A longitudinal evaluation of the impact of STEM enrichment and enhancement activities in improving educational outcomes

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Abstract

This paper summarises the research plan for a longitudinal evaluation project conducted on the population of secondary schools and pupils in England. STEM enrichment and enhancement activities are delivered for pupils across the United Kingdom with the aim of improving pupil engagement. These activities give students the chance to explore these subjects as done outside classrooms. The impact of these activities will be evaluated in terms of school and pupil educational outcomes. The study makes use of secondary official datasets - the National pupil database. Year 7 cohort will be followed up to their learning trajectories. Research findings from this study will form evidence base for policy and practice and recommendations will be useful for academic and non-academic beneficiaries.

Key words: Longitudinal evaluation, STEM, education, school

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1. Policy background

Science, technology, engineering and mathematics skills are considered very important for economic progress. This is because STEM skills are valued by every sector as is reflected in labour market reports (SEMTA, 2006; UKCES 2015). Successive governments across countries have supported policy initiatives linked to increasing and widening participation in STEM education and careers (House of Commons, 2011; Wynarczyk 2009). During the last few years concerns were raised by the learned societies in the United Kingdom about the insufficient number of young people wanting to study these subjects beyond compulsory education (Royal Society, 2008, 2011). The UK Department for Education (2014) had prioritised finding out the most effective ways of increasing young people’s take-up and attainment of strategically significant subjects, especially science and maths. To ensure economic progress is not compromised by a lack of people with STEM skills (Garnham, 2011) several measures were introduced.

One such initiative was the introduction of STEM informal education sector (POST, 2011). This sector was primarily introduces to augment the understanding and enjoyment of learning science and maths. These enrichment and enhancement activities were delivered in the form of hands-on activities, mentoring programmes, ambassador visits, school visits, outreach programmes and summer schools. It was hoped that these schemes would link the lessons taught in classrooms to the real world via STEM professionals, higher education institutions and ambassadors. A likely outcome of which could be improved attitudes and aspirations of young people towards STEM subjects (Osborne 2003, 2007). This is very important as students with better attitudes towards maths and science have been shown to attain higher in these subjects (TIMSS, 2007). These students are also more likely to make STEM subject choices and continue into STEM careers (TISME, 2010).

2. Significance

These schemes were introduced more than a decade ago and have grown profusely in number and variety since then (STEM mapping review, 2004) operating at the local and national level. A need was felt to bring all relevant information linked to these schemes at one place. This was required to ensure schools could have one stop destination for all information they need to decide which of these activities would best suit their pupils. This idea led to the creation of the online STEM directories in 2009. It lists all activity providers operating in the UK, the programmes run by them, age groups catered to and whether these schemes are free or have costs attached to them. The common theme which unites all of them is the fact that they work towards a common goal and share the same objective of introducing young people to the fascinating world of STEM, targeting efforts towards improved attainment in science and maths and continued post-16 engagement in STEM subjects.

STEM enrichment and enhancement activities are certainly a very promising policy based implementation. However, these schemes are funded by various sources such as the government, public, private, charity organisations and call for a huge investment not only in terms of money but also in terms of time and resources. Organisations delivering these programmes as well as part taking schools both believe these activities will have a positive impact on participating pupils. However, in the absence of large scale robust evaluations we do not know how successful these programmes have been (DfES, 2006). Major evaluations of long term educational outcomes of participating schools or pupils from these interventions are relatively scarce. Assessments and reports currently available are mainly testimonials from head teachers or teachers of participating schools or pupils immediately after programme delivery (NFER, 2011). These reports themselves suggest looking into pupil attainment and participation in more rigorous studies. Educational research has now shifted in favour of evidence based policy and practice with a growing interest in large-scale studies with experimental trials and the more general use of official data already collected for another purpose. Use of secondary data allows significant projects to be carried out within a realistic time scale. Addressing this gap in literature, making use of secondary official datasets in the form of National Pupil Database and management information systems, this research project evaluates the impact of STEM interventions on measurable educational outcomes through a longitudinal study.

