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Improving Gender Balance in uptake of physics qualifications aged 16-18: a cluster randomised controlled trial in England

Sam Sims
UCL

The proportion of female students taking up physics qualifications at age 16-18 is far below that of male students and the reasons for this remain somewhat unclear. One possible explanation is that peers, teachers and parents are (perhaps inadvertently) perpetuating gendered stereotypes around subject choice. We study the effects of a whole-school intervention - Improving Gender Balance (IGB) - which aims to counter such stereotypes. A team of experienced IGB coaches worked directly with schools to increase gender balance in the way that students, teacher and parents thought and talked about physics and other school subjects. We tested the effects of IGB on uptake of A-level physics among female students using a school-level cluster randomised trial. The COVID-19 pandemic caused school closures for around half of the time that the IGB programme was running. We found uptake of A Level physics to be 0.7 percentage points higher in our overall sample ($p=0.07$). Based on a pre-registered definition of treatment compliance, we found a larger effect (0.9 percentage points; $p=0.046$) among the group of schools that persisted with implementation after the first COVID-19 lockdown.

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Highlights

- The Improving Gender Balance (IGB) programme involves experienced coaches working with teachers, parents and pupils to improve equity in the way all three groups think and talk about physics. The ultimate goal is to improve gender balance in the proportion of male and female students choosing to study physics at A Level.
- 149 schools took part, half of which were randomly assigned to either take part in the IGB programme and the other half to continue with business-as-usual.
- The Institute of Physics delivered the IGB programme to treatment schools in 2019/20 and 2020/21. COVID-19 school closures disrupted delivery of the programme in 2019/20 and only 54 of 71 treatment schools continued in 2020/21.
- The proportion of female students in the IGB treatment schools who subsequently completed A Level physics was 3.6% compared to 2.9% in the control schools. Physics A Level uptake was therefore 0.7 percentage points higher, or 21% higher, for females exposed to the IGB programme. This difference was not statistically significant ($p=0.07$).
- Among the subset of 54 treatment group schools that continued with the programme into the 2020/21 academic year the proportion of female students completing an A Level in physics was 0.9 percentage points higher, or 31% higher, than in control group schools. This difference was statistically significant ($p=0.046$).
- IGB can improve female students' uptake of physics at age 16, particularly if the programme is implemented over more than one year, as intended. These results justify further piloting and evaluation of the IGB programme.

Why does this matter?

There are long-standing concerns about whether the UK and other nations are producing enough STEM skills. If female students are being put off studying physics by gender norms around subject choice, this also represents an unjust constraint on female autonomy and may in turn contribute to gender pay gaps later in life.

**Improving Gender Balance in uptake of physics qualifications aged 16-18:
a cluster randomised controlled trial in England**

Sam Sims

Centre for Education Policy and Equalising Opportunities, UCL

The proportion of female students taking up physics qualifications at age 16-18 is far below that of male students and the reasons for this remain somewhat unclear. One possible explanation is that peers, teachers and parents are (perhaps inadvertently) perpetuating gendered stereotypes around subject choice. We study the effects of a whole-school intervention - Improving Gender Balance (IGB) - which aims to counter such stereotypes. A team of experienced IGB coaches worked directly with schools to increase gender balance in the way that all three groups thought and talked about physics and other school subjects. We tested the effects of IGB on uptake of A-level physics among female students using a school-level cluster randomised trial in England. The COVID-19 pandemic caused school closures for around half of the time that the IGB programme was running. We found uptake of A Level physics to be 0.7 percentage points higher in our overall sample ($p=0.07$). Based on a pre-registered definition of treatment compliance, we found a larger effect (0.9 percentage points; $p=0.046$) among the group of schools that persisted with implementation after the first COVID-19 lockdown.

