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Is informal education the answer to increasing and widening participation in STEM education?

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This paper summarises research findings from a longitudinal national evaluation of science, technology, engineering and mathematics (STEM) 'enrichment and enhancement activities'. The activities included science practical lessons, supported by ambassador visits, trips to laboratories, STEM centres and higher education institutions. The common theme for these activities was their aim to improve understanding and enjoyment of science in the short term and encourage STEM participation in the long term. The 2007 cohort across all state maintained secondary schools in England was followed up from the beginning of key stage 3 to the end of key stage 5 making use of school and pupil level datasets from the national pupil database. The study investigated whether engaging in these STEM programmes, run for 11–16 year olds, in secondary school is likely to affect subject choices during post-compulsory education? Do young people sparsely represented in STEM courses such as those from a lower socio-economic class and black ethnic minority engage better with STEM subjects because of actively participating in these activities? A direct noticeable impact of these activities was not seen on STEM take-up. The analysis presented here concludes there is no evidence to suggest continued engagement in these activities is manifested in terms of increasing or widening STEM participation.

Introduction

Labour market reports show a skills gap in the areas of science, technology, engineering and mathematics (STEM) in the UK (Wright & Carmichael, 2015; Kuczera *et al.*, 2016). Reportedly, there has been a mismatch between the available workforce and the required STEM skills for the jobs available [Science, Engineering and Manufacturing Technologies Alliance (SEMTA), 2006; Department of Business, Innovation and Skills (BIS), 2009; but see Smith & Gorard, 2011; Broughton, 2013; UK Commission for Employment and Skills (UKCES), 2015]. The need to check this shortage has been reiterated as it can adversely affect the UK's economic growth [The Royal Society, 2011; Confederation of British Industry (CBI), 2013].

The Science and Innovation Investment Framework 2004–2014 (HM Treasury, 2004, 2006) set out priorities for addressing these skill shortages. Improving engagement in STEM was identified as a key element, leading to the STEM programme that

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was launched in October, 2006. This provided a strategic framework through which support for STEM subjects in schools and colleges was made more effective and accessible [Department for Education and Skills (DfES), 2006]. Increasing post-compulsory participation in STEM subjects was a priority (Homer *et al*., 2014; Banerjee, 2017). This was important because the admissions selection criteria for undergraduate programmes have always heavily valued subject choices made in school. Similarly, an undergraduate STEM degree is a prerequisite towards pursuing a STEM career, hence a good predictor of the STEM skill set likely to be available in the population.

Significance

The general trend for entries for science and maths A levels as a percentage of all A level entries had been downwards over the last 15 years (Hoyles *et al*., 2011; The Royal Society, 2011; see also Table 1) except for further mathematics [Department for Education (DfE), 2015]. Research evidence from large scale national surveys conducted in the UK on 10–14 year olds reported most students enjoyed learning science in school but did not consider pursuing it as a career (Dewitt *et al*., 2014). To develop a positive attitude towards STEM early on (Osborne *et al*., 2003; Archer, 2013), the formal and informal education sector (UK Parliament, 2011) worked together. The focal point for these efforts had been the 11–14 age group—a critical period for forming views on STEM and developing aspirations (Archer, 2013). A strong correlation has been shown between interest, attitudes and aspirations towards STEM subjects and the take-up of these courses (Archer, 2013, 2014, 2015; Banerjee, 2016a; Tripney *et al*, 2010). STEM enrichment and enhancement activities were thus delivered across primary and secondary schools.

Attainment and participation in STEM is known to be stratified by socio-economic status, ethnicity and other pupil background characteristics (Gorard & See, 2009; Strand, 2014). Factors promoting high post-compulsory participation of some minority ethnic groups have been investigated (Torgerson *et al*., 2008). Individual aspirations, careers advice and close personal engagement of adult mentors (See *et al*., 2012) have been shown to play an important role in promoting continued participation of some disadvantaged ethnic minority groups. Children exposed to the

Table 1. Mainstream science qualifications as functions of cohort-size[a]

	A levels			Highers
	England	Wales	N Ireland	Scotland
Cohort size	283,798	15,087	11,805	36,654[d]
Numbers taking core sciences	78,540	4008	4412	18,233
Percentage of cohort taking core sciences	27.7 (28.6)[b] (28.9)[c]	26.6 (27.5)[b] (32.2)[c]	37.4 (38.2)[b] (37.6)[c]	49.7 (50.1)[b] (49.4)[c]

Notes: [a]A proportion of these students also took mathematics. [b]Equivalent percentage for 2007. [c]Equivalent percentage for 2005. [d]Includes candidates taking Highers and Advanced Highers.
Source: The Royal Society (2011).

idea of ‘science capital’ (Archer *et al.*, 2015) have been known to engage better with the subject. Homer *et al.* (2014) analysing national datasets show once prior attainment is accounted for, gender differences across science and some other subjects largely remain but those owing to socio-economic status are to some extent ameliorated. Can STEM activities widen post-16 STEM participation of young people from backgrounds under-represented in these courses?