3. Research questions

The study tries to ascertain how effective the interventions have been over the last decade. Have participating schools and pupils performed any better than the national average or the comparator. The educational outcomes chosen to measure the effectiveness are attainment and continued participation in STEM subjects after the intervention. The main research questions being addressed in this study are:

1. Do schools or pupils participating in STEM enrichment and enhancement activities attain higher in science and maths?
2. Can STEM interventions reduce the attainment gap between disadvantaged pupils and their peers?
3. Are intervention group pupils more likely to continue with STEM subjects later on in their learning trajectories?
4. Were these schemes more effective for certain social groups for example those qualifying for deprivation measures?
5. Do varying time periods and point of delivery of intervention impact students differently?

Research findings will help to understand if the targets have been met or the initiative outturn has differed from what was predicted. Recommendations arising from this evaluation will highlight factors which need to be considered to make these activities more effective and their implications for future programme management or policy decisions.

4. **Methodolog**y – The systematic approach adopted for the evaluation of STEM interventions considered the following elements:

a) Assessment – A detailed understanding of the process of the initiative was aimed at to estimate how it worked or did not work. For example, based on duration of administration in interventions, there will be categorises as ever, longitudinal, staggered, KS3 only and KS4 only interventions to understand what worked particularly well for certain groups of people but not for others. Thus put simply it means pupils who had participated at least for one complete academic year in STEM interventions will be placed in the ever-intervention group. Those who participate in interventions only across KS3 or KS4 will be put in respective categories. If pupil participate on and off across secondary school they will be included in the staggered intervention group. Pupils who participate in interventions every year from beginning of year 7 till taking up GCSEs were included in the longitudinal intervention group. Explanation of this sort of outcome has been deemed necessary by the Research Councils United Kingdom (RCUK) guidance document for a full and complete evaluation.

b) Comparison with target out turn – The success of STEM initiatives will be measured by comparing the actual output with a target. For example, when the criteria is percentage of pupils making expected progress in science and maths, the highest attaining ethnic group's performance will be compared with all other groups (Jones, 2005). The evaluation will also explain the possible reasons for the outcome.

c) Comparative assessment – The counterfactual is the outcome which would have occurred in the absence of the initiative. Such comparison is extremely valuable. The STEMNET 2010 report showed, 12% schools are known not to do any kind of STEM intervention. However, it was not possible to identify a comparison group with no STEM intervention for this study. In order to ensure assessment is not compromised a comparator group was created from the data available. This was all secondary schools in England excluding those which were definitely known to have been participating in STEM interventions. Thus, the comparator group had schools which did not do interventions as well as some which did participate in STEM activities. While the effect size of these estimations is expected to be smaller than it actually is, it is hoped the counterfactual would give some idea of what may have happened without the initiative in place.

d) Assessing success of initiatives in achieving objectives – The expected outcomes were well defined by activity providers and official documents. Thus data collected will be used to identify whether these outcomes have been achieved and also if there were some unexpected outcomes. Both short-term (immediate) and long-term (future) objectives set by providers were investigated. This was important to get a more continuous view of how the intervention develops and delivers outcomes.

5. Kirkpatrick model

The Kirkpatrick model is useful in deciding how much evaluation should be undertaken. This project considered four levels of potential impact:

a) Reaction – This was the initial response to participation. This included immediate feedback given by participants upon delivery of the initiative for example, exciting, boring, good and/or bad aspects. Some of this data was available from the management and monitoring system and a part of it was collected by the researcher.

b) Learning – This referred to student's understanding, or raising their awareness of an issue taught or discussed during intervention. The focus was to measure how things have changed as a result of the initiative. It was not possible to have a comparison group of non-participants to measure the difference with participants. Thus, a pre-intervention and post-intervention measure was considered. Thus, pupil prior attainment in maths and science, during end of key stage 2, before delivery of the intervention, was considered for regression analysis.

c) Results – The long term impact of interventions delivered to 11-14 year olds was tracked through measurable educational outcomes. The GCSE school performances, pupil GCSE science and maths results were used as a measure. One of the limitations of this long term complex analysis was the fact that it is difficult to segregate the effects of intervention with impact of other factors on GCSE results. However, as has been shown earlier in other prominent research reports led by the Department for Education (DfE) and ESRC, standardised national test scores are the best and unbiased way of assessing intervention results. However, admittedly a range of level 2 qualifications are available for pupils to choose from only one of which is the GCSE mapped here. It is certainly worthwhile exploring the other career routes taken by students. The GCSEs were chosen for the study as these are taken by a majority of pupils at the end of key stage 4.

