Valuing the impact of Science CPD

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Executive Summary

STEM Learning's Continuous Professional Development (CPD) programmes for science teachers supports their objective of promoting world-class education in Science, Technology, Engineering and Mathematics (STEM) subjects in the UK.

Teacher CPD has direct impacts on the teachers supported by STEM Learning activities, as well as indirect impacts on the pupils that they subsequently teach. As such, valuation of the impacts of science CPD must consider the social value created through both beneficiary groups.

The impact of STEM Learning Science CPD across different Key Stages were identified and valued. Best-practice valuation methodologies consistent with the government guidance on policy appraisal (HM Treasury, 2020a) were applied.

Pupil-related benefits were calculated on the basis of the expected wage premia for those pupils who increased their STEM attainment or took their STEM education further as a result of the CPD intervention. Values to wider society through the additional tax payments from these individuals were also calculated. Wage premia were calculated using a panel dataset allowing for estimation of separate wage premia at six time points across a person's career up until the age of 46.

Teacher-related benefits were calculated on the basis of improved teacher retention that results from effective CPD. The value of increased retention to society was valued through the reduced training costs that schools and government face as a result. Given that improved retention also means that individuals remain in a profession that is generally associated with higher wellbeing, this wellbeing boost from teachers remaining in the sector was also valued.

The overall **estimated value of the four sets of activities ranged from £51.9m to £213.8m** as set out in Table ES1.

The **majority of these benefits were estimated as being derived from pupil-related benefits**. The estimated additional future wages accruing to those pupils, whose attainment or uptake of STEM subjects increased as a result of the CPD, were estimated to be between £24.2m and £143.3m across the four sets of activities. The estimated additional taxes paid by these individuals were estimated to be from £16.4m to £67.4m across the four sets of activities.

Benefits as a result of increased teacher retention were estimated to be a smaller proportion of total benefits, ranging from less than £1m to £10.5m, with the majority of these representing the benefits from avoided training costs.

Table ES1: Overall estimated benefits of Science CPD activities

Activities	Pupil-related benefits		Teacher-related benefits		Total
	Direct	Indirect	Direct	Indirect	
KS2	£25.0m	£16.4m	£1.4m	£9.1m	£51.9m
KS4	£26.9m	£57.2m	£1.4m	£9.1m	£94.6m
Triple Science	£24.2m	£56.0m	£0.1m	£0.6m	£80.9m
KS5 Progression	£143.3m	£67.4m	£0.4m	£2.7m	£213.8m

Estimation of a total cost for these activities was out of scope of this research but an initial assessment of core costs suggests that the activities provided a significant positive return to society.

The estimates made in this research represent a robust and conservative estimate of the benefits of these four areas of CPD activity. The figures are likely to understate the full value of such activities because i) the wage premia are only calculated until 46 years of age (whereas several papers estimate them until age 67) and ii) a number of additional channels through which STEM Learning's Science CPD activities generate value were not assessed due to a lack of adequate data. In particular, the impact of such CPD activities on improving the grades of those students who were already likely to achieve the relevant standard (for example, the Science EBacc) was not assessed.

Further research should look to extend the range of benefits calculated by assessing additional benefits to a wider range of pupils. Estimation of teacher-related benefits could be strengthened through randomised control trials to examine the impact of CPD on teacher wellbeing and retention across different Key Stages.

1 Introduction

STEM Learning works towards providing world-leading education in Science, Technology, Engineering and Mathematics (STEM) subjects across the UK through the delivery of Continuous Professional Development (CPD) to teachers in STEM subjects. They do this by bringing in STEM role models into schools and working in collaboration with companies to provide long-term support around STEM education.

This study was commissioned by STEM Learning to identify and quantify the impact of their Science CPD activities in a way that is consistent with The Green Book (HM Treasury, 2020a), the government's framework for policy appraisal. STEM Learning's CPD interventions are intended to improve teachers' ability to teach STEM subjects and hence leads to pupils having enhanced engagement with, and greater success in, STEM subjects within the curriculum.

Existing STEM Learning evaluation reports highlight the increased number of pupils who achieved specific standards as a result of their CPD interventions[1]. This research takes this further by estimating the value of such impacts. This allows for a comparison of the different activities against each other and, ultimately, against the estimated cost of delivering such outcomes.