Higher education institutions, educational charities and other private organisations aimed to make science and maths more engaging and relevant for young people. Hands-on activity sessions, talks and outreach events, science weeks and ambassador visits were all organised at local and national level to show how interesting and do-able these subjects are. In addition to debunking common myths about STEM subjects and professionals these activities were very helpful in linking science and maths as done in classrooms to that done in the real world. STEM activities were supplemented with career guidance and information such as a single STEM qualification in school is not sufficient for entry into STEM undergraduate degree courses (von Behr, 2011) to check uninformed subject choices in secondary schools. Since these STEM enrichment and enhancement activities were designed and run by agencies other than schools to support classroom teaching these were termed as ‘informal education sector’ by the UK Parliament (2011).

Rationale

Increasing and widening STEM participation is important. One of the several steps being taken to meet national targets is the STEM enrichment and enhancement activities being run through a partnership of schools, government, private organisations and higher education institutions (HEIs). These STEM enrichment and enhancement activities, require substantial investment of resources in terms of time and money. Schools believe these schemes will benefit their participating pupils. Government, public, private and charitable organisations fund these schemes for creating positive impact. For accountability, it is extremely important to understand how effective they are and what the outcome has been. Are children engaging with STEM activities more likely to continue studying STEM subjects? Do children from different social groups benefit differently? This research project is a step towards this evaluation—an existing gap in the literature.

In this research project—a national evaluation, attainment data for schools in maths and science was considered, to see if schools enrolling their students from the beginning of key stage 3 (KS3) to the end of key stage 4 (KS4) did any better in GCSE science and maths. No significant impact of participating in these activities was found on school attainment data (Banerjee, 2015, 2017). Next the impact on pupil science and maths GCSE attainment was evaluated, which again showed those participating in these activities did not do any better than the rest (Banerjee, 2016b). The final evaluation was on the impact on continued post-16 STEM participation. This paper presents research findings for the impact of these activities on continued post-compulsory STEM engagement. The study focussed on the population of England as it had a lower proportion of students taking up core sciences (Table 1) among all the four nations in the UK during the last few years.

Research questions

The main research questions being addressed here are:

(1) Are young people participating in STEM enrichment and enhancement activities more likely to continue studying STEM subjects after compulsory education?
(2) Do different time periods of pupil enrolment in these activities affect STEM participation rates?
(3) Do disadvantaged pupils marked by a lower socio-economic status and ethnic minority status benefit from these interventions?

Research design

This quasi-experimental study followed a longitudinal design making use of secondary data from the national pupil database (NPD). The impact of continued participation in STEM activities throughout KS3 and KS4 was evaluated on AS and A level STEM participation. Pupil level data for the year 7 cohorts in 2007 was followed up to A levels. The STEM activities were treated here as interventions and the outcome measure was opting to study a STEM subject for AS/A level.

A high-quality sample and a good sample size are prerequisites for conducting robust research (Gorard, 2007). Sampling is thus a shortcut towards choosing a set of cases who can be representative of the population. This study made use of population data. Interventions, schools and pupils were identified and all other remaining cases were treated as comparator. When working with population data, generalisation is already achieved (Gorard, 2007, 2013; Banerjee, 2016b). The estimates of statistical power and statistical significance were thus not required for this study (Gorard, 2015).

The intervention

STEM enrichment and enhancement activities (hereafter termed interventions) were delivered by registered providers in England across secondary schools for 11–16 year olds. These were always in the form of out-of-classroom activities, for example, practical lessons through science weeks, engagement and outreach activities, day trips to higher education institutions and private organisations or STEM ambassador visits to schools, which were termed as the informal education sector (UK Parliament, 2011). As specified by STEM programme directors, 'These activities shared the common objective of making STEM subjects more interesting by linking science as done in classrooms to the real world. These activities increased pupil's understanding of these subjects. Students participating in these activities were more likely to be keen at these subjects later-on.' The main criteria (Banerjee, 2016b, 2017) for selecting these activities as interventions were, they shared the common objectives of:

(1) Improving student attitudes towards science and maths.
(2) Busting myths about scientists, STEM subjects and careers.
(3) Helping students to understand how science works.
(4) Improve students' knowledge of science and maths.
(5) Improve students' confidence in their ability to do science and maths.

Data collection

The secondary data was obtained from two main sources. First data collected by activity providers and stored in their management and information systems was used. Information shared by providers included details of schools and year groups, details of intervention, instruction materials and other administrative aspects of this initiative. The other major source of secondary data was the national pupil database. Standard extracts of school and pupil level data (census and performance tables) were made available by NPD. Using these datasets, it was possible to follow the schools, academic achievement and STEM subject choices made by children beginning year 7 to A levels.