d) Behaviour – In addition to educational attainment it was equally important to see whether taking part in interventions substantially modified what participating pupils do. Yet another such longer term assessment of changes was measured through pupil's post-16 continued participation in STEM education. All pupils from the intervention cohort (beginning of year 7 onwards) were followed up to A-levels to see if they opt for STEM subjects otherwise. A parallel estimate of those continuing even to AS levels was made. However, AS/A levels are only one of the several level 3 qualifications available at the end of key stage 5. These are of course taken by a majority of pupils and by those who plan to take up STEM programmes for higher education (Smith, 2011), so it was considered to be a fair indicator for the study

6. Overview

Is the level of STEM attainment and participation at school rising or declining as a result of STEM initiatives introduced as policy reforms in England? Are the results rising faster for schools identified as taking part in STEM initiatives? Is the gap in attainment and participation, between schools and pupils from various disadvantaged contexts and others, declining as a result of STEM initiatives? These questions are addressed via a quasi-experimental study - 'quasi' in the sense both that the researcher was not the one manipulating the environment via an intervention, and the cases were not allocated randomly. Such evaluations can provide information about naturally occurring events, behaviour, attitudes or other characteristics of a particular group. Also, these studies are helpful in demonstrating associations, for example here between STEM initiatives and attainment and/or continued participation in STEM without disturbing the informal and formal education system or introducing a bias.

The educational performances of intervention secondary schools will be compared with all other secondary schools in England. So far from a total of 2,400 eligible schools (only state maintained secondary schools were considered for the study) a thousand intervention schools have been identified. This is a little less than half of the population spread out across the country, as the activity providers deliver activities all over England. Subsequently, all participating pupils from these intervention schools will be followed from the beginning of key stage 3 to the end of key stage 5. GCSE science and maths results and continued participation in STEM subjects in A-levels will be the outcome measures for assessing the impact of STEM initiatives. Nearly 80,000 longitudinal intervention pupils have been identified so far.

Data for the project was collected from existing records of management and information systems of STEM activity providers, national pupil database (NPD) and desk research. Programme delivery to 11-14 year olds at STEM activity-providing organisations was observed to get an idea of what the actual activity entailed. Table 1 below summarises the framework for this research project. Each section is dealt with separately in the sections below.

Table 1

Overview of research project

Design type	Quasi-experimental and longitudinal
Method of data collection	Observation of programme delivery by staff of activity providing organisations
	Analysis of documents from management information systems
	Participant observation
	Secondary data – National Pupil Database
Data analyses	Correlation /regression methods – multiple linear regression and binary logistic regression
	'Effect' sizes, cross-tabulation, comparison of means

7. Research design

In the absence of secondary data relating to the entire population, a high quality sample and a good sample size are necessary preconditions for the pursuit of high quality and safe research findings (Gorard, 2007). This is because sampling is a useful shortcut leading to results that can be almost as accurate as those for a full census but for a fraction of the cost, time and efforts. This research project makes use of population data and identifies intervention schools and treats the remaining as comparator. A similar approach is followed for pupil level datasets. Population data is independent of the methods of data collection and by definition generalisation is already achieved. Thus estimates of sample size and statistical power were not required for this study.

This section describes the longitudinal component of this research project. Two distinct census datasets, a school-level and a pupil-level database along with respective performance/attainment tables were used. By the end of 2012, a total of 317 schools had participated in STEM enrichment activities every year from 2007 onwards. A further 483 schools had participated on and off, but for at least one complete academic year during this period (see table 2).

Table 2

Schools participating in STEM activities from 2007-2012

Participation status in intervention	Frequency	Percentage
Longitudinal	317	10
Staggered	483	16
Unknown	2287	74
Total	3087	100

7.1. Longitudinal design – school level

300 state maintained secondary schools were identified as the intervention group in phase one - which had continued to participate in STEM activities every year from 2007-12. The number of organisations the schools registered with varied from a minimum of one to a maximum of four of the ten being considered in the study. All of these interventions were delivered from the beginning of key stage 3 to the end of key stage 4. This meant students from these intervention schools were exposed to an advanced version of STEM activities every following year. A longitudinal record of these schools was constructed by merging several individually provided bulky files. The final dataset carried details of school census, attainment data and participation in STEM schemes. Mean school GCSE Performances for the intervention group were then mapped before and after intervention in 2007 and 2012 respectively. Correlation coefficients and population means of intervention group were compared with the comparator group.

