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Gender differences in science, technology, engineering and maths uptake and attainment in post-16 education

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Abstract

The underrepresentation of women in Science, Technology, Engineering and Maths (STEM) occupations is a world-wide phenomenon. The UK is simultaneously encountering a shortage of STEM skills. While gender imbalances in STEM study in higher education and A-level study are widely documented, gender imbalances are apparent in vocational post-16 education, though the existence and causes of these imbalances have received little attention. This paper uses administrative data to explore the extent of gender imbalances in STEM qualifications attempted and achieved in vocational post-16 education routes. Gender differentials in the uptake of vocational STEM qualifications are much starker than they are in A-levels and the roles of ability, socio-economic status and school characteristics in explaining gender differentials differ with the education route taken, though their power in explaining these gaps is limited.

KEYWORDS

gender, STEM, vocational education

JEL CLASSIFICATION

I24; J16; I21

1 | INTRODUCTION AND BACKGROUND

A sufficient supply of Science, Technology, Engineering and Mathematics (STEM) skills in the UK workforce is a crucial goal for policymakers. The shortage of STEM skills, especially at the graduate and post-graduate level, has caused concern with regards to the performance of the UK economy (Bosworth et al., 2013). From an individual perspective, there is a significant economic advantage to STEM occupations, particularly at an intermediate level, with many STEM qualifications offering sizeable earnings premiums and favourable employment perspectives. These benefits are not limited to STEM university graduates, with emerging evidence suggesting that positive returns may be gained from STEM qualifications and study in a Further Education (FE) setting and through vocational pathways in the UK (Aucejo et al., 2020; Greenwood et al., 2011).

Despite the potential labour market gains, marked gender imbalances exist in occupations in STEM fields in the UK. Much of this imbalance in STEM representation is explained by gender differentials in educational choices in higher education (HE). Women are underrepresented in STEM degree subjects; only 42% of female undergraduates in England enrolled in a science subject area in 2019/2020 compared with 51% of male undergraduates (HESA, 2021). These gender imbalances arise from and are apparent in earlier educational choices in post-16 education, with females receiving only 43% of awarded STEM A-levels in 2018 (IFS, 2018). Smith (2011) finds that the attainment of STEM A-levels is gender neutral, but participation in STEM A-Level subjects is not. Thus, gaps arise in educational choices and participation rather than performance. A substantial gender gap is also apparent in vocational routes of post-16 education in England with only 10% of engineering and manufacturing vocational qualifications gained by women in 2012/2013 (WISE, 2014), and this gender gap is growing as more males enter vocational STEM qualifications (WISE, 2017). Despite the vast gender imbalances and evident earning premiums from STEM vocational education (VE) and more generally in FE, gender gaps in graduate level STEM study dominate the literature while the studies that do examine gaps in STEM study in post-16 education predominantly focus on the academic, A-level route (see Section 2 for a discussion of the post-compulsory education system in England). To gain a complete picture of where gender gaps develop in STEM study and occupations, and more broadly, to improve our understanding of routes through which gender earning gaps arise, gender gaps in STEM in all pathways through education should be examined.

This paper contributes to the growing literature on gender differentials in educational choices, particularly in STEM subjects by focusing on the gender imbalances in vocational education. Very few studies have paid attention to VE, often focusing on subject choice in A-levels or in HE only, though only one third of students go on to HE by the age of 20 (Hupkau et al., 2017). Approximately half of all post-16 students in a cohort take the vocational route; thus, VE accounts for a substantial proportion of learners who have the option to choose STEM study. Using administrative data on a full cohort of school leavers in 2005/2006 England, this paper investigates the existence of gender imbalances in STEM subject uptake (in maths/science, technology and engineering fields) in vocational post-16 education routes in England. The focus on this particular cohort enables the magnitude and driving forces behind gender gaps in both the vocational and academic study to be explored while allowing a sufficiently long time period post-education to examine earnings profiles. We then address the research question: To what extent do gender differentials exist in the uptake of STEM subjects in VE, and how do these compare with the gaps in A-levels? Since there is little evidence on the prevalence of gender gaps in STEM subjects in VE and the magnitude of these gaps relative to those evident in academic tracks of post-16 education, it is unclear whether policy makers should address gender imbalances in a dissimilar manner across the different routes of education. Schemes to improve girls' confidence and interest in STEM subjects are often more focused on the continuation of the STEM academic study. Since gender gaps are also present in vocational study, there is a concern that the focus of such schemes may overlook opportunities for STEM learning via vocational routes. We also examine whether gender differentials arise in the attainment of STEM students.

The determinants of STEM gender gaps in both vocational post-16 education and in A-levels are explored in order to examine whether the determinants of gender gaps in vocational STEM education vary from those in the A-level STEM study. In particular, we examine the role played by prior attainment, a proxy for ability, which is the strongest predictor of maths and science subject choice in the post-16 study in England (The Royal Society, 2008), while perceived ability plays a significant role in subject choice (Wiswall & Zafar, 2015). Gender differences in attainment, particularly in maths, emerge and are apparent as early as during the primary school years (Ceci et al., 2014; Fryer & Levitt, 2010; Hannay, 2018)[1]; thus, differences in prior attainment can be responsible for gender gaps in subject choice during post-16 education. However, existing studies that have attempted to explain the causes of the STEM participation gap (predominantly in HE) have generally identified a minor role of gender differences in ability in maths and science (Justman & Mendez, 2018; Friedman-Sokuler & Justman, 2016). Gender remains a strong predictor of STEM uptake, even after conditioning on prior attainment (Noyes, 2009). Evidence suggests that a gender differential exists in the sensitivity of participation decisions to grades (Ost, 2010; Rask & Tiefenthaler, 2008). Justman and Mendez (2018), for instance, find that females require higher levels, or signals, of mathematical ability in order to choose STEM subjects. Furthermore, Cassidy et al. (2018) identify that low subject confidence is one factor which results in females' reluctance to study maths and physics A-levels. The influence of alternative factors may also be mediated by ability. For instance, Carrell et al. (2010) identify that the role of teacher gender in the likelihood of graduating with a STEM degree is strongest for females with strong maths skills. While the existing evidence suggests that prior attainment plays a role in the choice between vocational post-16 education and A-levels (Hedges & Speckesser, 2017), whether ability is a predictor of STEM subject choice within VE, and whether it explains gender differences in subject choice to a greater or lesser extent than in A-level study is currently unknown.

We also explore the extent to which Socio-Economic Status (SES) influences STEM decisions in post-16 education for males and females. SES is a significant determinant of STEM study (Gorard et al., 2008; McMaster, 2017). This is likely to be driven partly by differences in attainment across SES groups. The role of SES in explaining gender differentials is currently unclear though a number of existing studies recognise that socio-economic disadvantage plays a more prominent role in the subject choice of males, relative to females (Friedman-Sokuler & Justman, 2016; Justman & Mendez, 2018).

The remainder of this paper is structured as follows: the post-compulsory education system is described in Section 2; Section 3 provides a description of the methodology and administrative data; Section 4 reports and evaluates the results and Section 5 provides a discussion and summary of the findings.

[1]Evidence of a male advantage in maths is generally mixed and is dependent on age and cultural factors (Ceci et al., 2014; Fryer & Levitt, 2010; Nollenberger et al., 2016).

2 | THE POST-COMPULSORY EDUCATION SYSTEM IN ENGLAND

From the age of 5 to 11, young people in England attend compulsory primary education which is split into two stages: Key stage 1 (KS1) and Key stage 2 (KS2). At the end of primary school (KS2), children undertake national examinations in English, maths and science, before attending compulsory secondary education from the age of 11 to 16 where they complete two key stages of learning: Key stage 3 (KS4) and Key stage 4 (KS4). KS3 examinations were undertaken by children in their third year of secondary school (at age 14), until 2008. At the end of KS4, examinations for General Certificates of Secondary Education (GCSEs) are undertaken before leaving secondary education. Generally, GCSEs are taken in core subjects (Maths, English and Science)[2] in addition to chosen subjects (usually 2–3 years prior). In the academic year which we study, a GCSE grading system was in place, with grades ranging from A*-G where a grade U indicates an unclassified grade. A*-C grades are generally considered a 'good pass' and a pre-requisite to level 3 study. Prior to 2013, young people could choose to remain in education or enter the labour market at age 16. The Education and Skills Act 2008 increased the minimum age at which young people in England could leave Education and training from age 16 to 17 in 2013; in 2015, this was increased to age 18. For those who choose to remain in formal post-16 education, the route of education that they wish to pursue can be chosen. One option is to undertake academic qualifications known as Advanced level qualifications (A-levels) that are offered in a range of subjects, including STEM subjects, and are studied on average for two years. A-levels are the dominant route into university and higher education (HE) entrance where some courses and degrees require specific subject grades upon entry, for example, A-level maths (or equivalent) is often a prerequisite for a degree in civil engineering. The grade required may vary by institute. The alternative vocational route consists of a range of potential vocational qualifications typically at levels 2–3, including BTECs and NVQs (see Table A1) and apprenticeships which can also be taken in a range of STEM and non-STEM subjects. While the learning approach varies by qualification, vocational qualifications generally combine practical and theoretical training and learning while apprenticeships predominantly provide a work-based approach to learning. The level of qualification entered is usually determined by prior attainment in KS4, and level 2 vocational qualifications are typically entered following low GCSE attainment. These qualifications are valuable for labour market entry but usually do not lead to progression in education qualifications (Hupkau et al., 2017). While level 3 vocational qualifications may aid the direct transition into the labour market, these qualifications may also facilitate progression in education, including entry into HE, with progression including study for a bachelor's degree, foundation degree, or certificate of higher education.