Secondary data and group allocation

Information such as a list of participating schools, school year and ability groups, name of programme, instruction materials and contact person in school were shared by activity providers through their information management systems. Using this information all schools that registered pupils for STEM interventions at any point from the beginning of the academic year 2007/08 to the end of academic year 2013/14 were identified as intervention schools. Using pupil level data (NPD) the secondary schools attended by each pupil were now mapped. If a pupil attended the same secondary school from year 7 (beginning of key stage 3) to the end of year 11 (key stage 4) and the school registered its pupil for STEM activities every year they were included in the longitudinal intervention group. If a pupil moved schools and details of both old and new school were available from NPD, there were different possibilities. If both the old and new school were intervention schools, the pupil was included in a longitudinal intervention group. If a pupil was enrolled for intervention throughout KS3 but never during KS4 they were included as KS3 intervention subgroup. Similarly, if students engaged in STEM activities throughout KS4 but never in KS3, they were included as KS4 intervention subgroup.

Often their participation in STEM activities was in a random order for three possible reasons: (i) they were previously studying in another country and joined a state school somewhere in between the period of evaluation, (ii) they were previously home schooled (iii) their schools registered pupils only for a few years to take part in these activities and discontinued at some point. These pupils were termed as the staggered intervention group. All pupils in the staggered intervention group had been enrolled for STEM activities for at least one year in secondary school. Some pupils dropped out of education or moved to a different country. These cases were excluded from the analyses as NPD does not have a follow-up record for them. The number of pupils from this cohort in each subgroup at the end of KS4 and KS5 are shown in Table 2 below.

It was not possible to identify schools that had never registered for STEM schemes because of data protection reasons cited by activity providers. Hence pupils from all those schools whose participation status was not known were put together in the comparator group. This was thus the population of all pupils minus those who were in

Table 2. Breakdown of analytical subgroups

Pupil analytical subgroups	Number of cases	Percentage
KS3 intervention	13,311	2.1
KS4 intervention	1791	0.3
Staggered intervention	18,072	2.8
Longitudinal intervention	43,288	6.9
Comparator	555,295	87.9
Total	631,757	100

Table 3. Free school meat (FSM) eligibility—frequency table all pupils

Eligibility for FSM	Frequency	Percentage
Not on FSM	481,712	76.2
Taking FSM	80,337	12.7
Missing System	69,708	11
Total	631,757	100

any of the intervention groups. The size of these subgroups in terms of numbers and percentages of pupils are summarised in Table 2.

Indicators used in the study

The impact of participation in STEM enrichment and enhancement activities was considered on post-compulsory STEM engagement of (i) all pupils (ii) lower socio-economic status (SES) pupils and (iii) black ethnic minority pupils. The following variables were used.

Free school meals

Pupil eligibility for free school meals (FSM) was used as an indicator (Hobbs & Vignoles, 2010; Gorard, 2012) of lower socio-economic status. This is because FSM eligibility is assessed by a range of criteria set out by the Department of Education (DfE). The basic measure in these criteria is the family income. FSM data was not available for 11% pupils of this cohort (Table 3).

Ethnicity

Ethnicity aggregated into seven major ethnic groups was available as a non-sensitive pupil characteristic. The seven major ethnic groups were Asian, Black, Chinese, Mixed, White, any other ethnic group (AOEG) and unclassified if pupils' ethnicity details were not known. Black ethnic minority pupils have been identified as the lowest attaining ethnic minority subgroup for STEM subjects (Banerjee, 2016a). The evaluation focused only on STEM engagement of pupils from a black ethnic origin following the intervention.

Qualification routes

Several qualification routes are available for those aspiring to study a STEM subject beyond compulsory education. However, as Table 4 shows beyond compulsory education the biggest group of students was of those for whom attainment data was unavailable followed by the ones taking A level. A levels are the most popular choice for those wanting to study STEM at the university (Smith, 2011) and likely to pursue a STEM career. Thus, the analysis presented here focused only on one qualification route AS/A level.

Pre-requisites

Among the subjects studied across KS3 and KS4 in the National Curriculum, GCSEs are taken in three core subjects, English, maths and science, alongside other optional subjects. Students require at least five A*–C GCSE grades that include the core subjects, English and maths, to be eligible to take A levels. Typically, AS level is taken in four subjects in year 12 from among those in which a GCSE was taken. Thereafter, a pupil drops down to three or four subjects for A levels. An achievement of five A*–C grades is thus one of the most essential criteria for pursuing A levels and was tracked first to map STEM participation. Research shows students achieving an A*–C grade in GCSE science were more likely to enter AS and A level in science (Wenchao *et al.*, 2010). Meeting the prerequisites was one of the criteria considered in the evaluation.