Keywords: Physics, Gender, Subject Choice

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Around the world, female students are under-represented in post-compulsory education in science, technology, engineering and maths (STEM) subjects (Cheryan et al., 2024). For example, in England, the odds of taking up any STEM A-level (the main academic qualification at age 16-18) are 50% lower for female students than for equally high-achieving male students (Codioli McMaster, 2017). The disparities are even more stark when we focus on physics. In 2016, the proportion of 16-year-old male students who go on to study physics A-level at age 16-18 in England was 6.5% but the equivalent figure for female students was just 1.9% (IoP, 2018). At that time, just over one in five students starting A-level physics were female, making physics the most gender imbalanced subject at A Level after computer science (Plaister, 2025).

These disparities raise concerns about both efficiency and equity. There are long-standing concerns about whether the UK and other nations are producing enough STEM skills to meet the needs of their economies (Smith & White, 2024). The relatively low uptake of A-level physics among female students is seen as contributing to these skills shortages and potentially holding back economic growth. A second concern relates to potential gender inequities. If female students are being put off studying physics this represents an unjust constraint on female autonomy and life chances, which may in turn contribute to gender pay gaps later in life (Chevalier, 2007).

At a high-level, two broad sets of theories have been proposed to explain the gender disparities in uptake of STEM subjects, including physics (Kriesi & Imdorf, 2019; Yazilitas et al., 2013). The first of these emphasises rational choice, arguing that female students anticipate lower rates of return than their male counterparts from acquiring a physics qualification and are therefore less likely to choose to study it (Becker, 1981). These perceptions could be due to gendered preferences for studying different subjects, gendered perceptions of the likelihood of

succeeding in the qualification, or gendered perceptions of the likely rewards available for those skills in the labour market (see Gabay-Egozi et al., 2015). The second set of theories emphasise cultural influences, which are thought to constrain and shape subject choice (Archer et al., 2016; Ridgeway & Correll, 2004). On this account, children are socialised in a world infused with gender norms and stereotypes. As children grow and develop, they come to internalise these, developing gendered values, self-concepts and identities (Archer et al., 2013; Combet, 2024; Jansen et al., 2021; Sinclair et al., 2019; van der Vleuten, 2016). These learned influences may in turn over-ride innate or prior preferences to study physics among female students.

Drawing on the cultural perspective, researchers have explored the role of social networks in influencing subject choice (Kriesi & Imdorf, 2019). For example, studies have found evidence suggesting that peers (Riegle-Crumb et al., 2017; Raabe et al., 2019), parents and carers (Jones & Hamer, 2022) and teachers (Park et al., 2018) may contribute to gendered subject choices. This raises the question of whether changing the way in which these groups think about and talk about subject choice could improve the gender balance in uptake of physics. However, reversing years of socialisation would likely require concerted efforts to change the views of peers, parents and teachers. Until now, no such approach has been rigorously tested in the field.

The present study contributes to this literature by providing a large-scale experimental test of a two-year, whole-school programme designed to change the views of peers, parents and teachers. The programme – Improving Gender Balance in Physics (IGB) – was funded by the Department for Education in England and delivered in schools by the Institute of Physics between 2019 and 2021. We randomly assigned 149 schools to either participate in the programme or a business-as-usual control group and then tracked whether female students in these schools go on to complete a physics A-level over the subsequent two years. The COVID-

19 pandemic caused school closures for around half of the time that the IGB programme was running, which significantly disrupted delivery. We do not find an effect of the IGB programme in our overall sample. However, in a pre-registered analysis we do find an effect among the group of schools that persisted with implementation after September 2020, which is when schools re-opened after the first national lockdown in England. We also find suggestive evidence of larger effects among all-girls schools and schools with high uptake of GCSE physics. These findings are directly relevant to understanding the validity of cultural explanations for gender imbalances in uptake of physics at age 16-18 and have implications for how schools can address these disparities in future.