7.2. Longitudinal study design using pupil level data

Students from the 300 longitudinal intervention schools were followed from the beginning of year 7 till the end of KS5. The GCSE maths and science results of the various disadvantaged and privileged groups were compared. This cohort was further tracked to the end of key stage 5 to assess post compulsory STEM participation of this cohort. The number of pupils from this 2007, year 7 cohort in each sub-group at the end of key stage 4 and key stage 5 are shown in table 3.

Table 3

Number of students in sub-groups - STEM activity participation

Sub-groups	End of KS4		End of KS5	
	Numbers	Percentages	Numbers	Percentages
Comparator	5,55,295	88	5,54,861	88
Intervention group	76,462	12	76,406	12
Total	6,31,757	100	6,31,267	100

Students who dropped out of education or left the country were not followed up as their records were not available from NPD. The next section explains the data collection procedures.

8. The intervention

All activities considered in the study belonged to the category of informal STEM education (POSTNOTE, 2011), taking place outside classroom environment. It was thought by those involved in programme delivery and beneficiaries these schemes would support and add value to lessons taught in school. These activities aim to inspire students through hands-on, experience-based activities, fortifying their school experiences while also contributing to the national STEM learning agenda. This project evaluates the impact of such enrichment and enhancement activities administered to 11-14 year olds. The goals of these activities were to:

1. Improve students' attitudes towards science and maths.
2. Change students' preconceived ideas about scientists, STEM subjects and careers.
3. Allow 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.

Initiatives ranged from national level, to more localised ones often made possible through small public engagement grants. The initiatives were delivered by universities, learned societies, science museums, after schools clubs, ambassador visits working in partnership with schools to complement and extend formal education of its students. This was primarily through access to large scale scientific instruments, meeting scientists, conducting experiments in state-of-art laboratories, by participating in discussions and having the freedom to make mistakes. All of these activities broadly allowed and encouraged students to go beyond what is possible in the classroom and learn about any STEM topic of personal interest than the curriculum allows.

9. Indicators chosen for the study

The Department for Education (DfE) and Department for Business, Innovation and Skills (BIS) are jointly responsible for overseeing education in England. Local government authorities implement policies for public education and state-funded schools at a local level. The education system is divided into stages based upon age: Early years' foundation stage (ages 3–5), primary education (ages 5–11), secondary education (ages 11–18) and tertiary education (ages 18+). From the age of 16 there is a two-year period of education known as "sixth form" or "college" which typically leads to A-level qualifications (similar to a high school diploma in some other countries), or a number of alternate qualifications such as BTEC, the International Baccalaureate or the Cambridge Pre-U.

The National Curriculum sets out targets to be achieved in various subject areas at each stage. The 1988 Education Reform Act introduced the concept of key stages to accompany the first introduction of the National Curriculum. The precise definition of each of these key stages is age-related, incorporating all pupils of a particular age at the beginning of each academic year. A key stage is thus a stage of the state education system in England which sets the expected educational knowledge of students at various ages (Table 4).

Table 4

Key stages: Education system in England

Key stage	Age	School years	Final exams
0	3-5	Nursery, Reception	Teacher assessments
1	5-7	1-2	KS1 SATS, Phonics and Reading Check (teacher assessments)
2	7-11	3-6	SATS Tests (standardised national tests)
3	11-14	7-9	Teacher assessments
4	14-16	10-11	GCSEs – Standardised national tests
5	16-19	12-13	A-Levels, AS-Levels, NVQs, National Diplomas (standardised national tests)

The effect of STEM enrichment and enhancement activities on educational outcomes will thus be measured in terms of:

a) School GCSE performances in maths and science

b) Pupil educational attainment in GCSE science and maths

c) Continued post-16 participation in STEM subjects at AS and A levels

The indicators chosen for this study for both school and pupil level datasets are summarised below:

9.1. Socio-economic status

Pupil eligibility for free school meals (FSM) in England is decided by several factors such as parents on income support, income-based jobseekers allowance, income-related employment and support allowance. Parents who are supported under Part VI of the Immigration and Asylum Act 1999 or are under the guaranteed element of State Pension Credit/ Child Tax Credit/ Working Tax Credit/ Universal Credit. Children are also eligible for FSM if parents have an annual gross income of no more than £16,190. All of these criteria are indicators of a lower socio-economic status. FSM eligibility has been used as a proxy-indicator of lower SES in educational research (Vignoles, ; Gorard, 2007) and will be used here.

9.2. Performance indicators

For school level data, percentage of pupils achieving an 5+A*-C including English and maths will be the performance indicator for maths. Likewise, for science percentage of pupils at the end of key stage 4 achieving two GCSEs at grades A*-C or equivalents covering the KS4 science programme of study was considered as the school science performance indicator.

Attainment of a grade C or above in maths or science GCSEs will be considered a success for all analysis involving pupil level datasets. Similarly for post-16 STEM participation pupils studying physics, chemistry, biology, mathematics, further mathematics, statistics, will be considered to have participated in STEM education.

9.3. Pupil background identifiers - In addition to socio-economic status (Royal Society, 2008) other deprivation measures known to impact educational outcomes such as ethnicity, speaking English as an additional language, EAL, (OFSTED, 2005), gender and statement of educational needs (SEN), prior educational attainment (end of key stage 2) will be considered (Gorard, 2007; Smith, 2011; Vidal, 2007) for analysis.

10. Data collection

Data was obtained from the following sources:

a) Monitoring and management information systems – Data collected by activity providers as part of the intervention was used. This provided relevant information about the number of participants, age and year group; school details – such as name, address, specialist status; type of STEM activity, instruction material, duration of intervention and other administrative aspects of the initiative.

b) National pupil database – Bespoke data collection was not required for this project. Firstly, because this was a longitudinal project it was easier to monitor pupil progress in terms of before and after outcomes through NPD provided pupil level data collected on the same individual at different points of time during school life. Second, because this was a national evaluation and NPD provides details of all schools census and pupils in England from the age of 6 to 16. Third, because this aids comparability with other evaluations. Fourth, because the variables collected in NPD were very appropriate for the evaluation. Fifth, because request for tailored data from NPD would have cost more time as compared to standard data extracts readily available.

c) Additional data – Some data was collected through desk research. These were primarily lists of activity providers, the different types of interventions delivered, programme details and materials, names of participating schools, learning objectives and the expected outcomes. All of this data was available in the public access domain of individual websites of activity providing organisations.

11. Data analysis – educational outcomes for schools and pupils

The analysis has been planned to explore patterns within population and differences within sub-groups. Division of population data produces heterogeneous sub-groups which are populations themselves. Thus all advantages of population are still applicable to these sub-groups as created here. Claims about the comparisons, differences, trends and patterns are still claims about population. Thus analysis of population data is extremely simple.

Significance testing is thus redundant for this dataset. It can however use correlation and regression modelling approaches to find out if the inclusion of STEM initiatives over a baseline model can bring about any improvement in attainment data. Care needs to be taken about missing data treatment as population datasets are almost never complete, this is discussed later.

11.1. Analysis of attainment data - Effect size estimation

The best way to answer the question, 'What has the greatest influence on student learning?' is through the estimation of effect sizes (Hattie, 1999). Reverse effects of intervention are self-explanatory and less than 0. Developmental effects are 0 to 0.15, teacher effects are 0.2 to 0.4. All other desired effects are those above 0.30 and anything with an effect size of 1 would have blatantly obvious effects. However, in general in education an effect size of 0.2 or above is considered as effective intervention. A range of effect sizes will be used to estimate the impact of STEM interventions on educational outcomes such as odds ratio and the relative risk ratio (Gorard, 1999; Hedges, 2007). These indicate whether the intervention group performs any better than the comparator. These are discussed below.