Progression from GCSE to AS and A levels

Progression rates from GCSE (A*–C grades pupil level data) to AS level were calculated for the cohort who completed KS4 in 2012 for various science and maths subject choices. The analysis then follows up this cohort to look at the progression rates from AS to A level and from GCSE to A levels. Thus, the three progression routes being considered here are GCSE to AS level, AS to A level and GCSE to A level.

KS4 data for 2011/12 was used to obtain GCSE results for all students in year 11 in 2012. Records for these pupils were then extracted from the KS5 database 2013/

Table 4. Qualification routes taken by 16–18 year olds in England

Qualifications	Frequency	Percentage
International Baccalaureate	2580	0.4
Applied A level	6200	1
BTEC/OCR	2652	0.4
NVQ/VRQ	111,569	17.7
A level	222,506	35.2
Missing	285,760	45.3
Total	631,267	100

14, which had results from any AS/A levels they went on to take. A student was deemed to have progressed to A level if an A level result for them in the same subject was available for them in the database. Progression to AS level was recorded if the student had results for either AS/A levels (because all students do not have their AS level results reported separately).

Maths and science GCSEs are not offered in the same form at AS/A levels. Thus, specific matching had to be used. For GCSE, most students take the core, additional science qualifications or the separate sciences, whereas at AS/A levels only separate sciences are offered. Progression was thus recorded for subject pairings as GCSE science (either or both of core science or additional science) to any of AS/A level biology, human biology, chemistry, physics, psychology, electronics, environmental biology, geology, science for public understanding, computer science and ICT). Progression was also reported from mathematics GCSE to any of AS/A level maths, maths mechanics, pure maths, applied maths, statistics, further mathematics and additional maths.

Data cleaning

At the time of conducting this study only 'Un-amended' pupil level KS5 census data was available from NPD for the cohort being followed. It had a total of 796,192 cases. 'Un-amended' data meant the file had duplicate entries for some cases, here 22 such cases were identified. It was impossible to ascertain whether a case was primary or duplicate. This is because NPD allocates an anonymised pupil matching reference number (PMR) to each case. However, for these duplicate cases though the PMR was exactly same, the school names, attainment and participation data differed. To reduce ambiguity these 44 cases were deleted. Thus, pupil records for 796,148 were available for those who were expected to take A level from this cohort in 2013/14.

Similarly, KS4 attainment data had 631,757 cases. Two hundred and forty-five duplicate cases were identified for which KS5 data was not available. These pupils had either taken a gap year, dropped out of education or moved to a school type whose performance data was not available with NPD. These 490 cases were excluded from the analysis presented here. Thus, 631,267 cases were available from the year 7 cohorts of 2007/08 being followed up. KS5 attainment data was available from NPD for 55% of these pupils. This is because only these pupils took a qualification route evaluated here and cashed in on their qualifications in 2013/14.

A longitudinal record was now created by merging KS5 variables with the original KS4 attainment file for this cohort who took GCSEs in 2011/12 and A levels in 2013/14. A total of 76,406 cases (12%) from this cohort were exposed to STEM interventions at some point in secondary school from the beginning of year 7 until the end of year 11. As explained earlier under 'secondary data and group allocation' the intervention group was split up into various subgroups depending on the point of delivery of the intervention (Table 5).

Table 5. Number of cases in intervention subgroups and comparator—after data cleaning

Subgroups	Frequency	Percentage
Comparator	554,861	88
Participated in KS3	13,290	2
Participated in KS4	1784	0.3
Participated every year in KS3 and KS4	43,275	7
Staggered participation in KS3 or KS4	18,057	3
Total	631,267	100

The evaluation

Post-compulsory STEM participation gap (hereafter termed participation gap) between intervention groups and comparator was calculated using Newbould and Gray's formula (explained in Gorard, 1999; Banerjee, 2016b). The entry gap was calculated first—the fference in number of entries between comparator and intervention group pupils divided by the total number of all entries. To get the percentage entry gap this was multiplied by 100.

$$\text{Entry gap A level} = \left[\frac{\text{Entries}\,\mathbf{C} - \text{Entries}\,\mathbf{I}}{\text{Entries}\,\mathbf{C} + \text{Entries}\,\mathbf{I}}\right] \times 100$$

To calculate the participation gap, the difference between number of comparator and intervention pupils making a STEM subject choice was divided by the total number of all pupils who studied STEM subjects. The percentage entry gap was deducted from this value to obtain the percentage participation gap.

$$\text{Participation gap} = \left[\frac{\text{Nos. participated}\,\mathbf{C} - \text{Nos. participated}\,\mathbf{I}}{\text{Nos. participated}\,\mathbf{C} + \text{Nos. participated}\,\mathbf{I}}\right] \times 100 - \text{Entrygap}$$

Relative participation ratio was then calculated as the ratio between percentages of pupils in comparator to the intervention group who made a STEM subject choice at AS or A levels.