Methods

Participants

Schools were eligible to participate in the trial if they were providing 11-16 (secondary) education in England at the time of the trial. Recruitment began in April 2019. The IGB team used national data to prioritise recruiting schools with the highest levels of imbalance in the take-up of A-level physics by their pupils. For co-educational (mixed gender) schools, this was calculated using national data based on the metric: % male students taking up A-level physics - % female students taking up A-level physics. For girls-only schools, this was based simply on the % female students taking up A-level physics. Recruitment stopped in February 2022. At this point, there were 149 schools in the trial. There was an attrition rate of 7% (10 schools) which reflected schools failing to submit linkable data. Of these 10 schools, six had been allocated to treatment and four to control. This left 139 schools in the final sample.

Design

We employed a school-level cluster randomised controlled trial to evaluate the impact of the IGB programme. The primary outcome for the trial is the proportion of female students taking up A-level physics. Schools were assigned to treatment or a business-as-usual control at the point of recruitment to the trial, using an ordered list of random numbers generated using the Stata software. The ordering was kept secret from the IGB team and schools so that schools could not anticipate or manipulate their treatment assignment.

We pre-registered the trial design and analysis plan on the Registry of Efficacy and Effectiveness Studies (Registry ID: [16640.1v1](#)) on August 16th 2023. This was after recruitment and randomization had finished but prior to receiving outcome data in November 2024, thus ruling out specification searching or ‘*p* hacking’. This paper provides the answers to all three pre-registered research questions (RQ) for the trial:

- RQ1: Are females in schools randomly allocated to receive the IGB intervention more likely to complete an A-level in physics by August 2023, compared to those in schools assigned to business as usual?
- RQ2: Are females in *intervention-compliant* IGB schools more likely to complete an A-level in physics by August 2023, compared to those in schools assigned to business as usual? Intervention compliant schools are defined as those that engaged in any IGB activities with the relevant cohort of pupils (besides phone/email communication) after September 2020.
- RQ3: Conditional on progressing to A-levels, are females in schools randomly allocated to receive the IGB intervention more likely to complete an A-level in physics by August 2023, compared to those in schools assigned to business as usual?

We used the OptimalDesign package to estimate the minimum detectable effect size (MDES) of the trial. We based this on the known sample size of 149 schools (76 in the treatment,

73 in control), an assumption that each school would contain an average of 60 female pupils, and an assumption that baseline up-take of A-level physics by female students in these schools would mirror the national rate (1.9%). Based on this, we estimated that the trial would provide 80% power to detect an increase in up-take to 2.9% i.e., a one percentage point increase.

Procedure and timelines

The IGB programme is a five-term whole-school intervention (IoP, 2017). Participating schools began the programme in the autumn term of the 2019/20 academic year. During this first term, coaches visited the schools to conduct a ‘needs analysis’. This involved engaging with teachers, leaders, parents, pupils and governors to understand subject choice in each participating school. Coaches used a range of activities to understand the school context, including focus groups, surveys and lesson observations. Through this, coaches aimed to understand current staff practices around subject choice, internal and external communications relating to subject choice, current A-level physics progression rates, the science curriculum in the school, student perceptions of subject choice, and ways in which the school engages with the wider community.

After completing this needs analysis, coaches worked with their schools to put together an action plan aimed at reducing the impact of gender norms and stereotypes related to subject choice. These action plans were tailored to the specific needs of each school. The action plans were implemented from term two onwards, with coaches spending around half a day per week in each participating school to support this work. These activities were aimed at all pupils in Year 7 (age 11) to Year 11 (age 16) in the school and were intended to change the culture and norms around subject choice, with the ultimate goal of influencing pupils’ subject choices at age 16.