11.1.1. Comparison of means

Mean attainment figures (Comparison of means) of schools in GCSE science and maths will be compared. Similarly for pupil level data percentage of pupils attaining an A*-C in GCSE maths and science in intervention and comparator groups will be compared. The effect size is the ratio between the differences of means of both groups to the population's standard deviation.

$$\Delta = \frac{\mu_1 - \mu_2}{\sigma}$$

11.1.2. Pupil achievement gap

Achievement gap will be calculated using Newbould and Gray's formula (explained in Gorard, 1999).

$$\text{Entry gap} = \frac{\text{Number of entries}_I - \text{Number of entries}_C}{\text{Number of entries}_I + \text{Number of entries}_C}$$

$$\text{Achievement gap} = \frac{\text{Numbers attaining}_I - \text{Numbers attaining}_C}{\text{Numbers attaining}_P} - \text{Entry gap}$$

Here, 'I' denotes the intervention group, 'C' the comparator and 'I' the population of all eligible pupils.

11.1.3. Correlations

Pupil eligibility for free school meals (FSM) is considered a proxy indicator of pupil's lower socio-economic status (Hobbs & Vignoles, 2010). Children from disadvantaged backgrounds are known not to perform very well in school science and maths. It is thus logical to expect if STEM interventions have been effective they can negate the effect of pupil background characteristics on educational achievement. An indication of this can come from comparison of correlation coefficients for percentage pupils eligible for FSM in a school and its maths and/or science attainment, and b) percentage of FSM pupils in each of the groups - intervention and comparator, and their maths/science attainment. Pearson's R will used to estimate if the link between FSM and maths/science GCSE attainment is weakened in the intervention group or comparator. A value of +1 denotes strong association, 0 denotes no link and -1 denotes negative association.

11.1.4. Regression

Regression findings provide an estimate in making judgements. Baseline models willBinary logistic and multiple linear regression methods will be used to estimate whether STEM interventions make any difference to school and pupil attainment. Using a continuous and another binary variable of maths and science attainment regression models will be created and compared. All known predictors of attainment such as FSM eligibility, gender, ethnicity, EAL, SEN and prior attainment will be used in the regression analysis along with a recoded variable of STEM intervention. This model will enable to understand if taking part in STEM interventions makes any difference to pupil maths and/or science attainment.

11.1.5. Cross-product ratio

The cross-product ratio was estimated for mean maths and science school performances in the longitudinal group. No change was defined as ad=bc or ad/bc=1. Here 'a' was the attainment of intervention group before intervention, 'b' after intervention, 'c' was attainment of comparator at the beginning and 'd' at the end of the study.

11.1.6. Relative risk ratio

This is defined as the ratio of probability or chances of success in intervention group to that in the comparator. This was used to estimate effect size of the intervention in pupil level data. The formula used was:

$$\text{Relative risk ratio} = \frac{\text{Percentage pupils attaining the target indicator in intervention group}}{\text{Percentage pupils attaining the target indicator in intervention group}}$$

A value of 1 indicates that chances of success are similar in either of the two groups with or without intervention. A value less than one means students perform better in comparator and more than one means intervention helps students perform better.

11.2. Analysis of participation data

NPD allocates an anonymised pupil matching reference number (PMR) to each case. All pupils from the year 7 cohort being followed up will be tracked. Details of pupils who drop out of education, take a gap year or leave the country are not available. Excluding these cases all those who are eligible for level 3 qualification routes and whose records are available with NPD will be followed up. For analysing continued post-16 STEM participation of pupils, the intervention group will be further split up into various sub-groups depending on the point of delivery of the intervention (table 5).

Table 5

Number of cases in intervention sub-groups and comparator

Sub-groups	Frequency	Percentage
Comparator	554861	88
Participated every year in KS3 and KS4	43275	7
Total	631267	100

The year 7 cohort of 2007-08 comprising of 631267 pupils was followed up. Key stage5 (KS5) data was available from the national pupil database for 55% of these pupils either because only these pupils took a qualification route and cashed in on their qualifications in 2013-14 or perhaps because some had moved out of England or even equally probably some had dropped out of education.