Results

The percentage of all pupils meeting the requirements for A levels are discussed first followed by the actual percentages of those who took AS and A levels in STEM subjects. The next section discusses STEM participation of FSM pupils and black ethnic origin pupils. These estimations are important as it is the year after interventions have been stopped and reflect pupil attitudes towards STEM subjects.

Meeting the prerequisites

More intervention group pupils achieved an A*–C grade in GCSE science than the comparator (Table 6). Similarly, more intervention group pupils attained 5+ A*–C grades including English and maths than the comparator (Table 6).

Table 6. GCSE attainment by subject

Subjects	Percentage taking GCSE		Percentage A*–C grades in GCSE	
	Intervention	Comparator	Intervention	Comparator
Maths	98	95.8	72.9	68.1
Science	79.4	75.9	63.6	58

Table 7. Percentage pupils achieving five or more GCSE/GNVQs at grades A*–C

Intervention subgroup	Percentage of pupils
Ever intervention	63
Longitudinal intervention	60
KS4 only intervention	35
KS3 only intervention	58
Staggered intervention	76
Comparator	56

However, a breakdown of the intervention pupils into various subgroups based on the duration for which they had participated in STEM activities shows that the maximum percentage of such pupils who met the prerequisites were from the staggered intervention group (lowest participation rates in STEM activities in secondary school). The lowest percentage of pupils meeting the pre-requisites were those who had the intervention only in KS4 (lower than comparator), the KS4 intervention subgroup (Table 7). The next section shows how many of those who met the prerequisites and were eligible to take up a STEM course, took these qualifications.

Post-compulsory STEM participation—all pupils

Attainment data was used as a proxy indicator of participation data. This is because there was no variable in NPD data that could give an estimate of the number of pupils who had wanted to study a STEM subject for post-compulsory education. The only criteria considered was whether the pupils take an AS/A level examination from this cohort. Hence pupils awarded grades A–E, marked as query 'Q' or ungraded 'U' were all counted as having participated in STEM. Table 8 shows participation data subject-wise.

Students taking an A level exam are not counted in the AS level entries by the NPD. Thus, for AS level data the table above shows only those pupils who had their AS level results cashed in. This meant if a student went on to complete an A level in maths this pupil was not counted in the AS level data. However, as NPD does not provide the number of those who failed an exam it is believed that the actual numbers of those opting for a certain subject would be slightly higher than what is projected here.

For estimating the participation gap, rather than an individual subjects' participation in any of the above subjects was now considered as STEM participation.

Table 8. Number of pupils progressing from GCSE to AS/A levels subject-wise

Subject		Numbers cashing-in AS level			Numbers progressing to A level		
		Population	Intervention	Comparator	Population	Intervention	Comparator
Biology	Numbers	8468	1246	7222	47,272	6675	40,597
	Percentages	1.3	1.6	1	7.5	8.7	7.3
Chemistry	Numbers	6746	1025	5721	39,711	5743	33,968
	Percentages	1.1	1.3	1	6.3	7.5	6.1
Physics	Numbers	5011	767	4244	27,467	3840	23,627
	Percentages	0.8	1	0.8	4.4	5	4.3
Environmental science	Numbers	0	0	0	797	107	690
	Percentages	0	0	0	0.1	0.1	0.1
Geology	Numbers	354	45	309	1818	255	1563
	Percentages	0.1	0.1	0.1	0.3	0.3	0.3
Computer studies	Numbers	1059	133	926	3308	394	2914
	Percentages	0.2	0.2	0.2	0.5	0.5	0.5
Maths	Numbers	11,139	1551	9588	63,017	9142	53,875
	Percentages	1.8	2	1.7	10	12	10
Statistics	Numbers	168	13	155	0	0	0
	Percentages	0.02	0.01	0.03	0	0	0
Further mathematics	Numbers	4659	638	4021	10,824	1698	9126
	Percentages	0.7	0.8	0.7	1.7	2.2	1.6
From among	Numbers	631,267	76,406	554,861	631,267	76,406	554,861

Thus, all students taking up an AS/A level in STEM subjects were counted together. A marginally higher percentage of intervention group pupils participated in STEM education than the comparator (Table 9).

The participation gap was calculated considering the actual number of entries and attainment. Calculations for STEM participation gap for A levels are shown below between comparator and all intervention group pupils.

$$\text{Entry gap A level} = \left[\frac{554,861 - 76,406}{554,861 + 76,406}\right] \times 100$$

$$\text{Entry gap A level} = 75.79$$

$$\text{Participation gap A level} = \left[\frac{166,360 - 27,854}{166,360 + 27,854}\right] \times 100 - 75.79$$

$$\text{Participation gap A level} = \mathbf{4.5\%}$$

The relative participation ratio for AS and A level between comparator and intervention group is shown in Table 10. The ratio was always one. All these estimations show the likelihood of intervention group pupils pursuing STEM subjects post-16 is the same as comparator.