All 21 coaches all submitted monthly reports on the activities they conducted with the 71 treatment schools. There was no standardised approach to coding or reporting the activities,

making it hard to quantify the frequency with which different activities occurred. However, we reviewed the reports to understand the range of activities implemented by coaches. We found five themes. The first was leading staff professional development, which covered topics including general inclusive teaching practices and effective physics teaching methods, coupled with physics teaching resources. Second, coaches promoted awareness of careers in physics through hosting stand-alone careers fairs, integrating careers knowledge in the curriculum, and bringing in external speakers. Third, coaches provided careers mentoring, either by pairing students with mentors working in the physics industry or by directly engaging in structured mentoring conversations. Fourth, coaches shared resources with the schools. This included posters, booklets and books for the school library, all promoting gender equality in subject and career choices. Fifth, coaches led or initiated reviews of curriculum to ensure diversity of case studies and inclusion of diverse role models across subjects, including in physics.

In March 2020, schools in England closed to pupils (besides children of Key Workers), due to the COVID-19 pandemic, and remained closed for the remainder of the academic year. Coaches were therefore unable to visit schools for the remainder of term 2 and all of term 3, which seriously disrupted delivery of the IGB programme for participating schools. In September 2020, schools reopened allowing delivery of the programme to resume for the Autumn Term and there was also an online IGB Festival in October 2020. In January 2021, schools partially closed again due to the pandemic. In March 2021, the IGB team reached the end of their funded delivery period and handed over responsibilities for all programme activities to the participating schools. In sum, three of the five terms over which the programme was due to be delivered were affected by COVID-related school closures. This left two and half terms

(autumn term 2019, half of spring term 2020, and autumn term 2020) for the planned programme delivery to occur. Table 1 provides a timeline.

Table 1

Timeline for the trial

Academic Year	Term	Event
2018/19	Autumn	Power calculations finalised
	Spring	April: recruitment begins
	Summer	Recruitment continues
2019/20	Autumn	Term one of IGB programme: needs analysis Focal cohort enters Year 10 (age 14/15)
	Spring	Term two of IGB programme: actions plan implemented March: schools partially closed for rest of term
	Summer	Term three of IGB programme Schools partially closed for summer term
2020/21	Autumn	Schools reopen Term four of IGB programme Focal cohort enters Year 11 (age 15/16)
	Spring	Term five of IGB programme January: schools close again March: IGB programme delivery ends Focal cohort makes A-level subject choices
	Summer	Focal cohort take final GCSE exams
2021/22	Autumn	Focal cohort start A-levels (or other employment/training)
	Spring	February: recruitment to IGB ends
	Summer	
2022/23	Autumn	Focal cohort start second year of A-levels
	Spring	
	Summer	May/June: focal cohort take terminal A-level exams
2023/24	Autumn	August: pre-registration
	Spring	
	Summer	
2024/25	Autumn	Data received

As stated in our pre-registration, the pupil cohort that we analyse is the one that took their Year 11 GCSE examinations in summer 2021. This cohort made their A-level choices in Spring Term of 2021, by which point their schools had (in theory) received up to five terms of exposure

to the IGB programme. This cohort would naturally have studied for their A-levels in the 2021/22 and 2022/23 academic years, with their final grades awarded in summer 2023. We chose not to analyse data for the prior pupil cohort (that took their GCSE examinations in summer 2020) because they had only been exposed to up to two terms of the intervention prior to making their A-level subject choices in Spring Term 2020.

Data

We gave parents/pupils in all participating schools the option not to take part in the trial. Participating schools then sent us a list of all remaining relevant pupils in the 2019/20 academic year. For each pupil, schools provided their first name, second name, date of birth, gender, and Unique Pupil Number. This allowed us to request an extract of the National Pupil Database (NPD) pertaining to all pupils in the trial, with the data linkage conducted by the data owner.

The NPD is an administrative census dataset containing information on demographic characteristics and qualifications for all school pupils in England. Unique pupil identifiers in the data allow us to track pupils if they move between different educational institutions between age 16 (when subject choices are made) and age 18 (when they would complete their A-level qualifications). A-level subject choices are not directly captured in the NPD. We therefore operationalize our outcome measure (take-up of A-level physics) as the receipt of any grade in A-level physics. Among the students in our control group, 2.92% received a grade in A-level physics.