Since these alternative routes through post-compulsory education are diverse and the motivation for initially participating in this type of study and choosing these qualifications may vary, the nature of the STEM courses and the implications of enrolling in them may vary across these three categories of post-compulsory education.

3 | METHODOLOGY AND DATA

3.1 | Methodology

The starting point of our analysis is to estimate a simple model of the probability that an individual studies a STEM subject in the highest qualification they have attempted by age 19. To do so, we estimate the following equation as a linear probability model:

[2]In some schools, it may be compulsory to take GCSEs in other defined subjects.

$$\text{Prob}(\text{STEM}=1)_i = \alpha \text{Female}_i + \gamma X_i + \varepsilon_i. \tag{1}$$

The outcome variable is a dummy variable equal to one if the individual has, in their highest attempted qualification by age 19, attempted a STEM subject. X is a vector of control variables that we describe in detail in the next section. Our interest is in the estimate of the parameter α—the gender differential in the probability of studying a STEM subject. We estimate our equations separately by highest qualification, focusing on A-Levels, vocational level 3, and vocational level 2. Throughout, we estimate specifications that include only the female dummy to obtain the raw differentials, as well estimating the full model to obtain conditional differentials. In models with school controls, we cluster standard errors at the school level and control for school characteristics since in the administrative data we observe pupils within the same schools.

Females may be less likely to take a STEM subject if their expected performance is lower than the expected performance of males. Having modelled participation, we then examine the achievement of those learners who do take STEM subjects in A-level study and VE to observe whether gender differences that we observe in participation are also reflected in achievement. Once females enter STEM fields of study, do they then perform worse than males? A gender gap in performance could inform and deter females from studying STEM and may explain why fewer females opt into STEM subjects. We estimate the effect of gender on a binary indicator of achievement, conditional on participation in each STEM outcome (i.e., vocational STEM overall, engineering vocational qualification etc.). We again estimate linear probability models to examine whether females are more or less likely to achieve their highest qualification in a STEM subject, conditional on having attempted STEM.

$$\text{Prob}(\text{Achieved}|\text{STEM}=1)_i = \mu\, \text{Female}_i + \pi X_i + \varepsilon_i \tag{2}$$

We then explore whether gender differentials in A-levels and VE STEM subjects vary by socio-economic status. SES is included as a control variable in the previous models, and we now consider whether the role of SES differs for males and females in the choice of STEM participation. We again estimate separate equations indicating participation in STEM A-levels, STEM vocational level 3, and STEM vocational level 2 as the highest qualification attempted by age 19. While SES is included in the preceding models, we here additionally interact it with gender.

$$\begin{aligned}\text{Prob}(\text{STEM}=1)_i = \; & \alpha\, \text{Female}_i + \beta_1\, \text{SES1}_i + \beta_2\, \text{SES2}_i + \beta_3\, \text{SES3}_i + \beta_4\, \text{SES4}_i + \delta_1(\text{SES1} * \text{Female})_i \\ & + \delta_2(\text{SES2} * \text{Female})_i + \delta_3(\text{SES3} * \text{Female})_i + \delta_4(\text{SES4} * \text{Female})_i + \gamma X_i + \varepsilon_i\end{aligned} \tag{3}$$

In this equation, the variables SES1 to SES4 are indicator variables placing the individual in quintiles of the socio-economic status distribution. SES1 represents the bottom quintile (the most deprived 20%) of the cohort. SES5, the omitted reference category, is correspondingly the top quintile (the least deprived 20%) of the cohort. The estimated parameters of this equation show the gender differentials across SES groups, by differentiating with respect to gender and interpreting the α and δ coefficients. Differentiating with respect to SES allows us to recover the socio-economic gradients for both genders, i.e., for each gender, showing the differential likelihood of STEM participation across socio-economic groups relative to the least deprived quintile.

The SES-varying gender gap is given by:

$$\frac{\partial y}{\partial\, \text{female}_i} = \alpha + \delta_1\, \text{SES1}_i + \delta_2\, \text{SES2}_i + \delta_3\, \text{SES3}_i + \delta_4\, \text{SES4}_i \tag{4}$$

The SES gradient, relative to SES5, in STEM participation for females is given by:

$$\frac{\partial y}{\partial \text{SES}_i} = (\beta_1 + \delta_1)\text{SES1}_i + (\beta_2 + \delta_2)\text{SES2}_i + (\beta_3 + \delta_3)\text{SES3}_i + (\beta_4 + \delta_4)\text{SES4}_i \tag{5}$$

For males the SES gradient is given by:

$$\frac{\partial y}{\partial \text{SES}_i} = (\beta_1)\text{SES1}_i + (\beta_2)\text{SES2}_i + (\beta_3)\text{SES3}_i + (\beta_4)\text{SES4}_i \tag{6}$$

3.2 | Data

We use administrative data on a full birth cohort of English young people. We use linked data from the National Pupil Database (NPD) and the Individualised Learner Record (ILR) to observe the cohort who leave school in 2005/2006. We chose this cohort in order to observe a fairly recent cohort of school leavers while allowing us a sufficiently long time period post-education to examine earnings profiles. We restrict the sample and the analysis to those individuals taking vocational qualifications at levels 2 and 3[3] or A-levels. We exclude apprentices and individuals studying vocational qualifications at levels 1 and 4 from the analysis.

For these individuals we are able to observe KS2 (age 11) and KS3 (age 14) Average Point Scores (APS)[4] in individual subjects, including English, maths and science. The other individual characteristics we control for include government office region, ethnicity, and an index of SES, based upon the existing evidence on the role of these factors in STEM participation (Gorard et al., 2008; McMaster, 2017; Osikominu et al., 2020). We create the index using a Principal Components Analysis including localised measures of multi-dimensional deprivation, home ownership, education and occupation.[5] We construct the index using the first principal component. We also control for a range of KS4 school cohort characteristics. These school characteristics include the number of pupils in the school, the proportion of pupils receiving free school meals (FSM), the average number of GCSEs[6] attempted per pupil, the ethnic composition, and whether the school is a mixed gender school.

In order to classify STEM subjects, we use the subject areas given in the ILR Sector Subject Area (SSA) tier 1 variable that gives the subject area of each learning aim in one of fifteen categories. As in WISE (2014), we look, in addition to STEM participation overall, at four categories of STEM:

1. Science and maths (SSA 2)
2. Engineering and manufacturing (SSA 4)
3. Construction (SSA 5)
4. IT and telecoms (Technology) (SSA 6)

[3]See Table A.1 for examples of STEM qualifications and Table A.2 for an illustration of the range of occupations in which Vocational Level 3 Engineering are Employed.

[4]Average point scores are the average scores attained in assessments in individual subjects at KS2 and KS3.

[5]Components include lower super output area (LSOA) measures of the Index of Multiple Deprivation, the Acorn type and LSOA level information on home ownership, level 3+ qualifications and managerial/professional occupations of residents.

[6]GCSEs grades are awarded on a scale of A*-G where fails are given the letter U.

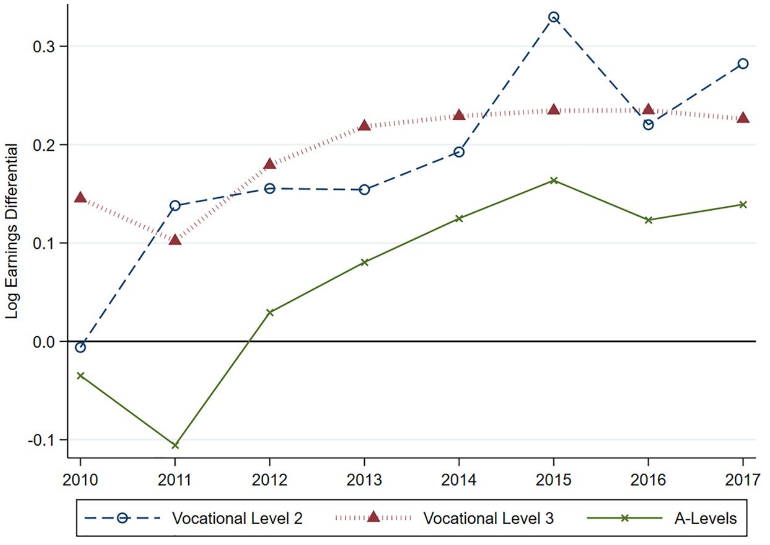

FIGURE 1 Earnings premium associated with studying of a STEM subject

In order to define individual learners as a STEM learner or not, we take the highest qualification individuals have attempted by age 19. We define the learner as taking STEM if they take any STEM subjects at this highest qualification level. We note that the nature of STEM study will differ between vocational qualifications and A-levels. The construction category is not observed for individuals taking A-Levels, as it is a purely vocational subject.