11.2.1. Qualification routes

Several qualification routes are available for those aspiring to study a STEM subject beyond compulsory education. However, as table shows beyond compulsory education the biggest share was of those students from the cohort for whom attainment data was not available. This was followed by A-levels (table 6). A very small percentage of pupils pursued other qualification routes. Also, A-levels remain the most popular choice amongst people wanting to study at the university (Smith, 2011). Thus the analysis presented here focusses on AS/A level STEM participation.

Table 6

Qualification routes taken by 16-18 year olds, England 2013-14.

Qualifications	Frequency	Percentage
International Baccalaureate	2580	0.4
Applied A level	6200	1.0
BTEC/OCR	2652	0.4
NVQ/VRQ	111569	17.7
A level	222506	35.2
Missing	285760	45.3
Total	631267	100

11.2.2 Progression from GCSE to AS/A levels

This analysis considers the 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 (Vidal Rodeiro, 2007) such as enjoyment of the subject, ability, career plans school/college based constraints – whether the subject is offered, GCSE attainment. Participation in STEM enrichment and enhancement activities earlier in life thus may arguably have a very insignificant role to play if all of these parameters were added up. This study does not attempt to credit/discredit STEM initiatives for continued participation in science and maths subjects. However, it was taken up only to see the participation pattern in post-16 education of this cohort – with particular focus on two most disadvantaged and lowest attaining groups – those currently in receipt of free school meals and black ethnic minority pupils.

Data from the National Pupil Database will be used to calculate progression rates from GCSE (A*-C grades pupil level data) to AS level for the cohort who completed key stage 4 in 2012 for various science and maths subject choices. The analysis will then follow up this cohort to look at the progression rates from AS to A level and also 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 based on 'unamended' data available from NPD at this point of time for the cohort.

The key stage 4 database for 2011-12 was used to obtain GCSE results for all students in year 11 in 2012 (regardless of when they had been taken). Records for these pupils were then extracted from the KS5 database 2013-14 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 cashed in 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 and additional science qualifications or the separate sciences, while only separate sciences are offered at AS/A levels. 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, science, 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.

12. Missing data

Descriptive statistics for all independent and dependent variables showed missing data in the range of 9 to 11%. The percentages of missing data and the treatment for logistic regression are discussed below. For key stage 2 prior attainment in maths and science all missing data was excluded list-wise. This was because using mean for missing data imputation rendered the data biased between the groups. However, for all other predictors missing data was treated as ineligible. For instance, all missing FSM were treated as FSM ineligible, missing data for SEN was treated as not SEN (table 7).

Table 7

Missing data

Missing data	FSM eligible now	FSM_6	Major language group	Major ethnic group	Gender	SEN	KS2 prior attainment	
							Maths	Science
Percentage	11	11.1	11	11	0	11	9.3	9.2
Treatment	FSM ineligible	FSM ineligible	Excluded cases list-wise		NA	Not SEN	Excluded cases list-wise	

13. Work plan and timeline

The project will be completed in three years (table 8) in three main phases – preparation and data collection, analysis, writing up and dissemination of research findings:

Table 8

Work plan and timeline for the research protocol.

Task	Duration
Lists of STEM activity providers in England to be collected and intervention inclusion/exclusion criteria to be decided.	3 months
Relevant programme materials to be collected through desk research and data requests to be sent to all providers.	5 months
School and pupil level data to be requested from the National pupil database and approval	3 months
Initial analysis of secondary data for estimation of missing data	1 month
Compilation of all school and pupil level data from activity providers in similar formats and selection of cases in to various groups.	3 months
Data analysis on educational outcomes including attainment for schools and pupils and post-16 continued participation for pupils.	6 months
Writing up of research report	3 months
Dissemination of research findings through seminars, conferences, peer reviewed journal articles, presentations to local schools. Research findings will also be shared with participating activity providers.	6-8 months

14. Ethics and evaluation guidelines

The National STEM Center, UK has developed guidance for organisations and individuals undertaking first evaluations of STEM initiatives. These joint set of guidelines were initially issued for the Department for Children School and Families, DCSF (replaced by the Department for Education in 2010) and the Department for Innovation Universities and Skills (DIUS) to implement when undertaking evaluations of STEM initiatives, to ensure comparability across assessments. This document relies on Her Majesty's Treasury Green Book and DCSF/DIUS guidance on evaluation procedure to set out a standard practice. It also draws on advice from the Research Councils UK publication *'Evaluation: Practical Guidelines'* on STEM evaluations. Synthesising the above documents and feedback from a range of STEM organisations the final evaluation guidance, "*Does it work? Better evaluation: better STEM"*, was issued by the National STEM centre and has been followed for this evaluation research project.