Analysis

As pre-registered, we answer RQ1 and RQ3 using the following multi-level binary logistic regression model, implemented using the `melogit` command in Stata (see Appendix A):

$$\ln\left(\frac{P(Y_{is} = 1)}{1 - P(Y_{is} = 1)}\right) = \beta_0 + \beta_1 T_s + \beta_2 \mathbf{S}_s + \beta_3 \mathbf{X}_s + \beta_4 \mathbf{Z}_{is}$$

Where:

- i indexes pupils and s indexes schools, with pupils nested within schools
- Y is the binary dependent variable indicating completion (receipt of any grade) in an A-level physics exam taken prior to August 2023 (1), or not (0).
- T is a binary variable indicating random allocation to the IGB treatment arm (1), or the business-as-usual control group (0).
- \mathbf{S} is a vector of school random effects (school-specific intercepts) to account for the cluster random assignment at school level
- \mathbf{X} is a vector of two school-level covariates: a dummy capturing whether the school offers A-level (16-18) qualifications and a dummy capturing whether the school is girls only (1) or co-educational (0)
- \mathbf{Z} is a vector of seven pupil-level covariates: a dummy capturing whether pupils were ever eligible for Free School Meals (FSM), a dummy indicating whether pupils have Special Education Needs (SEN) as indicated by having an Education Health and Care Plan, a set of dummies indicating pupils' (broad) ethnic group, pupils' grade in GCSE maths, pupils' average grade across science GCSEs, the number of science GCSEs that pupils took (science = 1, double award science = 2, 'separate' science = 3).

Answering RQ2 involves looking the impact among the subset (71.3%) of treatment group schools that met our pre-registered definition of compliance. Simply dropping the non-compliant schools from our analysis could undermine the balance achieved by the initial randomisation. We therefore instrument for compliance using initial treatment status and estimate the complier average causal effects using the ivprobit command in the Stata software. This recovers the average causal effect for the compliant units under the standard instrumental variable identifying assumptions, which are usually uncontroversial in the case of an RCT with one-sided non-compliance (Gerber & Green, 2012).

Results

Table 2 shows descriptive statistics for the schools in the treatment and control group of the trial. The typical individual in our sample is a white female, who does not receive free school meals (FSM) and does not have special education needs (SEND), took the equivalent of two

science GCSEs and received a grade 6 in GCSE maths and science, and attended a mixed-gender school that did not offer A-levels. As would be expected if the randomisation had worked, differences in the pre-treatment characteristics of pupils in the treatment group and control group are not statistically significant. In any case, all variables in Table 2 are used as covariates in our estimating equations which ensures they are balanced between our treatment and control groups when we estimate the effects of the IGB programme.

Table 2

Descriptive statistics

	Treatment Group	Control Group	Difference
School offers A-levels (%)	83.7%	83.3%	$p=0.93$
All-girls school (%)	16.4%	22.5%	$p=0.55$
Pupils ever FSM (%)	16.0%	17.5%	$p=0.80$
Pupils SEND (%)	1.8%	2.0%	$p=0.05$
Pupils White British (%)	63.7%	60.3%	$p=0.83$
Pupils grade GCSE maths (mean)	5.7	5.5	$p=0.14$
Pupils grade GCSE science (mean)	5.7	5.5	$p=0.12$
Pupils no. science GCSEs (mean)	2.4	2.4	$p=0.74$
N (schools)	71	68	
N (pupils)	7,307	7,293	

Note: Schools provide education up to age 16 but do not necessarily provide A-level qualifications for those aged 16-18. FSM = free school meals. SEND = special educational needs and disabilities, as indicated by pupil having an Education Health and Care Plan. GCSE = general certificate of secondary education, which this standard age-16 qualification taken at the end of compulsory schooling in England.