Earnings information are obtained by matching these data to HMRC tax records.[7] Specifically, P14, P45 and P60 forms completed by employers provide accurate information on earnings during the tax year and start and end date of spells of employment. We use this information to construct a daily earnings measure, which is preferable to an annual earnings measure since it does not depend on the number of days worked per year. Unfortunately, no information on hours of work is included in the tax data, and so we could not derive an hourly wage measure.

3.3 | Descriptive statistics

Figure 1 illustrates the benefits of STEM study to individuals in terms of their future earnings profiles. We plot the log earnings differential between those who did and did not attempt their highest achieved qualification (by age 19) in a STEM subject. The earnings premia are generally positive, the only exception being for the group with A-Levels as their highest qualification by age 19 in the 2010 and 2011 tax years. A large proportion of this group are, however, likely to not be in the labour market at this point due to progression to HE. A typical education pathway from GCSEs, to A-Levels, to a three-year undergraduate degree would not enter the labour market

[7]Using lookup tables kindly produced by officials at the Department for Education, with the matched anonymised data provided to us.

with a completed degree until the end of 2011. Such individuals observed with earnings before then are likely to be in relatively low-paid part-time work not reflective of their eventual career pathway. By the tax year ending April 2013 however, when most students who achieved A-Level qualifications and progressed to higher education would have completed their education spells, this group exhibit a positive earnings premium associated with studying STEM subjects.

For vocational qualifications we draw the same conclusions. While for those whose highest achieved qualification is at level 2 the series exhibits some noise year-on-year, for both level 2 and level 3 there is an earnings premium associated with studying STEM subjects and this premium is consistently larger than that observed for those who take the academic route. For vocational level 3, this is particularly stable at around 23% after 2014 while the premium for those who took the A-Level route is around 15%. This indicates that not only is there a significant earnings advantage to choosing STEM subjects when taking a vocational route through further education, but that this subject choice is even more important to future earnings than in the academic route.

Table 1 presents descriptive statistics on STEM participation. The table illustrates that fewer females in the cohort, who enter any form of post-16 education, study STEM subjects; only 37% of females study STEM relative to 53% of male post-16 education students. These gender gaps in participation in STEM subjects are clear in both vocational and A-level routes of study but are most pronounced in the uptake of vocational STEM subjects; only 1.5% of female students choose vocational STEM study subjects relative to 13% of male students. Of course, there are gender differences in the post-16 education route taken, with 23% of female students attempting their highest qualification in level 2 or level 3 vocational routes, relative to 26% of males.[8] However, large gaps are clear in subject choice. Fewer than 400 females in the cohort choose vocational engineering (equal to 0.2%) while 2.5% of male students choose this subject and route. In A-levels, females who study STEM subjects predominantly choose maths and science A-level subjects. These statistics motivate the importance of the study of gender STEM gaps in VE since the large gender gaps are apparent in this route. Furthermore, large disparities in gender gaps are apparent across subjects within vocational study, demonstrating a need to analyse gaps across different subject areas. Vocational study in level 2 and 3 (highest) qualifications accounts for over 86,000 learners from this single cohort, thus it is a substantial route into STEM study.

A potential driver of these gender gaps in STEM subject uptake is differences in prior attainment, since women typically achieve lower maths scores than males (Ellison and Swanson, 2010; Fryer & Levitt, 2010; Hannay, 2018). The age 11 and 14 test scores[9] and GCSE grades in maths, English and science are used as measures of prior attainment. Test scores and the GCSE grade A*-C attainment rates are provided by gender for individuals in the cohort who continue into post-16 education, either vocational or A-level routes in Table 2. Significant raw gender differences in the prior attainment scores of males and females are apparent. In English, females outperform males at all key stages (KS2, KS3 and KS4 (GCSE)). At GCSE level, 12pp[10] fewer males obtain A*-C grades than females. In maths and science, conversely, males perform better than females at all stages. Large gaps are observed in maths at KS2 and KS3; this gap persists into GCSE attainment but is more pronounced in science than maths. The performance of females in maths and science may deter females from choosing STEM subjects since females are typically

[8]Post-16 education pupils may alternatively take A-levels or GCSEs (considered academic routes) or below level 2 qualifications in vocational study. We focus on only level 2 and level 3 routes in vocational and A-levels (level 3) in this study.

[9]Average Point Scores (APS) at KS2 and KS3.

[10]Percentage points.

TABLE 1 STEM subject uptake conditional on qualification and level attempted

	Pooled	Female	Male
Attempted STEM subject	0.446	0.372	0.528
Vocational			
STEM voc.	0.071	0.015	0.133
Construction voc.	0.025	0.001	0.051
Construction voc. level 2	0.021	0.001	0.043
Construction voc. level 3	0.004	0.000	0.008
Engineering voc.	0.025	0.002	0.050
Engineering voc. level 2	0.016	0.001	0.032
Engineering voc. level 3	0.009	0.001	0.018
Math/Sci. voc.	0.006	0.005	0.007
Math/Sci. voc. level 2	0.005	0.004	0.006
Math/Sci. voc. level 3	0.001	0.001	0.001
Technology voc.	0.018	0.007	0.031
Technology voc. level 2	0.010	0.005	0.016
Technology voc. level 3	0.009	0.002	0.015
Academic			
STEM A-level	0.375	0.357	0.395
Engineering A-level	0.054	0.041	0.069
Math/Sci. A-level	0.319	0.314	0.325
Technology A-level	0.063	0.033	0.096
Observations	*358,529*	*188,709*	*169,820*

Notes: (i) Mean values presented in the table (ii) Pupils may take multiple STEM subjects within their post-16 education route e.g. a small number of pupils choose both A-levels in technology and in Maths and science subjects.

more risk averse than males. Previous research suggests that females are more sensitive to signals of maths ability than males in choosing STEM subjects (Friedman-Sokuler & Justman, 2016) while females are more likely to suffer greater 'maths anxiety' and have lower subject confidence than males (OECD, 2014).

At GCSE level, female English grades are highly skewed to the right; females are much more likely to achieve the higher A*-C grades in English than males and much less likely to achieve below a C grade (Figure 2). Males are overrepresented in the bottom end of the distribution, receiving a higher proportion of D-U grades. In GCSE maths, a higher proportion of males receive an A*, A or (marginally) a B grade than females who are overrepresented in the D-F grades. GCSE grades in science follow a very similar pattern to maths with males achieving a higher proportion of A-C grades (and only marginally A*) and a smaller proportion of the grades D-F.

While the distributions of KS2 and KS3 test scores evidently differ by gender, the differences in these distributions also vary over age, this can be seen more clearly between KS2 and KS3 where we have data on fine graded test scores. Figure 3 illustrates the distributions of KS2 and KS3 scores by gender for our sample by plotting the proportion of individuals at each percentile at KS2 and at KS3 that are female. In English, females remain consistently dominant in the upper end of the distribution at KS2 and KS3. However, in maths, females are underrepresented in the upper end of the distributions in both KS2 and KS3, though it is evident that males become

TABLE 2 Test scores and GCSE results by gender

	Pooled	Female	Male	Difference	*t*-stat
KS2 English	27.632	28.103	27.109	−0.994***	(−80.548)
KS2 Maths	27.567	27.211	27.963	0.752***	(51.520)
KS2 Science	29.075	28.931	29.234	0.304***	(28.698)
KS3 English	35.056	35.849	34.175	−1.674***	(−93.564)
KS3 Maths	37.746	37.338	38.199	0.861***	(37.421)
KS3 Science	35.044	34.849	35.261	0.412***	(21.080)
% GCSE English A*-C	73.5	78.9	67.5	−11.5***	(−78.434)
% GCSE Maths A*-C	67.0	66.1	68.0	1.9***	(12.000)
% GCSE Science A*-C	64.9	63.8	66.1	2.4***	(14.743)
Observations	*358,527*	*188,705*	*169,822*	*358,527*	

Note: (i) Mean values presented in the table (ii) Difference indicates Male–Female (iii) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