STEM Learning CPD targeted at four separate outcomes defined by the Key Stage at which they were aimed were considered as part of this report. High-level descriptions of each of the outcomes are set out in Table 1. Two of these areas of activity (referred to in this report as KS2 and KS4) are the most recent core Science CPD outcomes for which data is available. Triple Science was a targeted programme aimed at increasing uptake of Triple Science at GCSE in those schools with historically low uptake. The final outcome considered was a previous iteration of the KS4 core Science CPD with an alternative outcome measure.

This report sets out the overall approach to valuing CPD interventions and explains the approach to estimating the number of beneficiaries from the different activities. It sets out the data and methodology used for each of the two main areas of benefits, those relating to the pupils impacted and those relating to the teachers who undertake the CPD. These results are brought together to provide an overall estimate of the value of these CPD interventions. The report then considers some of the caveats that should be considered in using these figures and further areas for research in the future.

[1] See www.stem.org.uk/impact-and-evaluation/evaluation for a range of reports highlighting the impact of CPD on progression to STEM A-levels, GCSE Science attainment and primary school science attainment.

Table 1: CPD activities considered in this report

Activity	Description	Period considered
KS2	Core science CPD available to any teachers teaching Key Stage 2	CPD undertaken in 2016 and 2017
KS4	Core science CPD available to any teachers teaching Key Stage 4	CPD undertaken in 2016, 2017 and 2018
Triple Science	Targeted CPD available to teachers in schools with low Triple Science uptake at GCSE	2016-2020 (3 cohorts of schools each engaged for 2 years)
KS5 Progression	Core science CPD available to any teachers teaching Key Stage 4	CPD undertaken in 2014, 2015 and 2016

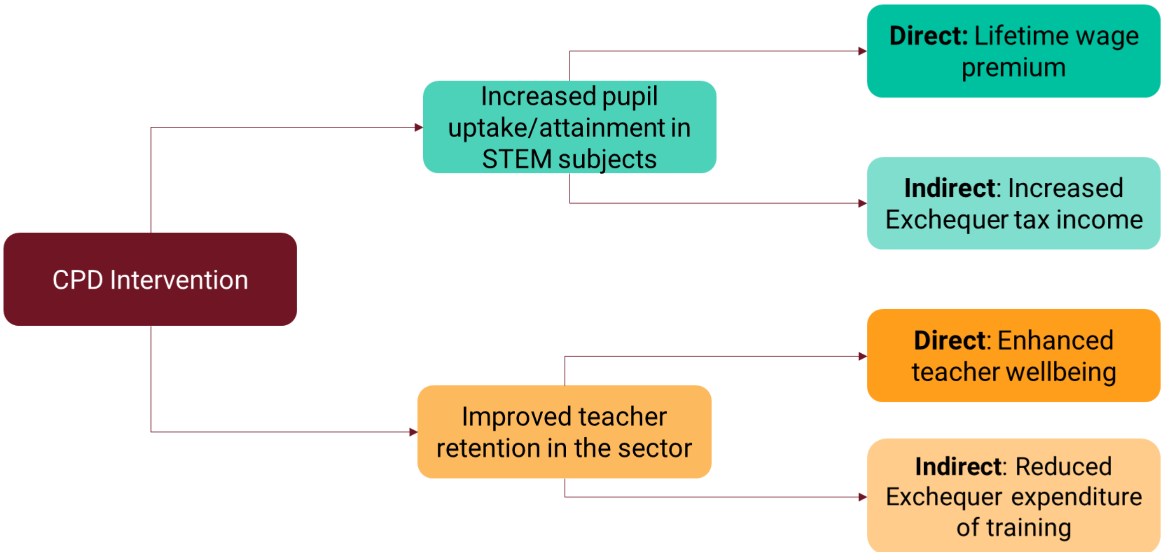
2 Valuing CPD Interventions: Theory and Context

Teacher CPD interventions are generally seen as relatively cost-effective ways to enhance education outcomes while also supporting teachers to remain positively engaged with the sector. A recent Education Policy Institute review (Fletcher-Wood and Zuccollo, 2020) reviewed 52 randomised control trials to look at the impact of CPD on both teachers and pupils. Their report highlighted that high-quality CPD for teachers had a significant impact on pupil outcomes, similar in scale to the impact of having a teacher with ten years of experience rather than a new graduate. They also noted that CPD interventions were generally positively received by teachers and increased teacher retention. Van den Brande and Zuccollo (2020) conclude that, under their central estimate, a policy of providing all teachers with an entitlement to 35 hours of high quality CPD would yield benefits around 19 times the costs.