Table 3 shows the results for each of our three pre-registered research questions (RQs). Each column reports the results from a separate regression. The coefficients in columns 1 and 3 are odds ratios. An odds ratio of 1.2, for example, corresponds to a 20% increase in the odds of receiving any grade in A-level physics and an odds ratio of 0.8 corresponds to a 20% decrease in the odds of receiving any grade in A-level physics. The coefficients in column 2 are average marginal effects (from the complier average causal effects analysis) and show a change in probability. For example, a coefficient of 0.1 corresponds to an increase in probability of 10

percentage points. An asterisk indicates that the estimated effect is statistically significantly different from zero at our preregistered alpha level of 0.05. All models also include five indicators of broad ethnic group (see notes to table), but these are all non-significant across all specifications and the coefficients have therefore been suppressed in the tables.

Table 3

Results for pre-registered research questions

	(1) RQ1: All schools	(2) RQ2: Compliant schools	(3) RQ3: A-level takers
IGB treatment group	1.25 (0.16)	-	1.24 (0.15)
IGB compliant treatment	-	0.009* (0.004)	-
School offers A-levels	1.42 (0.29)	0.01 (0.01)	1.38 (0.28)
All-girls school	1.48* (0.20)	0.01* (0.004)	1.44* (0.19)
Pupil SEND Support	0.73 (0.21)	-0.01 (0.01)	0.80 (0.23)
Pupil EHCP	0.84 (0.91)	-0.01 (0.02)	0.98 (1.08)
Pupil ever FSM	1.81 (0.23)	0.005 (0.01)	1.31 (0.26)
Pupil grade GCSE maths	1.86* (0.23)	0.02* (0.002)	1.80* (0.31)
Mean science GCSE grade	1.48* (0.10)	0.01* (0.002)	1.40* (0.09)
No. of science GCSEs	1.97* (0.25)	0.02* (0.004)	1.85* (0.24)

Coefficients above are:	Odds ratios	AME change in probability	Odds ratios
IGB effect in probability change	+0.7pp	+0.9pp	+0.7pp
N (schools)	139	139	139
N (pupils)	14,600	14,600	8,658

Note: Standard errors in parentheses. * $p < 0.05$. Schools provide education up to age 16 but do not necessarily provide A-level qualifications for those aged 16-18. FSM = free school meals. SEND = special educational needs and disabilities as reflected in an Education Health and Care Plan. GCSE = general certificate of secondary education, which is the standard age-16 qualification in England. Compliant (treated) schools are those that engaged in any IGB activities with the relevant cohort of pupils after September 2020. Broad ethnic group (Black, Chinese, Mixed, Other, White Non-British, White British) also included in the models but coefficients are not reported for visual clarity. AME = average marginal effects. pp = percentage point. Equivalent change in probability calculated assuming a 2.9% baseline probability.

Column 1 is based on all the schools in the experimental sample and therefore answers RQ1. The variable of interest is 'IGB treatment school' which takes the value 0 for control group schools and 1 for treatment group schools. The odds ratio on the variable of interest is 1.25 indicating that pupils in the treatment group had an odds of receiving any grade in A-level physics 25% higher than the those in the control group. Using the control group up-take of A-level physics as a baseline (2.9%), this amounts to a 0.7 percentage point increase, to 3.6%. However, this difference is not statistically significant ($p=0.07$), meaning that we cannot be confident that it reflects the effect of the IGB programme as opposed to by-chance residual imbalance in the characteristics of the treatment and control group after randomisation. The study is therefore inconclusive as to whether IGB improved female progression to A-level physics *across all participating schools*.

Column 2 shows the results based on the complier schools and therefore answers RQ2. The variable of interest in column 2 is 'IGB compliant treatment' which takes the value 1 for all 54 treatment group schools defined as being compliant with the treatment and otherwise takes the value 0. The coefficient of interest is 0.009 indicating that treatment increases the probability of A-Level physics take-up by 0.9 percentage points. This difference is statistically significant ($p=0.046$) meaning we can be confident that this reflects the impact of the IGB programme, rather than any residual imbalance between treatment and control groups after the randomisation. We therefore conclude that IGB improved female progression to A-level physics *in the subset of compliant schools*.