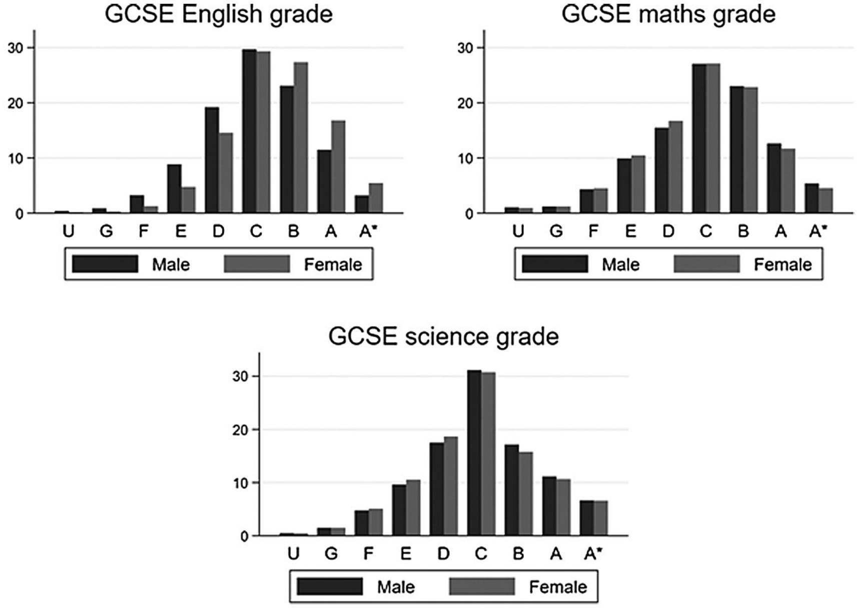

FIGURE 2 GCSE grades by gender

slightly less dominant in the upper end of the distribution by KS3 while the overrepresentation of females in the lowest quartile of the distribution observed at KS2 reduces by KS3. However, males do continue to dominate in the top 20% of the distribution for maths. In science, females dominate the bottom end of the distribution to a greater extent in KS2 than KS3 while also becoming more equally represented in the top 20% by KS3, with the differences in males and females reducing between KS2 and KS3 producing a 'flatter' line. The distributions of males and females are more similar in science than in other subjects in both KS2 and KS3. The magnitudes of the differences in the distributions for science and maths are, however, much smaller than those observed for English. At the bottom fifth percentile of test scores for maths and science in KS3, the gender balance is almost equal (43% of males), whereas for English 60% of those at the bottom fifth percentile of performance are male.

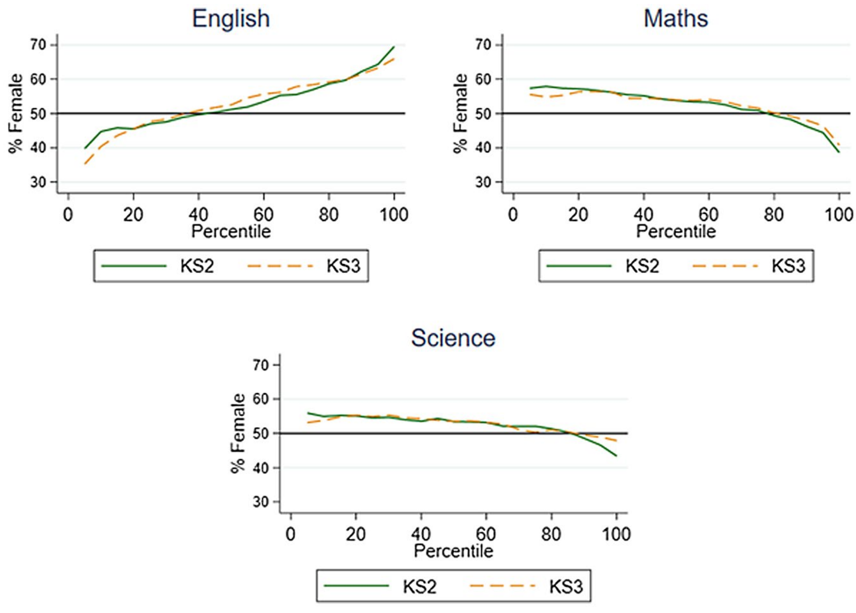

FIGURE 3 Percentile of Average point scores by gender

Figures 4 and 5 present the mean test scores and GCSE attainment by post-16 education route taken and gender. A-level STEM students are more able in terms of English, maths and science, at KS2, KS3 and KS4 (GCSE) than non-STEM students. However, in both KS2 and KS3, vocational STEM pupils gain lower English scores and are less likely to achieve an A*-C grade in GCSE English, relative to a vocational non-STEM student. This is perhaps since students who are more able in English specialise in subjects more closely associated with English such as communication studies or Arts and Humanities.[11] Alternatively, such students may have more choice in which subjects to study; Wang et al. (2013) identifies that females are more likely to have higher verbal abilities than males of similar prior attainment in maths, thus allowing females to consider a wider range of subjects and occupations. Comparing students in VE to A-level study, it is clear that A-level pupils generally attain higher scores across all subjects in KS2, KS3 and at GCSE level than vocational students as we may expect since high attaining pupils typically opt into more academic routes of post-16 education, rather than vocational routes (Hedges & Speckesser, 2017); this may be driven by higher entry requirements into A-levels. The most pronounced differences in test scores between vocational and A-level routes amongst STEM pupils are observed at maths, especially at KS3 and in GCSEs. KS3 scores are gained two years prior to post-16 education choices being made and provide pupils with indicators of their relative ability which may inform route and subject choices. The figure provides support for analysing STEM study in vocational and A-level routes separately, given the differences in prior attainment between vocational and A-level pupils. To establish the relationship between prior attainment and STEM uptake we must take account of the fact that these two routes attract students of different levels of prior attainment before analysing subject choice within these routes.

[11]Our data suggests that amongst A-level learners, the correlation between GCSE English grade and subject area is highest in languages, literature and culture subjects alongside humanities; these highest grade-subject correlations persist amongst those achieving above a B grade in GCSE English, maths and Science.

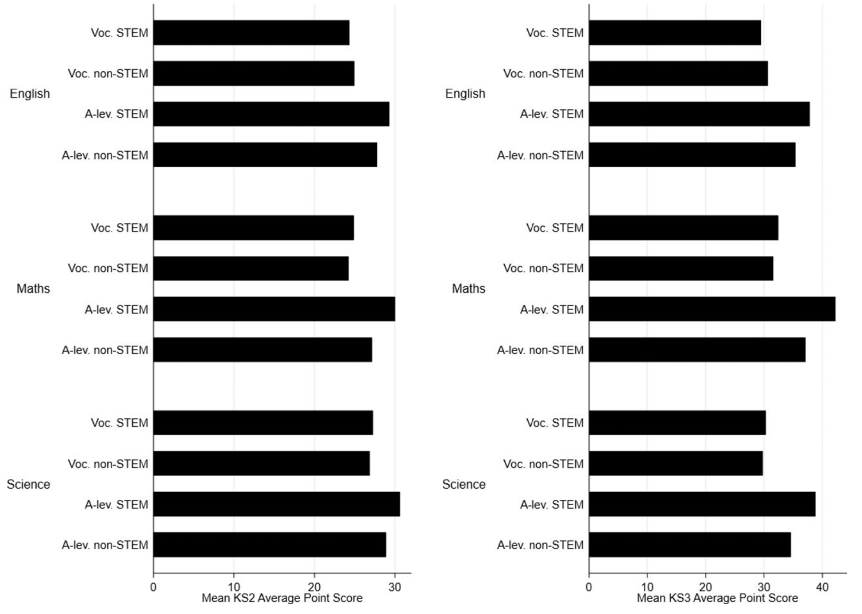

FIGURE 4 Mean KS2 and KS3 test scores (APS) by route

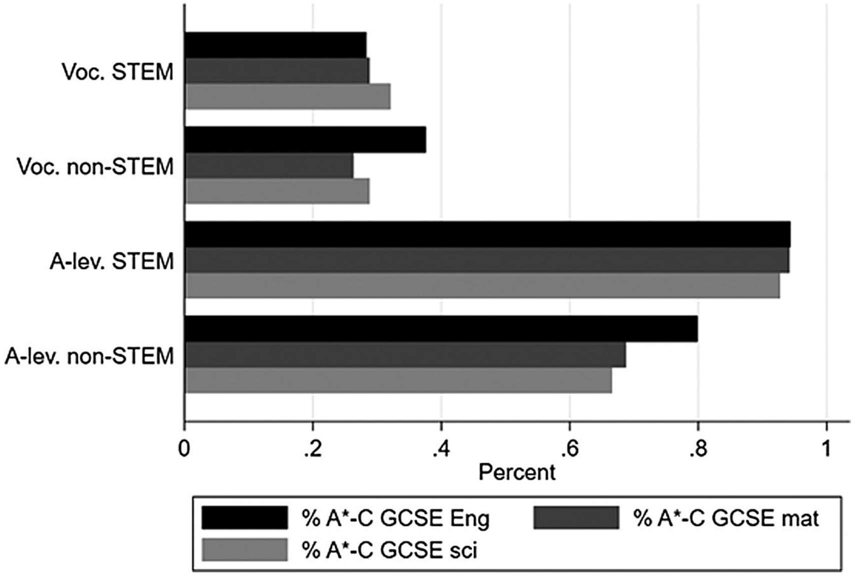

FIGURE 5 GCSE attainment by route

Table 3 presents the covariates by vocational and A-level study. The raw differences from Table 3 suggest that students who study vocational STEM subjects are typically white males from the north of England or the midlands from low socio-economic backgrounds who attended deprived, mixed sex schools. On the contrary, more females, ethnic minorities and higher socio-economic background status pupils who opt into vocational study, opt for non-STEM subjects. As expected, A-level pupils are often characteristically dissimilar to vocational students. The raw statistics suggest that A-level STEM pupils are typically more likely, than A-level non-STEM