This project was an independently conceived standalone evaluation rather than being embedded in any initiative design from the planning stage of the ROAMEF (Rationale, Objective, Appraisal, Evaluation planning, Monitoring, Evaluation, Feedback) cycle. The research will adhere to RCUK ethical guidelines as well as Durham University's guidelines on ethical research. The project has been scrutinised by Durham University's ethics approval committee.

The study involves use of secondary data from two different sources. The aims of the evaluation research project, planned use of data, strategy for dissemination of research findings and its likely implications were provided in writing to all activity providers at the onset when data request was made. Wherever required the researcher met heads of these organisations in person to answer queries. Thereafter, the providers were asked if they were willing to be named in the research reports. Anonymity of names of schools and activity providers was promised and has been maintained. None of the schools or activity providers will be identifiable in any publications arising from this piece of work.

The second source of secondary data was the National pupil database. Data provided by NPD was stored in encrypted hard disks in compliance with all relevant requirements of the Data

Protection Act 1998. Data was transferred by the NPD data request team through the “key to success” folder – a temporary folder created on the internet. The data was downloaded into a hard disk, unzipped and save as encrypted files. The password was known only to the researcher. A copy of this data was available with the researcher’s data custodian as agreed upon in the application process. The school and pupil level data will be used only for the specified purpose in the request – this research project and will be destroyed using shredding software upon completion.

15. Limitations of the study

A set of 300 schools, registered for STEM activities every year from the beginning of 2007 till the end of 2012, were identified as the longitudinal intervention group. During these five years some schools were closed and some new were opened. A school was included in this sub-set only if it participated consistently each year. Thus if a school participated for some years but closed even during the last year of data collection it was excluded. Similarly, if a school just opened during the second year of data collection and participated every year it was still excluded. Some schools converted into academies, the new URN was checked in NPD records and Edubase to ascertain it was the same school. All such schools were included only if they participated each year.

The project focusses on summative evaluation. A 2011 report (STEMNET) suggested twelve percent of all secondary schools in England did not use any core activities. A set of those schools could have been an ideal comparator for this study. However, this claim could not be verified as it was not possible to identify non-participating schools due to data protection issues cited by providers and head-teachers. For phase one study focussing on school attainment, the comparator is thus the population of all secondary schools minus those that were definitely known to have participated in STEM activities from 2007-08 to 2012-13.

A similar approach was followed with the pupil level data. The cohort of year 7 students in England during 2007-08 were tracked for the study. Their attainment and participation in science and maths GCSEs was mapped. If a child moved secondary schools and new school details were available from NPD, the student was included in the intervention group only if both old and new schools were known intervention schools. However, on several occasions students left the country or dropped out of education or simply their details were not available from NPD after the first few years. Such students were excluded from the analysis. Similarly, new students who joined the cohort any time after the first year of intervention or moved to a school whose intervention status was not known, they were also excluded from analysis even if they were at an intervention school before.

Case selection procedures were based on actual treatment received as far as possible and there was no ‘intention to treat’ as sometimes done in RCTs. This elimination of bias was deemed important despite causing attrition to ensure a direct effect of longitudinal interventions could be seen in pupil attainment. It is expected that there might have been a few instances when students were absent on the actual day of intervention delivery, it was not possible to check these cases and is one of the known limitations of this study. However, the huge sample size of nearly 80,000 intervention pupils reduces these considerations.

It is difficult to imagine all of the educational or behavioural outcomes as seen in pupils in this longitudinal evaluation could be solely attributed to STEM interventions. This is because children are not immune to their surroundings and they are exposed to learning or lifechanging experiences all the time which could often end up having a deeper impact than STEM interventions alone.

These are known limitations of the study and further research addressing other educational or behavioural outcomes following a range of study designs is strongly encouraged to make valid assessments. It would also add value if rigorous studies are conducted addressing similar research questions with clean matched comparators - if they can be identified.

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