Column 3 shows the results for all the pupils in the treatment and control groups that progressed to study any A-level and therefore answers RQ3. The variable of interest is again 'IGB treatment school'. The odds ratio on the variable of interest is 1.24 indicating that, conditional on progressing to study any A-level, pupils in the treatment group schools had an odds of receiving a grade in A-level physics 24% higher than the those in the control group. Using the control group up-take of A-level physics as a baseline (2.9%), this again amounts to a 0.7 percentage point increase, to 3.6%. However, this difference is also not statistically significant ($p=0.08$). The study is therefore inconclusive as to whether IGB improved progression to A-level physics *in the subset of pupils who did progress to A-levels*.

Table 4 shows the results of exploratory analysis investigating whether there are heterogenous effects among different types of participants. All coefficients are odds ratios. While these analyses are not pre-registered, each of them is closely related to the nature of the intervention and has a clear theoretical motivation. Column 1 looks at the subgroup of 18 all-girls schools in the sample, on the basis that gender norms in all-girls schools plausibly operate differently to in mixed sex schools. The coefficient on the treatment variable here is 1.45, meaning that participants in treated all-girls schools had odds of receiving any grade in A-level physics 45% higher than those in control group all-girls schools. Using 2.9% as the baseline again, this amounts to a 1.25 percentage point increase, to 4.2%. This difference is statistically significant ($p=0.038$). Column 2 looks at the subset of schools with above median (for our sample) proportion of (male and female) pupils taking a stand-alone GCSE in physics. The coefficient on the treatment variable is 1.53, meaning that participants in treated high-physics-uptake schools had odds of receiving any grade in A-level physics 53% higher than those in

control group high-physics uptake schools. Using 2.9% as the baseline again, this amounts to a 1.5 percentage point increase, to 4.4%. This difference is also statistically significant ($p=0.003$). In conclusion, we find suggestive evidence that IGB is particularly effective in all-girls schools and schools with higher uptake of physics.

Table 4

Exploratory heterogeneity analysis

	(1) All girls schools	(2) High physics GCSE take-up schools
IGB treatment group	1.45* (0.26)	1.53* (0.22)
School offers A-levels	4.07* (2.59)	1.71 (0.56)
All-girls school	-	1.58* (0.22)
Pupil SEND support	0.65 (0.27)	0.67 (0.22)
Pupil EHCP	-	1.33 (0.00)
Pupil ever FSM	1.06 (0.34)	1.50 (0.33)
Pupil grade GCSE maths	1.91* (0.24)	1.82* (0.16)
Mean science GCSE grade	1.36* (0.16)	1.45* (0.12)
Number of science GCSEs	1.29 (0.29)	1.78* (0.27)
Equivalent change in probability	+1.25pp	+1.5pp
N (schools)	18	68
N (pupils)	2,822	7,434

Note: Standard errors are shown in parentheses. * $p < 0.05$. Schools provide education up to age 16 but do not necessarily provide A-level qualifications for those aged 16-18. FSM = free school meals. SEND = special educational needs and disabilities as reflected in a n Education Health and Care Plan. GCSE = general certificate of secondary education, which this standard age-16 qualification taken at the end of compulsory schooling in England. Broad ethnic group (Black, Chinese, Mixed, Other, White Non-British, White British) also include in the models but coefficients are not reported for visual clarity. pp = percentage point. Equivalent change in probability calculated assuming a 2.9% baseline probability.

