change. It is important to recognise that the last eight years have seen an increase in A Level uptake in England for Biology, Chemistry and Physics (JCQ 2022). Nevertheless, the selectivity in science study identified in our prior work and elsewhere (Archer et al. 2017; Banner et al. 2010; Mortuza 2018) has concerned various organisations and learned societies in the UK for some time, leading to an impetus to ensure a single comprehensive offer. This has manifested in various contemporary campaigns denouncing Triple Science in favour of a comprehensive offer for all (SCORE 2015; Koenig 2019); with a tilt towards Double Science for all given some of the resource challenges of the alternative proposition of Triple Science for all (see Koenig 2019). However, our findings should give cause for pause. The very low numbers of Double Science students presently proceeding to pursue further study of science suggests that, whatever the reason, Double Science as presently delivered is unlikely to supply sufficient numbers of A Level and undergraduate science students, and indeed may be hindering pupils from pursuit of science. It is possible that, by addressing the factors relating to the selective nature of Triple Science in removing it, Double Science provision can adequately engage and prepare students for future science; but this is by no means certain. Likewise, if it proved to be the case that the already scarce supply of specialist science teachers prefer teaching the extended Triple Science curriculum, moving to a less developed curriculum could further challenge retention. Hence, any changes to reduce science content – and especially, to default to Double Science – should approached with caution, and any changes be carefully piloted.

It is also worth noting that any reduction in the depth and breadth of pupils' science curriculum coverage presently provided via Triple Science at GCSE (as the main supply path to A Level) would likely have consequences for A Level curricula, which would require amendment to recognise and address this gap; and in turn for undergraduate course admission and design, for which there would be the same implication.

A further possibility is that all students be given the option to study Triple Science. As with the scenario of Double Science for all, Triple Science for all would address the distributive and recognitive social justice challenges of selectivity. And, by opening up access for all to an extended science curriculum, this might also further expand the pool to supply the STEM pipeline (see ASPIRES2 2018). However, this latter is also uncertain without further research, given the other possible explanations for the relationship between Triple Science and science study progress. It is also likely that such an approach is constrained by teacher supply, given it would require more specialist science teachers – in addition to the issue about squeezing the curriculum for those pupils not attracted to future science study.

These matters are complex and consequential and deserve further attention, but this needs to be informed by careful evidence, and consultation. Until further research can illuminate the cause/s of the different rates of Triple and Double Science GCSE students progressing to further science study, it is important that schools reflect on the impact of allocation to Triple/Double Science for pupils' futures, and review present approaches to ensure that where feasible student preference and choice drives these decisions. For reasons of equality of opportunity, it is desirable that schools follow similar processes so that life chances are not impacted by a particular local policy approach, and that as many students that wish to are facilitated to take Triple Science. And indeed, that students and their parents are made aware of the potential consequential implications of this choice for pupils' future trajectories. Although the causes remain uncertain, the low numbers progressing from Double Science GCSE to further science study are a concern, and schools that do not offer Triple Science should review their A level science take-up rates to consider whether there is evidence of impact. Likewise, those schools that base Triple Science allocation on (indicatively maths) attainment sets should reflect on whether lower set students that wish to study Triple Science can be facilitated, given the implications for their further study and future trajectories. We hope that our findings may provoke reflection and further productive conversations among practitioners, policymakers, curriculum designers and researchers, in support of widened access and sustainability in science.

Notes

1. For example, the Progress 8 accountability measure for Key Stage 4 (age 14–16) measures pupils' progress across 8 subjects from age 11–16. It encourages schools to limit the number of GCSE (General Certificate of Secondary Education) subjects pupils study to 8, given the evidence that studying more GCSEs begins to erode pupils' GCSE grades (DfE 2014; Paton 2013). Maths and English Language are mandated in the National Curriculum, and English Literature is incentivised via the Progress 8 measure. Hence the separate study of Physics, Biology and Chemistry in addition to Maths, English Language and English Literature leaves relatively little room for other subjects (Ashton and Ashton 2022).
2. The General Certificate in Secondary Education (GCSE) exams are national exams taken by all pupils in England and Wales at the age of 16. As well as certifying relative levels of knowledge and competence, they comprise an element of selection in admission to different routes in further and higher education.
3. A Levels are General Certificate of Education Advanced Level qualifications taken by some young people in England age 16–18. They are often requirements to progress onto Higher Education degrees in England.

4. In terms of recognitive injustice, attainment grouping often involves pupils in low sets and streams being labelled as being of 'low ability', when low prior attainment and 'ability' are discrete, and when low prior attainment is not always the reason or lead predictor for track allocation (see e.g. Connolly et al. 2019; Dunne et al. 2007). And regarding distributive injustice, the inequitable direction of high quality resources (such as well-qualified or subject-specialist teachers) towards pupils in high attainment groups and away from pupils in low attainment groups is likewise well documented (see e.g. Gameron and Nystrand 1994; Ireson and Hallam 2001). Moreover, given the demonstrable impact of placement in an attainment group on pupil self-confidence in learning (Francis et al. 2017, 2020) and on educational attainment (Hodgen et al. 2022) it is also arguable that labelling pupils as 'low attainers' (or 'low ability'), and the consequent impact on self-perception and learning outcomes, comprises both recognitive and distributive injustice.
5. This work is supported by the ESRC under Grant ES/S01599X/1.
6. We focused on a defined categorisation of 'higher status' science degrees which require one or more science A levels for undergraduate entry, that included Chemistry, Biology, Physics, Medicine, Engineering and interdisciplinary science degrees. Of all first year undergraduates in England, 13.5% fit into our definition of high-status science.
7. Although there are a number of high entry-tariff institutions that are not Russell Group universities, and a few of the Russell Group members do not feature so highly in global league tables as others, nevertheless the Russell Group offers a good proxy for highly selective, prestigious institutions most likely to support future well-remunerated career paths.
8. Ofqual (2017) analysis shows that schools and colleges tend to operate different progression requirements across subject areas from GCSE to A Level, with a CGCSE 'minimum C' policy to access English and humanities A Levels; 'versus a "minimum B" policy for the sciences and languages.' (p. 9).
9. Black students are very slightly less likely to take Triple science than their White counterparts, while pupils from Asian backgrounds and 'Other' categories of ethnicity are very slightly more likely to do so. Pupils from all minority ethnic backgrounds are slightly more likely to take science A levels than their White counterparts, and significantly more likely to pursue university study of science.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the ESRC under Grant ES/S01599X/1

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