In line with this literature, the research presented here considers the impact of CPD intervention in two parts defined by the beneficiary being considered: impacts that are mediated through the pupils and those directly mediated through the teachers engaged. The routes through which CPD interventions are considered to create value is illustrated in Figure 1.

For each of the two groups through which interventions have an impact, two areas of benefits are considered. The first is direct benefits, which are the benefits that result that directly accrue to the individuals concerned. Conversely, indirect benefits are those that accrue to wider society through changes in the tax and spending level of the government or costs to wider stakeholders (e.g., schools).

Figure 1: Channels for impact of CPD interventions



For the pupils impacted, the direct benefits are considered to be the increased human capital that the pupils get as a result of improved performance in (or enhanced uptake of) STEM subjects. This human capital is then reflected in increased earning power through the individual's career which is manifested as an overall wage premium across their working life. The positive impact of STEM education on wages is widely seen in the literature. A recent paper by Engineering UK (Armitage et al., 2020) showed that engineers earnt a premium of around £10,000 a year over the median income of the entire UK workforce. Similarly, a report by the British Science Association (2018) found a premium to taking a STEM degree of £34,700 over the first ten years of an individual's career compared to those taking non-STEM degree subjects.

The indirect benefits from this area are the increased tax income that the government receives as a result of these pupils earning more throughout their career.

For the teachers involved in STEM Learning training, the benefits are associated with individuals staying in the profession as a result of the CPD. Teacher retention is a significant issue in the sector. According to the latest national statistics on school workforce in England, in 2020 alone, 34,100 qualified teachers (7.8% of the total sample of teachers in the dataset) left the profession[2].

Retention is valued through two routes. The wellbeing valuation approach estimates the impact of retention in the teaching profession. This is calculated through statistical estimation of the monetised difference in wellbeing between teachers and non-teachers.

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[2] Available at https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england

This reflects an assumption, supported by the analysis in this report, that teaching is a profession that is generally seen as rewarding and hence enhances the overall wellbeing of those working in it, compared to other career choices. Under this assumption, the wellbeing boost that comes from keeping a teacher in the profession for longer is a benefit resulting from the CPD activity.

The indirect benefits in this area relate to the reduced cost of training that result from lower staff turnover. These costs could include costs to government and to schools themselves.

The selection of these four elements as a means to value CPD interventions is not exhaustive. It is likely that there are further channels of impact that could be considered with further research. These are considered in more detail in Section 6.2.

This study applies best practice approaches to valuing the impact through the four channels identified. These are consistent with The Green Book (HM Treasury, 2020a) which sets out approaches to valuing the non-market impact of policies/interventions.

3 Estimating the Number of Beneficiaries

In order to value the impact of CPD, it is necessary to first establish a robust estimate of the number of beneficiaries across the two different stakeholder groups, i.e., pupils and teachers. This figure can then be multiplied as a unit value per beneficiary to estimate the social value for the different channels identified.

3.1 Pupils

STEM Learning provided data on the number of pupils in the relevant cohorts at schools that engaged with the different science CPD training outcomes. Overall, the four sets of activity helped to support over 2 million pupils. It is possible that a large number of these students would benefit in some way from the CPD intervention. However, to avoid over-attribution, it is only considered feasible to attribute the impact on those pupils who achieve a specific STEM-related outcome. As such, specific outcome measures, either assessed by the teacher or evidenced by entry for or attainment in an exam, had been established for each set of activity. The outcome measure used for each set of activity is set out in Table 2.

STEM Learning provided data on the outcome measure for a baseline year and subsequent years in those schools engaged in CPD and equivalent data for non-engaged schools. In general, STEM Learning consider that the impacts of CPD are not realised until at least six months after the intervention. This reflects the need for teachers to adjust their teaching and implement new skills learnt during the training. Classroom activities and tasks need to be amended and or produced for students to fully benefit from the advanced teaching techniques. This is reflected in the approach in this research which looks at impacts on these outcome measures in the academic year following the CPD intervention.