Discussion

We set out to test whether the IGB programme increased the uptake of physics at A-level among female students in England. Our pre-registered cluster randomised controlled trial provides causal estimates of the impact of the IGB programme, as delivered. The results from our main analysis (RQ1) suggest that uptake of A Level physics was 0.7 percentage points higher, or 21% higher than in the control group. However, this difference is not statistically significant ($p=0.07$) and we therefore cannot conclude that IGB programme had an effect in our experimental sample as a whole. We planned the sample size for our trial based on the assumption that the IGB programme would be delivered in treatment group schools across five terms over two academic years. However, as discussed above, two and a half of the five terms were directly affected by COVID-related school closures. That left two and a half terms in which schools were open for delivery of IGB. This likely diluted any effect of the programme, which would have reduced our power and may account for the lack of statistical significance of our main findings.

To further probe the importance of treatment adherence, in our pre-registration we defined compliant schools as those that engaged in any activity after September 2020, which is when schools re-opened after the first of the national school closures. We did find evidence of an effect among this group of complier schools, with uptake being 0.9 percentage points higher, or 31% higher ($p=0.046$). When interpreting this finding, it should also be kept in mind that schools were targeted for recruitment based on having (relatively) low female progression to A-level physics. It is not clear whether the positive results among complier schools would generalise to schools with significantly higher uptake, which may itself be the result of less gendered norms around subject choice.

We also found suggestive evidence of an effect of the programme among all-girls schools and among schools with higher levels of GCSE physics uptake. The estimated effects in these groups were almost twice as large as those in the main sample (1.25-1.5 percentage point increase, or a 43-52% increase) and these differences were statistically significant. We can only speculate as to why this might be the case. It is well documented that female students go on to study A Level physics at much higher rates in all-girls schools than in mixed sex schools (IoP, 2012), which may reflect differences in how gender norms operate. For example, in mixed-sex schools girls may notice that many of the boys are taking physics and conclude that it is a ‘boys subject’, whereas in all-girls schools there would be no male students in the school for whom subject choices could be observed. As regards GCSE physics, it is plausible that the marginal students in schools with a high uptake of GCSE physics are confident of their ability to do A-level physics but do not want to do A-level physics. This would make a programme aimed at supporting them to choose A-level physics sufficient to change their choices. This contrasts with a situation in which the marginal student is both does not feel confident and does not want to do A-level physics.

The evidence presented above should, of course, be interpreted in light of the limitations of this research. First, as discussed, delivery of the IGB programme was significantly disrupted by COVID-19 related school closures. Our findings only provide evidence on the effects of the programme as delivered. This means that our results cannot be considered an evaluation of the IGB programme when delivered as intended. Second, our findings for the sub-groups of all-girls schools and high GCSE physics uptake schools are not strictly causally identified because we drop many of the units from the initial randomisation, which may undermine comparability. Third, our outcome measure is imperfect in that anyone who initially took up A-level physics but

did not receive a final grade due to dropping out of the qualification would be mis-classified in our analysis. Having said that, we believe receipt of any grade in A-level physics is likely to be a good proxy for uptake of A-level physics and is far less susceptible to missing data than alternative survey-based measures would have been.

Based on the promising findings among complier schools, there is a good case for another evaluation of the IGB programme to establish its effects when delivered with less disruption. This would also provide an opportunity to stratify the randomisation based on a) whether schools are all-girls and b) uptake of GCSE physics, which would provide causally identified estimates within these subgroups. A repeated evaluation would also allow for more in-depth survey research to explore potential explanations for any impacts and why these might differ across subgroups. In sum, another evaluation would provide valuable evidence about whether the IGB programme works when implemented as intended, for whom, and why.

In conclusion, this research provides one of the first causal tests of whether an intervention aimed at equalising gender norms around subject choice improved take-up of A-level physics among female students. Although we did not find any effect of the programme across all the schools in our study, schools that persisted with implementation after the first COVID-19 lockdown did have more female students progress to study A-level physics. This suggests that existing gender differences in subject choice are driven, in significant part, by cultural and normative factors. Further research is now required to replicate and extend these findings, ideally without the disruption of a pandemic.

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