TABLE 3 Individual and school characteristics by post-compulsory education route

	Voc STEM	Voc Non-STEM	Difference	*t*-stat	A-level STEM	A-level Non-STEM	Difference	*t*-stat
Female	0.112	0.558	0.446***	(206.832)	0.501	0.542	0.041***	(23.544)
White	0.872	0.862	−0.010***	(−4.536)	0.840	0.877	0.037***	(30.368)
Asian	0.062	0.074	0.012***	(7.718)	0.102	0.056	−0.046***	(−47.756)
Black	0.035	0.033	−0.002	(−1.773)	0.027	0.037	0.009***	(15.849)
Mixed ethnicity	0.023	0.023	0.000	(0.003)	0.022	0.024	0.002**	(3.193)
Other ethnicity	0.007	0.007	−0.000	(−0.246)	0.009	0.006	−0.002***	(−7.756)
East Midlands	0.094	0.087	−0.007***	(−3.662)	0.091	0.086	−0.005***	(−4.908)
East of England	0.114	0.111	−0.003	(−1.375)	0.103	0.116	0.013***	(12.012)
London	0.123	0.129	0.006**	(3.018)	0.131	0.127	−0.004***	(−3.492)
North East	0.054	0.049	−0.004**	(−2.996)	0.047	0.051	0.004***	(5.105)
North West	0.160	0.147	−0.013***	(−5.427)	0.151	0.147	−0.004***	(−3.434)
South East	0.142	0.159	0.017***	(7.482)	0.161	0.156	−0.006***	(−4.677)
South West	0.082	0.100	0.019***	(10.480)	0.099	0.099	0.000	(0.056)
West Midlands	0.128	0.114	−0.014***	(−6.517)	0.112	0.117	0.005***	(4.367)
Yorkshire and The Humber	0.103	0.102	−0.001	(−0.557)	0.104	0.102	−0.002*	(−2.371)
SES 1—most deprived	0.255	0.143	−0.112***	(−39.859)	0.099	0.182	0.083***	(72.093)
SES 2	0.235	0.177	−0.058***	(−21.120)	0.149	0.200	0.051***	(39.957)
SES 3	0.209	0.204	−0.005	(−1.811)	0.197	0.208	0.011***	(8.147)
SES 4	0.174	0.224	0.050***	(20.231)	0.241	0.209	−0.032***	(−22.126)
SES 5—least deprived	0.128	0.252	0.124***	(55.712)	0.314	0.200	−0.114***	(−74.755)
Total number pupils KS4 school	210.145	213.154	3.009***	(6.736)	212.838	213.002	0.163	(0.680)
% FSM pupils KS4 school	14.428	11.192	−3.235***	(−39.566)	9.989	12.281	2.292***	(59.418)
Average num. GCSEs KS4 school	8.500	8.858	0.358***	(50.083)	9.035	8.712	−0.324***	(−92.430)
% white pupils KS4 school	83.809	84.097	0.288*	(2.023)	83.598	84.364	0.766***	(10.300)
Mixed sex school	0.936	0.881	−0.055***	(−33.460)	0.856	0.903	0.047***	(41.342)
Observations	*25,410*	*333,117*	*358,527*		*134,422*	*224,105*	*358,527*	

Note: (i) Mean values presented in the table (ii) Difference indicates Voc. STEM—Voc. Non-STEM (iii) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

pupils, to be Asian and other ethnicity males from London, the south east and north west from higher socio-economic backgrounds and from high performing secondary schools.

4 | RESULTS

4.1 | Are females under-represented in STEM subjects?

We are interested in identifying whether gender gaps in participation in STEM study exist and differ across A-level and vocational routes of post-16 education. We also wish to identify whether they persist even after controlling for a range of individual and school characteristics alongside prior attainment. Table 4 presents the gaps in STEM uptake within A-level and vocational routes overall, before focusing on STEM subject within each post-16 education route. The coefficients presented in the table represents the female coefficient in the regressions, which indicates gender gaps in participation in each of these STEM subject areas.

The results suggest that significant gender gaps exist in STEM study both in A-levels and in vocational study. The gaps in STEM uptake overall are actually larger in vocational study than in A-level study once individual, school and prior attainment are held constant. These significant gender participation differentials persist even after controlling for a range of characteristics including prior attainment. Thus, a male with an identical average point score, individual and school characteristics as a female would be more likely to opt into STEM study both in A-level and vocational study. Prior attainment explains a large part of the gender gap in participation in A-level STEM uptake; with individual, school and prior attainment controls included in the regression, females studying A-levels are only 1.8 pp less likely to take STEM A-levels. This could be due to the academic nature of A-level study and the GCSE performance requirements for A-level entry that are captured by and controlled for in the models. The largest gender gaps in A-level study are evident in technology subjects where prior attainment controls explain only a small part of the raw gender gap. Interestingly, once prior attainment is controlled for, the gender gap in maths and science A-levels is positive and significant suggesting that when holding prior attainment constant, females are more likely to attempt maths and science A-levels than male A-level pupils.[12] Given the raw statistics in Table 1, it seems that a higher number of females than males in post-16 education choose maths and science subjects; the negative raw effect is identified once we condition on the route that individuals select into, before holding ability constant. Further investigation reveals that KS2 and KS3 maths scores drive the change in the sign of the coefficient[13]; when these controls are omitted, the female coefficient remains negative, even when holding GCSE maths grade and any measure of science scores (KS2, KS3 or GCSE) constant. Though maths scores are likely to be correlated across the key stages, it is possible that GCSE maths does not have a strong effect on subject choice, relative to previous test scores (e.g., KS3), as the informative effect of GCSE results of an individual's own ability in a given subject is likely to come after decisions about A-level subjects have been made (Ferretti, 2007).

In VE, gender gaps in STEM subjects are more prominent than in A-level, both in overall STEM uptake, engineering and technology, but gaps are also more persistent; the role of prior

[12]Although we do not investigate specific subjects within these STEM areas, it is important and interesting to note that gender differences may exist within these subject clusters. For instance, within science study, females are more likely to study biology while physics is of greater interest to males than females (Baram-Tsabari & Yarden, 2008).

[13]Results available on request.

TABLE 4 Gender gap in A-levels and vocational STEM subject participation

	(1)	(2)	(3)	(4)
Panel A) A-level				
STEM	−0.073***	−0.072***	−0.072***	−0.018***
	(0.002)	(0.002)	(0.003)	(0.002)
Engineering	−0.039***	−0.040***	−0.039***	−0.031***
	(0.001)	(0.001)	(0.002)	(0.002)
Maths/Science	−0.034***	−0.034***	−0.033***	0.023***
	(0.002)	(0.002)	(0.003)	(0.002)
Technology	−0.088***	−0.087***	−0.088***	−0.077***
	(0.001)	(0.001)	(0.002)	(0.002)
N	*271,950*	*271,950*	*271,950*	*271,950*
Panel B) Vocational				
STEM	−0.445***	−0.444***	−0.444***	−0.418***
	(0.003)	(0.003)	(0.003)	(0.003)
Construction	−0.193***	−0.195***	−0.195***	−0.191***
	(0.002)	(0.002)	(0.002)	(0.003)
Engineering	−0.183***	−0.183***	−0.183***	−0.166***
	(0.002)	(0.002)	(0.002)	(0.002)
Maths/Science	−0.004***	−0.003**	−0.002**	−0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Technology	−0.088***	−0.085***	−0.085***	−0.081***
	(0.002)	(0.002)	(0.002)	(0.002)
N	*86,577*	*86,577*	*86,577*	*86,577*
Individual	No	Yes	Yes	Yes
School characteristics	No	No	Yes	Yes
Prior attainment	No	No	No	Yes

Notes: (i) Standard errors in parentheses (ii) Each coefficient in the table represents the coefficient on the female binary variable. The raw differences, with no controls are included in the regressions, are presented in column (1). Controls are added with the final specification with all controls including individual, school and prior attainment controls in column (4) Controls include—Individual characteristics: female, ethnicity (Asian, black, mixed, other, with white as the base category), Government office region, SES index (see Section 3.2 for details). KS4 school characteristics including total number of pupils, percentage of pupils receiving free school meals (FSM), average number of GCSEs attained, percentage of pupils who are white, mixed sex school. Prior attainment controls include average point score achieved in English, maths and science at KS2 and KS3, GCSE grade in English, Maths and Science. (iii) Each cell represents a different regression with the dependent variable being indicated in the first column and the model's controls indicated below the results. The coefficients are interpreted as in the following example: The probability of choosing an engineering STEM subject in post-16 vocational education is 18.3 percentage points lower for females than males in column (1); when controls are added, females are 16.6 percentage points less likely to choose engineering STEM subjects, ceteris paribus. These results are conditional on attending post-16 education, either on the academic or vocational route.

**p* < .1; ***p* < .05; ****p* < .01.

attainment in explaining gender gaps in VE is much more limited than in A-levels. However, we find that the small gender gap that exists in the take up of vocational maths and science study is partly explained by individual and school characteristics; the remaining gap that persists after controlling for these factors is reduced to zero once ability controls are added to the model. The lower achievement scores of females that we observe through schooling (maths and science at KS2, KS3 and GCSE) are therefore detrimental to the take up of vocational maths and science STEM study in post-16 education; when achievement is equal, females are just as likely to choose maths and science study as males in VE.

In vocational study, gender gaps are most pronounced in the subjects where returns to the qualifications are the highest, including engineering and construction. In these subjects, the positive earning differentials are particularly strong for women (Battison et al., 2019).