Post-compulsory STEM participation of lower SES pupils

Pupils from the cohort who were on FSM (N = 80,289 pupils) during GCSEs were tracked from the census. As done for previous analysis with all pupils, FSM pupils in each of these intervention subgroups and comparator who were awarded a grade

Table 9. Pupils progressing from GCSE to AS/A levels for all STEM subjects combined

STEM subjects	Cashing-in AS level			Progressing to A level		
	Population	Intervention	Comparator	Population	Intervention	Comparator
Numbers	37,604	5418	32,186	194,214	27,854	166,360
From among	631,267	76,406	554,861	631,267	76,406	554,861
% participating	6	7	6	31	36	30

Table 10. Post compulsory STEM participation for all pupils—effect sizes

STEM participation	Participation gap between intervention group and comparator (%)	Relative participation ratio
AS level	4.6	1
A level	4.5	1

A–E, Q or U in the KS5 attainment table for STEM subjects were considered as having participated in post-compulsory STEM education. Progression rates from GCSE to AS and A levels in STEM subjects were much lower than the national average for 2013/14. However, neither all pupils in each subgroup took an exam nor did all have a result reported. It was therefore difficult to ascertain whether these pupils had failed an exam, dropped out of education or took a gap year between GCSE and AS/A levels. For all STEM subjects, more students from staggered intervention subgroups showed a higher participation rate, except computer studies where most pupils from KS4 intervention subgroup took an AS/A level. The longitudinal intervention groups consistently had a lower participation rate (Table 11).

Post-compulsory participation rate for all STEM subjects combined was now calculated. All students from Table 11 were now marked as having participated in post-16 STEM education. The highest percentage participation was from the staggered intervention group (Table 12)

The participation gap between the various intervention subgroups and the comparator was always very small. Calculations are shown below for the participation gap between the longitudinal intervention FSM group and the comparator for A level here.

$$\text{Entry gap A level} = \left[\frac{71,026 - 5657}{71,026 + 5657}\right] \times 100$$

$$\text{Entry gap} = 85.24\%$$

$$\text{Participation gap} = \left[\frac{7085 - 510}{7085 + 510}\right] \times 100 - 85.24$$

$$\text{Participation gap} = \mathbf{1\%}$$

Similarly, the probability of pupils' continuing with STEM subjects was highest in the staggered intervention subgroup for A level and other subgroups had almost similar participation rates as the comparator (Table 13).

Thus, longitudinal intervention was not particularly effective in promoting post-16 STEM participation. The staggered intervention subgroup had a higher success rate, however, most students in this group were not exposed to the intervention regularly so their continuation with STEM subjects cannot be directly attributed to the intervention.

Post-compulsory STEM participation of black ethnic origin pupils

Black ethnic minority pupils are the lowest attaining group in GCSE science and maths as was seen in other papers from this research project currently under production or peer review. This section reports if black ethnic minority pupils are more likely to make STEM subject choices beyond compulsory education following a STEM

Table 11. Progression rates of FSM pupils from GCSE to AS/A levels subject-wise

Subject	Percentage progressing to AS level					Percentage progressing to A level				
	KS3 intervention	KS4 intervention	Longitudinal intervention	Staggered intervention	Comparator	KS3 intervention	KS4 intervention	Longitudinal intervention	Staggered intervention	Comparator
Biology	3.2	3.4	3.1	9.1	3.7	2.4	1.1	2.2	6.6	2.6
Chemistry	2.4	2	2.6	8	3.3	1.8	0.9	1.9	5.6	2.3
Physics	1.1	1.1	1.6	3.4	1.7	0.9	0.6	1.2	2.1	1.2
Environmental science	0	0	0	0	0.03	0	0	0	0	0.03
Geology	0	0	0.1	0.1	0.1	0	0	0.03	0	0.1
Computer studies	0.1	1.1	0.4	0.2	0.3	0.1	0.6	0.2	0.1	0.2
Maths	3.4	3.7	0.04	10.8	4.4	2	1.7	2.98	7.4	3.1
Statistics	0	0	0.01	0.05	0.02	0	0	0	0	0
Maths further	0.2	0	0.5	1.2	0.7	0.2	0	0.4	0.7	0.4

Table 12. Number of FSM pupils taking up AS and A levels for all STEM subjects combined

STEM subjects	Cashing in AS level					Progressing to A level				
	KS3 intervention	KS4 intervention	Longitudinal intervention	Staggered intervention	Comparator	KS3 intervention	KS4 intervention	Longitudinal intervention	Staggered intervention	Comparator
Numbers	39	23	184	204	2961	98	17	510	435	7085
From among	1309	352	5657	1945	71026	1309	352	5657	1945	71026
% participating	3	7	3	10	4	7	5	9	22	10

Table 13. Post-16 STEM participation FSM—effect sizes

Intervention subgroup	Grade							
	AS level				A level			
	KS3	KS4	Longitudinal	Staggered	KS3	KS4	Longitudinal	Staggered
Participation gap	1	0.5	3	8	0.8	0.5	1	6
Relative participation ratio	0.8	1.7	0.8	2.5	0.7	0.5	0.9	2.2

intervention. The section also reports whether the duration and point of delivery of the intervention makes any difference to their STEM take-up.