Table 2: Activity measure for CPD activities

Activity	STEM Learning's pupil outcome measure
KS2	Increase in students achieving the expected standard or above in teacher-assessed science at KS2 across up to two full academic years after completing the CPD
KS4	Increase in students achieving their science EBacc GCSE across up to three full academic years after completing the CPD
Triple Science	Increase in students being entered for Triple Science GCSEs at the end of the 2-year engagement
KS5 Progression	Increase in students progressing to take at least 1 STEM A level in the three full academic years after the end of the engagement.[3]

For each outcome a difference-in-difference approach was taken to assess the number of additional pupils achieving the outcome as a result of the CPD intervention. Difference-in-difference is a well-established method (see, for example, HM Treasury, 2020b) for evaluating impact. It ensures that any growth in achievement/uptake observed following the CPD intervention is not just indicative of wider trends.

Changes in the percentage of pupils achieving the relevant standard/taking the relevant subject in schools that engaged with the relevant CPD activity were compared against the equivalent changes in non-engaged schools. The difference was then used alongside the population of pupils in the engaged schools to estimate the number of children who benefited from the activity.

Full calculations for each of the four outcomes is provided in Annex A. The estimated number of additional pupils achieving the relevant outcome as a result of the CPD activity is set out in Table 3.

[3] A STEM A Level is defined as entries into: Mathematics, Further Mathematics, Computing, Biology, Chemistry or Physics. The reason for using STEM A Levels rather than Science A Levels is that there is an association with achievement at science GCSE and progression to STEM A Levels.

Table 3: Pupils engaged and estimated additional pupils achieving relevant outcome

Activity	Pupils Engaged	Estimated Additional Pupils Achieving Relevant Outcome
Key Stage 2	225,314	1,112
Key Stage 4	859,364	3,175
Triple Science	45,329	3,530
KS5 Progression	1,114,301	4,559

3.2 Teachers

This research drew on previous estimates conducted by Wellcome Trust (Allen et al., 2017) of the impact of STEM Learning Science CPD on teacher retention. That study found that 1 in 30 teachers engaged in CPD subsequently left the profession the following year compared to 1 in 12 for those who did not engage. This means that 5% of teachers who engaged with CPD are retained in the profession who would otherwise have left.

This figure was then applied to the number of teachers engaged on each of the CPD activity. For the KS5 Progression activity, the number of teachers engaged was estimated from the number of schools engaged. A conservative assumption that only one teacher was engaged per school was applied. The estimated number of teachers retained as a result of CPD for each set of activity is set out in Table 4.

Table 4: Teachers engaged and estimated additional teachers retained

Activity	Teachers Engaged	Estimated Additional Teachers Retained
Key Stage 2	7143	357
Key Stage 4	7125	356
Triple Science	491	25
KS5 Progression	2108	105

4 Valuing Pupil-related Benefits

Estimation of the pupil-related benefits of CPD interventions focused on the impact of the resulting improved attainment in/uptake of STEM subjects on the individual's wages once they enter the labour market. Associated with this, the increased tax revenue to the Exchequer from this increased wage was also estimated. This approach fits within a Human Capital Theory framework (Becker, 1994), whereby education is seen as an investment that increases productivity of recipients and hence their wage-earning potential.

The returns to specific qualifications can be seen as potentially arising from two mechanisms. Either they reflect the productivity boost that comes from skills and knowledge gained, or the possession of the qualification signals a broader set of qualities that allow the individual to access further education and employment. Empirically distinguishing between the two mechanisms is difficult. However, from the perspective of this study, it is not critical as, for the individual concerned, the wage boost that comes from having the qualification exists regardless of the mechanism.

4.1 Literature Review

The academic and government literature has taken several approaches to assessing the returns to education. The Department of Education (2018) investigated the relationship between achievement at GCSEs and the impact on wages. Hayward et al. (2014) similarly looked at the impact on lifetime earnings. There is a broader range of papers that investigate the returns to education at KS5/A-level such as Conlon & Patrignani (2015) or Capsada-Munsech & Boliver (2021), with some authors looking across educational levels such as (Uysal, 2013). There are slight variations in the relationships between educational uptake/ attainment and returns but a majority report that better educational results and uptake is correlated to higher earnings. No evidence in the previous literature has quantified returns to higher achievement in STEM-related subjects at Key Stage 2. As such, the focus of this review is on the wage returns associated with GCSEs and A-levels, with an emphasis on STEM-related returns where available.