Females who take the vocational route are significantly less likely to study all other STEM fields. This could be due to the 'traditions' of subject uptake within VE as also found in apprenticeships; typically, beauty and social care subjects and sectors are female dominated in terms of participation, whilst building and construction and engineering are male dominated (Cavaglia et al., 2018). The gender stereotypes associated with construction and engineering subjects may therefore drive the differences in participation to a greater extent than differences in prior attainment; a lack of other females expected to participate in the course but also the occupation field as a whole may be off-putting for potential female participants. Further, whereas A-levels are typically all classroom based with little difference in setting in which subjects are taught, VE may vary vastly in the environmental setting involved in study that may reinforce gender stereotypes. As seen in the raw differences in engineering for example, the gaps are much larger in vocational routes than A-levels. Perceptions of male-dominated STEM careers have been found to deter females from STEM study even in A-levels and university (Cassidy et al., 2018) where gender is more balanced than in vocational study.

One other possible determinant of the persistent gender gap may be the greater risk aversion of females relative to males; we identify that after controlling for ability, maths and science are more likely to be studied by females, and that there are no significant gender differences in the study of maths and science in VE . These subjects are already taught throughout all compulsory schooling therefore pupils have prior experience of these subjects and are informed of their ability in these areas from KS2 and KS3 test scores at the time of making post-16 education decisions. For risk averse females, these may therefore be deemed a 'safer' STEM subject to study once the decision of route has been made.

Overall, the results suggest that differences in prior attainment between males and females in English, maths and science cannot fully explain the gender participation gaps in STEM uptake in either A-levels or VE, aside from maths and science subjects. Further, these gaps are not explained by individual or school characteristics that may influence males and females differentially. The size and significance of the gender gap persists when we take account of selection into FE which leads to a sample which is not representative of the gender or SES composition of the cohort, due to the restriction of the sample to those in FE and vocational or A-level study.[14]

[14]We model the likelihood of selection into any form of FE as a function of gender and SES and calculate an inverse probability weight, which is applied to the regression models and estimate the raw gender differentials and within SES groups. We continue to restrict the sample to those in FE as the decision to study STEM in vocational qualifications levels 2–3 and STEM A-levels requires continuation of study in FE, thus the decision to study STEM cannot be disentangled from the decision to remain in FE. The application of these weights does not lead to a statistically different female coefficient from those estimated in the models without weights, nor do the weights lead to a change in the level of statistical significance of any female coefficient which indicates the gender differential in each model. Results available on request.

4.2 | Do gender gaps exist in vocational education once we take account of the level of study?

When analysing the gender gaps in academic post-16 education, we specifically observed A-Level (level 3) study, whilst observing choices in VE as a whole. However, individuals may choose to study at either level 2 or level 3 in VE, thus they may take STEM subjects at either level. In order to fully understand the relationship between prior attainment and STEM study in VE, we must take into account the level of study since lower attaining pupils typically opt into, or only have the option to take lower-level qualifications. Table 5 presents the results from the previous analyses but when splitting the vocational subject areas into level 2 and level 3 qualifications. The results continue to suggest that females are under-represented in vocational STEM study, and more specifically in construction, engineering and technology. These gaps are only partly explained by differences in prior attainment between males and females. Gender gaps are smaller in level 3 study than level 2 in construction, engineering and maths and science subjects, but these are driven by the raw differences in participation rather than the explanatory power of individual and school characteristics and prior attainment. The results suggest that the previous findings are not driven by female underrepresentation in STEM participation in a particular level of VE.

4.3 | Conditional on attempting STEM subjects, is there a gender achievement differential?

The results presented in Table 6 indicate that on average, a female taking an A-level STEM subject is more likely to achieve the A-level qualification than a male taking an A-level STEM subject with identical KS2 and KS3 scores, GCSE grades and individual and school characteristics. This positive female achievement gap is found for the overall STEM indicator and in maths/science subjects. This is not to say that females are simply better than males at these subjects. In all subjects, individuals select into the qualifications they wish to study based on their own preferences, interests, skills and prior attainment. Thus, forcing females to take these subjects may not result in this same performance gap since the females in the sample that perform better than males self-select into studying their chosen qualification and subject. What we may observe is that 'better' females than males select into maths and science STEM study. The existing literature suggests that females may be more risk averse in subject choice than males and may require higher grades in the associated prior qualifications to encourage them to study a given STEM subject (Friedman-Sokuler & Justman, 2016). Thus, this positive performance gap exists once these gender differences are accounted for via the selection process, since we condition on participation in these subject areas. Conversely, we find that females taking engineering A-levels are significantly less likely to achieve the qualification than males. The underperformance of females, comparable to males in terms of prior attainment, in engineering A-levels may be off-putting for prospective female students who observe female performance in engineering A-levels.

Conversely, when observing the gender gap in achievement for vocational STEM subjects overall, the results suggest that females who take vocational STEM subjects at level 2 and 3 are on average, significantly less likely to achieve the qualification than males. Thus, even after holding constant prior attainment and individual and school characteristics, males are more likely to achieve their vocational STEM qualification than similar females who opt into the study for these qualifications. However, this significant underperformance of females, compared with males is not identified when observing specific subjects and interestingly, females taking vocational level

TABLE 5 Gender gap in vocational STEM subject participation by level

	(1)	(2)	(3)	(4)
STEM level 2	−0.480***	−0.479***	−0.479***	−0.462***
	(0.004)	(0.004)	(0.004)	(0.005)
STEM level 3	−0.371***	−0.370***	−0.370***	−0.335***
	(0.004)	(0.004)	(0.004)	(0.005)
Construction level 2	−0.267***	−0.269***	−0.269***	−0.266***
	(0.003)	(0.003)	(0.003)	(0.004)
Construction level 3	−0.077***	−0.078***	−0.078***	−0.076***
	(0.002)	(0.002)	(0.002)	(0.003)
Engineering level 2	−0.191***	−0.190***	−0.190***	−0.174***
	(0.003)	(0.003)	(0.003)	(0.003)
Engineering level 3	−0.167***	−0.169***	−0.170***	−0.148***
	(0.003)	(0.003)	(0.003)	(0.003)
Maths/Science level 2	0.003*	0.005***	0.005**	0.005**
	(0.002)	(0.002)	(0.002)	(0.002)
Maths/Science level 3	−0.004***	−0.004***	−0.004***	−0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Technology level 2	−0.056***	−0.054***	−0.054***	−0.053***
	(0.002)	(0.002)	(0.003)	(0.003)
Technology level 3	−0.130***	−0.127***	−0.127***	−0.118***
	(0.003)	(0.003)	(0.003)	(0.003)
N	*47,512 in level 2*			
	39,065 level 3			
Individual	No	Yes	Yes	Yes
School characteristics	No	No	Yes	Yes
Prior attainment	No	No	No	Yes

Notes: (i) Standard errors in parentheses. (ii) Each cell represents a different regression with the dependent variable being indicated in the first column and the models controls indicated below the results. (iii) Controls include—Individual characteristics: female, ethnicity (Asian, black, mixed, other, with white as the base category), Government office region, SES index (see Section 3.2 for details). KS4 school characteristics including total number of pupils, percentage of pupils receiving free school meals (FSM), average number of GCSEs attained, percentage of pupils who are white, mixed sex school. Prior attainment controls include average point score achieved in English, Maths and Science at KS2 and KS3, GCSE grade in English, maths and science.

$^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

2 engineering and level 3 technology qualifications are significantly more likely to achieve the qualification than their male counterparts. The results suggest that once prior attainment and individual and school characteristics are constant, there is an insignificant difference in the attainment of vocational level 2 qualifications in construction, maths/science and technology and level 3 qualifications in construction, engineering and maths/science.

Overall, the results may provide some evidence that expected achievement could play a role in explaining the participation gaps observed in vocational STEM study, given that results overall suggest that females who do study these STEM subjects (overall) are less likely to achieve the qualification than their male counterparts. Although we see achievement gaps in vocational

TABLE 6 Gender gap in vocational and academic STEM subject attainment

	(1)	(2)	(3)	(4)	(5)
	STEM	Construction	Engineering	Math/Sci	Technology
Panel A) A-level	0.064***	–	−0.076***	0.060***	0.006
	(0.005)		(0.009)	(0.005)	(0.011)
N	*134,422*	*358,527*	*19,462*	*114,417*	*22,462*
Panel B) vocational level 2	*−0.024***	*−0.048*	*0.076***	*−0.031*	*−0.001*
	(0.012)	*(0.041)*	*(0.031)*	*(0.026)*	*(0.020)*
N	*17,555*	*7486*	*5734*	*1846*	*3546*
Panel C) vocational level 3	*−0.038***	*−0.039*	*−0.041*	*−0.021*	*0.042**
	(0.018)	*(0.049)*	*(0.050)*	*(0.039)*	*(0.025)*
N	*7855*	*1437*	*3091*	*422*	*3069*

Notes: (i) Standard errors in parentheses. (ii) Each cell represents a different regression with the route being indicated in the first column and the subject within 47,512 that route indicated in the column headings. (iii) Results with controls include individual characteristics, School characteristics and prior attainment. Controls include—Individual characteristics: female, ethnicity (Asian, black, mixed, other, with white as the base category), Government office region, SES index (see Section 3.2 for details). KS4 school characteristics including total number of pupils, percentage of pupils receiving free school meals (FSM), average number of GCSEs attained, percentage of pupils who are white, mixed sex school. Prior attainment controls include average point score achieved in English, Maths and Science at KS2 and KS3, GCSE grade in English, Maths and Science.
*p <.1; **p <.05; ***p <.01.