The 2011/12 GCSE cohort had a total of 26,223 known black pupils. All black pupils for whom a grade A–E, Q or U was available in the KS5 attainment table were counted as having participated in STEM. The fails were not recorded by NPD hence, it is expected that the actual number of participating pupils could be slightly higher than what is seen below. The percentage of pupils progressing from GCSE to AS levels was calculated by adding up the entries for AS and A levels while GCSE to A level progression was calculated by the number of A level entries (Table 14). Science, electronics, psychology, science for public understanding, information technology, mechanics, pure maths, maths discrete, maths applied and additional maths were not taken by any black ethnic minority pupil.

All black ethnic minority students taking STEM subjects for AS and A levels were recoded as having participated in STEM post-16. This meant studying one of the above subjects was counted as one for participation. So, if a student studied two STEM subjects, the participation was counted twice for the same student. The total number of entries for all subgroups and the percentages of those taking STEM subjects are summarised in Table 15 as combined post-compulsory STEM participation rate of black pupils.

The participation gap was very low for all intervention subgroups. Also, students from the various intervention subgroups were as likely to continue with STEM subjects as the comparator group students as seen from the relative participation ratios that were always one (Table 16). More students from the KS4 intervention group were likely to take up an AS level in STEM subjects. However, most of them did not go on to complete A levels in STEM and hence the relative participation ratio dropped from 1.8 to 0.9 for this group.

Discussion and conclusions

This longitudinal cohort study evaluated the impact of STEM enrichment and enhancement activities on continued post-16 STEM participation. A direct noticeable positive effect of engaging in these activities on pupil STEM subject choices was not found. The findings were similar for all pupils irrespective of their socio-economic

Table 14. Progression rates of Black pupils from GCSE to AS/A levels subject-wise

Subjects	Percentage progressing to AS level					Percentage progressing to A level				
	KS3 intervention	KS4 intervention	Longitudinal intervention	Staggered intervention	Comparator	KS3 intervention	KS4 intervention	Longitudinal intervention	Staggered intervention	Comparator
Biology	12.2	8.5	12.5	9.4	9.1	9.4	2.3	9.2	7.2	6.7
Chemistry	9	0	10.3	8.7	8.5	6.8	5.4	7.7	7	6.3
Physics	4.7	18.5	2.7	3.6	3.2	3.6	3.1	1.8	2.3	2.2
Environmental Science	0	0	0.1	0	0.01	0	0	0.1	0	0
Geology	0	0	0	0	0.1	0	0	0	0	0.05
Computer studies	0.4	1.5	0.5	0.3	0.5	0.4	0.8	0.5	0.1	0.3
Maths	12.2	13	11.6	12.2	11.3	9.7	9.2	8.3	8.8	7.9
Statistics	0	0	0.1	0.1	0.02	0	0	0	0	0
Maths further	0.4	0.8	0.7	1.02	1.02	0	0	0.4	0.6	0.6

Table 15. Number of Black pupils taking up AS and A levels for all STEM subjects combined

	Cashing in AS level					Progressing to A level				
Intervention subgroup	KS3	KS4	Longitudinal	Staggered	Comparator	KS3	KS4	Longitudinal	Staggered	Comparator
Numbers	25	23	157	184	2127	83	27	419	509	5394
From among	278	130	1499	1960	22,356	278	130	1499	1960	22,356
% participating	9	18	10	9	10	30	21	28	26	24

Table 16. Participation gap and relative participation ratio AS &A levels for Black pupils

Intervention subgroup	Grade							
	AS level				A level			
	KS3	KS4	Longitudinal	Staggered	KS3	KS4	Longitudinal	Staggered
Participation gap	0.1	0.9	1	0.2	0.5	0.1	1.85	1
Relative risk ratio	0.9	1.8	1	0.9	1.2	0.9	1.2	1.1

status or ethnicity. Pupils who were registered by their schools for STEM enrichment and enhancement activities every year did not have any greater likelihood of continuing to study STEM subjects than their peers after compulsory education. This was true for all pupils, FSM and black ethnic minority pupils.

Are young people participating in STEM enrichment and enhancement activities more likely to continue studying STEM subjects after compulsory education?