The impacts of improved attainment or increased uptake of a subject may be felt through a range of channels. There are shorter-term impacts from an individual's choice of subjects to study at subsequent educational levels and their choice of higher-education institution destination. There are also longer-term impacts on wages and/or the probability of gaining employment.

Two key issues need to be borne in mind in reviewing this literature. Firstly, the difference between so-called average returns and marginal returns. Average returns refer to a comparison of all individuals who hold that qualification, regardless of the rest of their educational achievement, against those who do not. This contrasts with marginal returns, which reflect the differential between those who have the relevant qualification as their highest qualification, against those who only hold a lower level of qualification. For this research, average returns are more relevant as it is understood that the outcomes that are recorded by STEM Learning are only the immediate educational outcomes, and do not allow observation of the individual's overall educational attainment.

The second important issue to consider is the degree to which estimates of returns are looking to understand a causal impact of education on earnings or, whether they are just describing a wage differential between groups. Establishing a causal impact is difficult because the underlying innate ability of an individual is largely unobservable in the data. It is important to capture this variable given the likelihood that those with higher underlying ability will have higher achievement/uptake of STEM subjects. The literature takes various approaches to this issue.

4.1.1 Returns to GCSEs

The Department for Education (2018) found a relationship between achieving good grades at GCSEs and receiving higher wages. Regardless of the highest level of qualification achieved, the individuals with GCSE grades in the top third of the sample had a higher median wage than the individuals with GCSE grades in the middle third. Similarly, the middle third had a higher median wage than the bottom third. However, this study is not intended to be a causal estimate, instead illustrating the association between GCSE grades and wages.

Hayward et al. (2014) estimated a more accurate measure of the causal impact of improved GCSE grades. They estimate that there were 15% and 16% average lifetime gross returns to five or more A*-C GCSEs (including English and/or Mathematics) compared to those with 1-4 A*-C GCSEs for men and women respectively. The marginal lifetime returns were smaller, but still substantial at 9% and 13% for men and women respectively. This estimation controls for people's highest level of qualification but is not able to control for background characteristics such as early test scores due to limitations in the dataset. Bibby et al. (2014) also found a 12% marginal gross return to achieving five A*-C GCSEs. However, the study included all Level 2 qualifications equivalent to five A*-C GCSEs and does not estimate average return figures.

These results are similar to work that uses older datasets. Blundell et al. (2003) found an average gross return to O-levels (the precursor to GCSEs) of 18% for men, and Uysal (2013) found only a 6.5% net return to O-levels. On the other hand, for women there was no statistically significant returns to O-levels.

Looking to the specific impact of STEM GCSEs on wages, a recent study by Hodge et al. (2021) calculated discounted earnings of £698,000 for those who took GCSE Triple Science. These estimates were around 30% higher than those who took Double Science. While this suggests there may be a wage premium associated with taking triple science, the study is focused on the returns to marginal changes in grades within subjects. This estimated difference between Triple Science and Double Science reflects the fact that those taking Triple Science are more likely to be male, have higher achievement at Key Stage 2 and take a higher number of GCSEs. These are all likely to be factors that are associated with higher wages. Looking at the wage impact of improved grades within subjects, the study shows that the most significant positive impacts are generally for moving from a Grade D to a Grade C (using the pre-2017 grading system) and that the returns to Double Science of moving across this boundary are approximately £20,000 over the individual's lifetime.

4.1.2 Returns to A-levels

There is a broader range of data on the returns to A-levels with estimates of the average returns ranging from 5% to 11% depending on the controls and population samples used. STEM A-levels have often been found to be associated with high salaries. Fitz-Gibbon (1999) found a correlation of 0.26 between curriculum choice of 'difficult' subjects and salary expected in five years. Although difficult subjects included foreign languages, which are non-

STEM subjects, it also included mathematics and was predominantly affected by science subjects.

This relationship between STEM A-levels and high wages has continued over time, with Department for Education (2019) report finding that 18 of the top 20 A-level qualifications for annual earnings are STEM subjects. Conlon & Patrignani (2015) estimated an average gross return to achieving at least one A-level with grade A-C of 7% compared to those with no A-levels. Hayward et al. (2014) found an average gross return of 11% to two or more A-levels compared to those with 5-7 A*-C GCSEs for both men and women, although they did not control for ability. Interestingly, Adkins & Noyes (2016) found that there is a 9% average gross return to a Mathematics A-level but no statistically significant positive returns to a science A-level (physics, chemistry, and biology) when controlling for ability and a wide range of socioeconomic indicators. However, they only looked at returns at the age of 33 rather than across the individual's lifetime.