STEM qualifications overall, the evidence suggests that these gaps are subject specific, and therefore may depend upon the extent of the information that females looking to select into these areas of study have access to and base their decisions on.

4.4 | Does the relationship between gender and STEM uptake also depend on socio-economic status?

Differences in participation in STEM take up in post-16 education have so far been partly explained by individual and school characteristics and prior attainment, though these characteristics do not fully explain why females partake in STEM study to a lesser extent than males both on an A-level route and vocational route. These differences exist despite the achievement of those females that do opt into STEM study typically being better than the males that do. We now explore whether SES may play a role in explaining the remainder of the gender gap. SES is controlled for in all previous models, and we now consider whether the role of SES differs for males and females in the choice of STEM participation. Existing studies, based on data outside of the UK, have identified that the role of gender is mediated by SES with a stronger negative association between SES and STEM take up for boys (Friedman-Sokuler & Justman, 2016; Justman & Mendez, 2018). We are able to observe whether this is also the case in the UK by allowing the effect of SES to vary with gender. This effect may also be compared between academic and vocational routes.

Table 7 shows the results obtained from estimating (Equation 3) and constructing the SES varying gender gaps, derived in (Equation 4) where we interact the gender indicator with quintiles of socio-economic status.[15] SES 1 corresponds to the most deprived 20% of the cohort, and

[15]Coefficient estimates are provided in Table A.3

TABLE 7 Gender gaps in vocational and academic STEM subject attainment within SES

	(1)	(2)	(3)	(4)	(5)	(6)
	A levels		Vocational level 3		Vocational level 2	
	Raw	+Control	Raw	+Control	Raw	+Control
Gender Gap in SES 1	−0.057***	0.004	−0.376***	−0.340***	−0.466***	−0.448***
$(\alpha + \delta_1)$	(0.006)	(0.005)	(0.008)	(0.008)	(0.007)	(0.007)
Gender Gap in SES 2	−0.066***	−0.011***	−0.378***	−0.340***	−0.481***	−0.462***
$(\alpha + \delta_2)$	(0.005)	(0.004)	(0.008)	(0.008)	(0.008)	(0.008)
Gender Gap in SES 3	−0.065***	−0.018***	−0.374***	−0.337***	−0.492***	−0.475***
$(\alpha + \delta_3)$	(0.004)	(0.004)	(0.008)	(0.008)	(0.009)	(0.009)
Gender Gap in SES 4	−0.074***	−0.022***	−0.374***	−0.338***	−0.495***	−0.479***
$(\alpha + \delta_4)$	(0.004)	(0.003)	(0.008)	(0.008)	(0.010)	(0.010)
Gender Gap in SES 5	−0.079***	−0.029***	−0.349***	−0.313***	−0.465***	−0.447***
(α)	(0.004)	(0.003)	(0.009)	(0.009)	(0.012)	(0.012)
N	*271,950*	*271,950*	*39,065*	*39,065*	*47,512*	*47,512*

Notes: (i) Standard errors in parentheses. (ii) Even numbered columns add individual school and prior attainment controls to the SES dummies. (iii) Each cell represents the coefficient from a different regression; each coefficient represents the parameters estimated in (Equation 3) as constructed from (Equation 4). (iv) Results with controls include individual characteristics, School characteristics and prior attainment. Controls include—Individual characteristics: female, ethnicity (Asian, black, mixed, other, with white as the base category), Government office region, SES index (see Section 3.2 for details). KS4 school characteristics including total number of pupils, percentage of pupils receiving free school meals (FSM), average number of GCSEs attained, percentage of pupils who are white, mixed sex school. Prior attainment controls include: average point score achieved in English, maths and science at KS2 and KS3, GCSE grade in English, maths and science. (v) Full results are available on request.

*$p < .1$; **$p < .05$; ***$p < .01$.

SES 5 the least deprived 20% of the cohort. For each qualification type we consider, we present results from a raw specification containing only the gender dummy, SES dummies, and their interactions, we then compare these raw coefficients with conditional coefficients obtained by adding in control variables. For all three qualifications, we observe gender gaps in STEM relative to non-STEM participation across the SES distribution. Females attempting the same qualifications are less likely to participate in STEM subjects than their male counterparts and this is true in every SES group except the least deprived quintile, where there is an insignificant difference in STEM A-level study between males and females. The gender gap is much larger for vocational qualifications than for A-Levels in all SES groups, and still larger for level 2 vocational qualifications than for level 3. A negative relationship between deprivation and the uptake of STEM A-level is apparent as gender imbalances are of the greatest magnitude in SES 5. The opposite is true for vocational level 3 qualifications where the largest gender imbalance exists in the two least deprived SES group. These results are already conditional on the post-16 education route taken and are therefore not driven by differences in route by SES.

The results obtained from estimating (Equation 4) and constructing the SES gradients derived in Equations (5) and (6) are presented in Table 8. The results present the effect of SES on female participation. The findings suggest that for those attempting vocational qualifications, SES background is not associated the probability of taking the qualifications in a STEM subject. This is not true for males, where positive and significant coefficients do indicate that background does play a role in determining STEM participation. For vocational level 2, the social gradient for males is

TABLE 8 Effect of SES on participation in vocational and academic STEM

	(1)	(2)	(3)	(4)	(5)	(6)
	A levels		Vocational level 3		Vocational level 2	
	Raw	+Control	Raw	+Control	Raw	+Control
SES1 Effect on Female	−0.124***	0.018***	0.012	0.007	−0.017	−0.009
$(\beta_1 + \delta_1)$	(0.004)	(0.004)	(0.008)	(0.009)	(0.011)	(0.011)
SES2 Effect on Female	−0.098***	0.011***	0.005	0.001	−0.020*	−0.013
$(\beta_2 + \delta_2)$	(0.004)	(0.004)	(0.008)	(0.008)	(0.011)	(0.011)
SES3 Effect on Female	−0.068***	0.007**	0.006	0.002	−0.017	−0.011
$(\beta_3 + \delta_3)$	(0.004)	(0.003)	(0.008)	(0.008)	(0.011)	(0.011)
SES4 Effect on Female	−0.047***	0.002	0.001	−0.002	−0.018	−0.014
$(\beta_4 + \delta_4)$	(0.004)	(0.003)	(0.009)	(0.008)	(0.012)	(0.012)
SES1 Effect on Male	−0.146***	−0.015***	0.039***	0.034***	−0.016*	−0.008
(β_1)	(0.005)	(0.005)	(0.009)	(0.009)	(0.009)	(0.009)
SES2 Effect on Male	−0.112***	−0.007*	0.033***	0.028***	−0.004	0.002
(β_2)	(0.004)	(0.004)	(0.009)	(0.009)	(0.009)	(0.009)
SES3 Effect on Male	−0.082***	−0.005	0.031***	0.026***	0.010	0.016*
(β_3)	(0.004)	(0.004)	(0.009)	(0.009)	(0.009)	(0.009)
SES4 Effect on Male	−0.053***	−0.006*	0.026***	0.023**	0.012	0.017*
(β_4)	(0.004)	(0.003)	(0.009)	(0.009)	(0.010)	(0.010)
N	*271,950*	*271,950*	*39,065*	*39,065*	*47,512*	*47,512*

Notes: (i) Standard errors in parentheses. (ii) Even numbered columns add individual school and prior attainment controls to the SES dummies (iii) Each cell represents the coefficient from a different regression; each coefficient represents the parameters estimated in (Equation 3) as constructed from (Equation 5) for females and (Equation 6) for males. (iv) Results with controls include individual characteristics, School characteristics and prior attainment. Controls include—Individual characteristics: female, ethnicity (Asian, black, mixed, other, with white as the base category), Government office region, SES index (see Section 3.2 for details). KS4 school characteristics including total number of pupils, percentage of pupils receiving free school meals (FSM), average number of GCSEs attained, percentage of pupils who are white, mixed sex school. Prior attainment controls include: average point score achieved in English, Maths and Science at KS2 and KS3, GCSE grade in English, Maths and Science. (vi) Full results are available on request.

*p <.1; **p <.05; ***p <.01.

considerably weaker than at level 3 with SES. There is a clear SES gradient for STEM A-Level participation. As deprivation increases, by SES quintile, the less likely a female attempting A-Level qualifications is to attempt STEM A-Levels. This gradient is much reduced—but still present and significant—when controlling for prior achievement and characteristics. For females, there is no effect of SES on STEM probability when the highest qualification attempted is either vocational level 3 or vocational level 2. This is the case even without conditioning on other observables. This is in accordance with the literature that suggests that SES less adversely affects females than males in subject choice.