Young people participating in STEM enrichment and enhancement activities did not have a greater likelihood of continuing with STEM subjects after compulsory education. Taking A levels was the most popular qualification route for the cohort. More pupils from intervention groups achieved 5+ A*–C grades in GCSEs and were expected to enter A levels than the comparator. However, results from post-16 STEM participation data did not meet these expectations. The STEM participation gap was very small between the intervention group and the comparator for both AS and A levels. Hence STEM interventions did not increase the chances of student's making STEM subject choices.

Do different time periods of pupil enrolment in these activities affect STEM participation rates?

Students taking part in interventions only during KS4 had the lowest STEM participation rates. On certain occasions the comparator group schools (Banerjee, 2015) and students performed better than this intervention subgroup (also see Banerjee, 2017). Those who participated in interventions only during KS3 (but never in KS4) and continuous longitudinal interventions were found to be slightly more likely to opt for STEM subjects. This is supported by some research that shows educational interventions early in the life of students are often more effective (Ayoub *et al.*, 2009).

Similarly, the post-16 participation gap between all intervention groups of varying duration for lower SES pupils and the comparator was negligible. Staggered intervention group pupils had the highest likelihood of continuing studying STEM subjects for A levels. Most students for this group were not exposed to the intervention regularly so their continuation with STEM subjects cannot be directly attributed to the intervention. The longitudinal intervention group where students were continuously participating in STEM activities from the beginning of KS3 to the end of KS4 each year did not have many students studying STEM subjects' post-16.

Do disadvantaged pupils marked by a lower socio-economic status and ethnic minority status benefit from these interventions?

FSM students from the staggered intervention group who were not continuously participating in these activities were likely to continue in STEM. However, this subgroup comprised of a large share of pupils who had not regularly been in an intervention school or had moved into the UK from elsewhere. Thus, it is likely that they might have had other exposure/experiences that motivated them to take up STEM subjects at AS/A levels or were already motivated to study these subjects in the first place and did not need an external motivation.

The participation gap for black pupils in the intervention group and the comparator was nearly zero. Also, the chances of their studying STEM subjects were similar in any intervention group or comparator, with perhaps marginally higher chances with a continuous longitudinal intervention. The percentage participation rates for black pupils was very low, between 0–2%. Some subjects were not taken by any black ethnic group pupil.

There are indications that school and student performances are gradually improving over the years (Banerjee, 2015). A range of factors could affect student's subject choices, attitudes and aspirations in secondary school (Strand, 2014; Tripney *et al*, 2010; Banerjee, 2016a). As is true for all longitudinal studies it is difficult to attribute the success of improved educational outcomes to STEM activities. It is expected that several factors can bring in a change by improving attainment, increasing and widening participation of disadvantaged pupils and all pupils in general (Tripney *et al*, 2010). However, there clearly is not any direct evidence to suggest these interventions increase the chances of young people wanting to take up STEM courses.

Limitations of the study

The pupil intervention group was created from the information provided by activity providers on schools. It was not possible to ascertain whether someone was absent on the day of intervention. This is a known limitation of the study. Similarly, students who dropped out of education or left the country could not be followed up as their records were not available from NPD. However, given the large sample size for the study these numbers were much smaller.

This analysis considers progression from GCSE to AS/A levels: the proportion of students who go on to take an AS or A level in the same subject. A student's decision to study a GCSE subject further may depend on a variety of factors (Rodeiro, 2007) such as enjoyment of the subject, ability, career plans school/college based constraints —whether the subject is offered, GCSE attainment, peer group and parental influence to name a few. Participation in STEM enrichment and enhancement activities earlier in school life is thus only one aspect that can impact engagement in STEM learning trajectories. Given the long time over which activities were delivered it is expected these other factors might have had a very significant role to play in decisions regarding subject choices. However, given the limitations of working with secondary datasets it was not possible to track these factors and hence they were not considered in the study.

Recommendations

There is no causal evidence to explain why disadvantaged pupils are less likely to attain higher and continue participating in STEM. The limited availability of secondary data such as details of participating schools or names makes it very difficult to conduct these evaluations. It is important to encourage research in this area and hence such data should be more easily available. For example, the use of a comparator such as a list of non-participating schools would have made the study more robust. Similarly, an additional variable in the NPD to show subject choices made by students could be very helpful for similar research. Cases would not have been lost as has happened in this study owing to the use of attainment data as a proxy indicator of participation data.

Continued post-compulsory STEM participation is a very important and desirable educational outcome. However, it is only one of the several possible factors likely to be impacted by engaging in these STEM enrichment and enhancement activities. Other similar educational outcomes, qualification routes and individual level psychological constructs could be equally influenced by these activities and need to be evaluated using a range of research designs to support or refute the claims being made here. This is essential given the high-priority STEM agenda, to understand whether, if these schemes are not working, perhaps the money could be spent elsewhere. Given the range of schemes being run it is also crucial to understand if any of these works better than others to be able to build on the best ones. This will help achieve better outcomes with a similar or reduced investment.

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