Capsada-Munsech & Boliver (2021) supported these findings with an estimated return (measuring disposable income) to academic upper secondary qualifications of 8% when controlling for ability, 7% when controlling for sociodemographic variables, and 5% when controlling for university attendance. For marginal returns, Bibby et al. (2014) found a 9% gross return to achieving two A-levels, although this study included equivalent Level 3 qualifications. Hayward et al. (2014) estimated more optimistic marginal gross returns of 15% for men and 16% for women when compared to those with 5-7 A*-C GCSEs.

Once again, these studies are broadly consistent with some of the research that uses older samples. Returns to achieving A-levels compared to O-levels ranged from 4% (Uysal 2013) to 6% (Blundell et al. 2003) for men, with Uysal (2013) finding larger average net returns, when comparing to individuals with no qualifications.

An analysis by Conlon & Patrignani (2015) found average gross returns of 13% for passing at least two STEM A-levels out of at least three total A-levels when compared to an individual with only O-levels or GCSEs and controlling for ability and family background. This falls to 6% for those with one STEM A-level and 5% for those with no STEM A-levels.

4.2 Direct Benefits Analysis

4.2.1 Data

The main data source used in estimation of the wage premia for this study was the 1970 British Cohort Survey (BCS70) which tracks a random sample of 17,000 individuals born in a single week in 1970. Over the course of the cohort's lives, BCS70 collected information on health, physical, educational, social development, economic and other factors.

The latest data available was a sweep taken at age 46 which was used as the upper age limit in the estimation of wage premia.

The variables used in the estimation of the wage premia are set out in Table 5.

Table 5: BCS70 variables used in estimation of wage premia

<table>
<tr><th>Variable</th><th colspan="3">Description</th></tr>
<tr><td>Wages</td><td colspan="3">Wages have been observed at age 26 (observed in 1996), 29, 34, 38, 42 and 46 (observed in 2016). Observations are taken once individuals have dropped out of education, so wages earnt whilst in education are not observed. Wages have been converted to annual figures and are all after-tax. They have also been converted into 2020 prices using the Bank of England (BoE) calculator[4]. Wage premia are therefore all presented in 2020 prices.</td></tr>
<tr><td rowspan="6">STEM Education</td><td colspan="3">Treatment variables were derived from the dataset to correspond to the activity measures for the four sets of activity. The treatment variables were defined as follows:</td></tr>
<tr><td>Activity</td><td>Treatment group</td><td>Control group</td></tr>
<tr><td>KS2</td><td>Those achieving a score in the top 83% of the maths test at age 10[5].</td><td>Those achieving a score in the bottom 17% of the maths test at age 10.</td></tr>
<tr><td>KS4</td><td>Those achieving a good grade (A-C) in two or more STEM GCSEs[6]</td><td>Those achieving one or no good STEM GCSEs but still taking other GCSEs.</td></tr>
<tr><td>Triple Science</td><td>Those taking three science GCSEs (Biology, Chemistry and Physics)</td><td>Those taking 2, 1 or no STEM GCSEs but also taking other GCSEs.</td></tr>
<tr><td>KS5 Progression</td><td>Those taking at least one STEM A-Level[7]</td><td>Those taking no STEM A-Levels but still taking other A-Level subjects.</td></tr>
<tr><td>Gender</td><td colspan="3">Male or female as specified in BCS70, taken at age 16.</td></tr>
<tr><td>Region of residence</td><td colspan="3">The region where the individual was living at age 10.</td></tr>
<tr><td>Family income</td><td colspan="3">Family income taken in 1980 for the cohort at age 10.</td></tr>
<tr><td>GCSE control</td><td colspan="3">Used in the regressions linked to A-Level uptake to control for the fact that those individuals who do well at KS4 science are more likely to take a science A-Level, regardless of any CPD intervention.</td></tr>
<tr><td>Early math test score at age 10</td><td colspan="3">Used in the regression linked to GCSE uptake and attainment as a proxy for innate ability in STEM subjects.</td></tr>
</table>

[4] Available at: https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

[5] No specific data was available on science-related achievement at this level. Maths achievement at the same age was used as the closest proxy. 83% represents the proportion of children meeting the expected standard in KS2 science within the dataset of engaged and non-engaged schools provided by STEM Learning.