5 | SUMMARY

The paper explores the impact of gender and socio-economic background on the likelihood of attempting and achieving qualifications in STEM. We contribute to the literature on the underrepresentation of women in STEM by focusing on the determinants of the gender gap in STEM study in vocational post-16 education (levels 2 and 3), in addition to the academic route (A-levels) which has received greater attention in the existing literature. Our findings indicate that gender differentials in the uptake of STEM subjects in vocational qualifications are much starker than they are in A-Levels. As in the existing literature, which predominantly focuses on female underrepresentation in STEM uptake in HE, we find that differences in ability play a minor role in the gender gaps that exist in vocational education, in both level 2 and 3 qualifications. The explanatory power of ability in understanding gender gaps in STEM subject choice is much greater in A-levels and in vocational maths and science subject choice. Finally, we find that gender imbalances in STEM study are apparent across every SES group and SES background is not associated with the probability of taking STEM qualifications. We find no evidence that females who select into in vocational STEM studies perform worse than their male counterparts, which could drive the gender participation gaps; instead, we identify that females are more likely to achieve their attempted qualification, than males, in some STEM subjects.

The vocational qualifications yielding the greatest qualification returns are STEM subjects, including engineering, technology and construction, where we find that females are most underrepresented, owing not to differences in school characteristics or differences in ability. Thus, whilst the returns for women in these STEM occupations are high and positively encouraging, we identify a large deficit in females selecting into these qualifications to obtain the skills and progress in further study to obtain the returns in the associated occupations. This combination of under-representation of women and strong earning potential suggests useful policy interventions, with both efficiency and equity benefits. This is not the case in A-level study where the uptake of STEM study is much more equal amongst males and females, and smaller gender gaps prevail once differences in ability are accounted for. This may in part reflect that A-Levels offer more choice of subject, with individuals able to study typically 3–5 different subjects, rather than vocational study that is focussed on one subject area. This does, however, still suggest that STEM is the "first choice" for males more so than it is for females. The role of gender stereotypes may be greater for vocational qualifications than for academic qualifications. While academic qualifications provide more general skills, the nature of vocational qualifications in preparing individuals with occupation-specific skills may make subject choice more sensitive to the idea of "traditional" occupations done by men (e.g., engineering, construction, plumbing) or by women (e.g., hairdressing). This could present a significant barrier to females who take a vocational route, particularly since labour market returns to vocational qualifications are typically highest—for both males and females—in the male-dominated subject areas.

The results of the analysis are based on a single cohort of English students who left school in 2005/2006 and thus it is important to note that the post-compulsory education landscape in England has changed somewhat over the past decade in terms of the choices and pathways that may be taken through post-compulsory education. It is therefore possible that the factors driving gender differentials in both participation and attainment may have evolved and altered over time as the composition of students choosing each route through compulsory education adapts. However, gender gaps in STEM study are evident today with a considerable underrepresentation of females in STEM occupations. While these gaps persist, the deficiency of STEM skills currently being experienced in the UK will remain. Furthermore, while observing an older cohort of school leavers, we are able to observe the sequential outcomes of these gaps in more recent years, in the form of earnings premiums.

It is vital to understand the determinants of STEM study in all routes of education. The continuing expansion of vocational further education and the growth of learners who choose this route over A-levels prompts further research into subject choice within vocational education and the gender gaps that exist within both route and subject choice. While policies and schemes to improve girls' confidence and interest in STEM subjects are beneficial, focusing on the continuation of STEM academic study may overlook opportunities for STEM learning via more practical, vocational routes and simultaneously disregard students who are more suited to vocational study. Reducing the gender gaps in education, which in turn drive gender imbalances in STEM occupations, is imperative for the economy but also for gender equality in the UK.

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DATA AVAILABILITY STATEMENT

This paper uses administrative data owned and held by the Department for Education (DfE). Applications to access this data should be made directly to DfE.

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APPENDIX A

STEM QUALIFICATIONS AND OCCUPATIONS

TABLE A1 Examples of STEM qualifications by qualification type

Vocational level 2	
Maths and Science	BTEC First Diploma in Applied Science NVQ in Clinical Laboratory Support Free Standing Mathematics Qualification: Calculating Finances Free Standing Mathematics Qualification: Handling and Interpreting Data
Technology	BTEC First Diploma for ICT Practitioners NVQ for IT Users NVQ for Communication Technology Practitioners
Engineering	BTEC First Diploma in Engineering NVQ in Performing Engineering Operations NVQ in Vehicle Maintenance and Repair BTEC First Diploma in Vehicle Technology
Vocational level 3	
Maths and Science	BTEC National Diploma in Applied Science
Technology	BTEC National Award/Diploma for IT Practitioners
Engineering	BTEC National Diploma in Electrical Engineering NVQ in Electrotechnical Services NVQ in Railway Engineering Certificate in Operations and Maintenance Engineering
A levels	
Maths and Science	Maths, Chemistry, Psychology, Physics, Biology, Geology
Technology	Computing, ICT
Engineering	Electronics, Design and Technology

Much of the discussion in academic research and the media about post-compulsory education pathways focuses on the academic route - towards higher education. This combined with the complexity of the vocational system and the consequent larger number of choices which individuals taking this route face means relatively little is known about the continued progression of individuals who under-take vocational education (Hupkau et al., 2017).

We pool quarterly Labour Force Survey (LFS) data from 2011 to 2017 and examine the most common occupations (at 4-digit standard occupational classification level) that individuals who have undertaken vocational qualifications are typically employed in. Specifically, we use the example of those whose highest qualification is a vocational qualification in the subject area of engineering. Table A2 shows the ten most frequently observed occupations in which these individuals are employed. Note that these occupations represent just under 40% of all employed individuals with this level of education, and the bottom three occupations in the table less than 2% each. There is therefore a diverse range of occupations which individuals with these qualifications progress to. Primarily, these most frequent occupations are relevant to the subject e.g. electricians and electrical fitters, engineering technicians, skilled metal electrical and electronic trades supervisors. There is however some evidence of those with this qualification ending up in occupations where it would not be directly relevant, e.g. sales account and business development managers, and large goods vehicle drivers.

While here we present the example of a vocational qualification in a particular subject area, this diversity of career pathways is typical of other qualifications.

TABLE A2 Distribution of occupations in which vocational level 3 engineering are employed

	Vocational level 3 engineering			
	SOC-10	**Occupation**	***N***	**%**
	5241	Electricians and electrical fitters	180	10.06%
	5231	Vehicle technicians, mechanics and electricians	137	7.66%
	5223	Metal working production and maintenance fitters	119	6.65%
	1121	Production managers and directors in manufacturing	48	2.68%
	3113	Engineering technicians	48	2.68%
	5250	Skilled metal, electrical and electronic trades supervisors	38	2.12%
	5215	Welding trades	36	2.01%
	3545	Sales accounts and business development managers	35	1.96%
	5249	Electrical and electronic trades *n*.e.c.	33	1.84%
	8211	Large goods vehicle drivers	32	1.79%
Total			1,789	39.46%

TABLE A3 Coefficient estimates of Equation (3)

	(1)	(2)	(3)	(4)	(5)	(6)
	A Levels		Vocational Level 3		Vocational Level 2	
	Raw	+Control	Raw	+Control	Raw	+Control
Female	−0.079***	−0.029***	−0.349***	−0.313***	−0.465***	−0.447***
	(0.004)	(0.003)	(0.009)	(0.009)	(0.012)	(0.012)
SES-1	−0.146***	−0.015***	0.039***	0.034***	−0.016*	−0.008
	(0.005)	(0.005)	(0.009)	(0.009)	(0.009)	(0.009)
SES-2	−0.112***	−0.007*	0.033***	0.028***	−0.004	0.002
	(0.004)	(0.004)	(0.009)	(0.009)	(0.009)	(0.009)
SES-3	−0.082***	−0.005	0.031***	0.026***	0.010	0.016*
	(0.004)	(0.004)	(0.009)	(0.009)	(0.009)	(0.009)
SES-4	−0.053***	−0.006*	0.026***	0.023**	0.012	0.017*
	(0.004)	(0.003)	(0.009)	(0.009)	(0.010)	(0.010)
(Female * SES-1)	0.023***	0.033***	−0.027**	−0.027**	−0.001	−0.001
	(0.007)	(0.006)	(0.012)	(0.012)	(0.014)	(0.014)
(Female * SES-2)	0.014**	0.018***	−0.029**	−0.027**	−0.016	−0.015
	(0.006)	(0.005)	(0.012)	(0.012)	(0.014)	(0.014)
(Female * SES-3)	0.014**	0.011**	−0.025**	−0.024**	−0.027*	−0.027*
	(0.006)	(0.005)	(0.012)	(0.012)	(0.015)	(0.015)
(Female * SES-4)	0.006	0.008*	−0.025**	−0.025**	−0.030*	−0.031**
	(0.005)	(0.005)	(0.012)	(0.012)	(0.015)	(0.015)
N	*271,950*	*271,950*	*39,065*	*39,065*	*47,512*	*47,512*

Notes: (i) Standard errors in parentheses. (ii) Results with controls include individual characteristics, school fixed effects and prior attainment.

*p <.1; **p <.05; ***p <.01.