[6] The cohort primarily took O-levels rather than GCSEs, but these were treated as equivalent within the sample.

[7] STEM A Levels have been defined in line with the official government definition. Available at: https://www.gov.uk/guidance/civil-service-fast-track-apprenticeship-list-of-qualifying-stem-subjects

4.2.2 Methodology: Regression Analysis

The advantage of the approach taken in this study is that it allows for flexibility in how the wage premium evolved over the individual's career. To allow for this, wage premia were estimated at six different ages once the individuals were active in the labour market, and these were used to estimate an overall wage premium across the career.

Wage premia have been calculated using six Ordinary Least Squares (OLS) regressions at age 26 through to age 46 for each type of STEM CPD intervention as described in Table 5. The general theoretical log-linear regression equation is described below:

$$\ln(Net\ annual\ wages_{it}) = \alpha + \beta STEM\ Education_{it} + \Phi Controls_{it} + \mu_{it}$$

$$i = observation, t\ (age) = 26, 29, 34, 38, 42\ and\ 46$$

The causal relationship estimated is the percentage change in net annual wages as a result of applying the treatment (increased STEM achievement/uptake) against a counterfactual of no such increase. β is the coefficient of interest and it describes the wage premia earnt as a result of undertaking or succeeding in the relevant STEM qualification. The interpretation of the coefficient is the percentage change in net annual wage as a result of a unit increase in the treatment group.

As an example, for the KS4 activity, the treatment and control group are defined as:

$$STEM\ Education_{it} = Achieving\ a\ good\ grade\ (A - C)\ in\ two\ or\ more\ STEM\ GCSEs$$

$$Control\ group_{it} = Achieving\ one\ or\ no\ good\ STEM\ GCSEs\ but\ still\ taking\ other\ GCSEs$$

If the coefficient $\beta = 0.16$ at age 26 this would represent a 16% wage premium earned by Group 1 - those achieving at least two good STEM GCSEs - compared to Group 0 who did not achieve either one or no good STEM GCSEs at this stage in their career. These wage premia are estimated at all time periods as specified in Table 5.

Control variables have been included in the regression model to avoid a problem of endogeneity, more specifically, omitted variable bias, as recommended by HM Treasury (2020b) guidance on estimating impact. This arises when explanatory variables are correlated to the error term μ_{it}. Bias in estimation will mean that on average, the estimate for wage premia does not equal the true population value. To avoid this problem, a number of control variables are included in the estimation that are known to be correlated with wages. It is important wherever possible to control for underlying ability. This underlying ability impacts on both achievement of the STEM educational outcome and future wages. The dataset allows for the inclusion of early math test scores (age 10) as a control for ability when considering GCSE uptake/attainment. For the regressions considering the uptake of STEM A-levels, GCSE attainment was included as a control to reflect both ability and prior skills obtained in science.

When considering the impact of greater achievement at KS2, no prior data was available to use as a control variable to proxy ability. Reviewing estimates of wage premium percentages with and without such controls at other levels highlighted the likelihood that estimates without such controls were likely to be upwardly biased. As such, the 95% confidence interval lower bound estimate of each of the wage premium percentages were used to calculate the wage premium.

4.2.3 Methodology: Wage Premium Calculation

The wage premium percentages derived from the regression analysis were applied to the median wage of the control group. For unobserved years (for example, before age 26, or between 42 and 46) the wage premium percentage and median wage were calculated using a straight-line interpolation. From the age at which individuals left full time education up to age 26, the wage premia calculated at age 26 was applied. The wages of the two groups (treatment and control groups) are assumed to start accruing from the respective average drop-out ages as calculated from the dataset.

It is assumed that no wage premia are earned beyond age 46. This reflects the fact that data is not available on this cohort beyond this stage of their career. As such, it is not possible to be sure how the wage premia evolve beyond age 46 (whether it widens or diminishes) nor whether there are systematic differences in retirement age between the two groups. Other studies such as Hodge et al. (2021) do look to model wages through until age 67 but this requires combining data on those recently in education with alternative data sources to model the potential evolution of wages further on in their career.

Overall, this assumption means that the figures presented here are likely to be somewhat conservative. However, it should also be noted that age 46 is close to a 30-year horizon from the time of the interventions that are being considered (the interventions are assumed to be undertaken with children aged between 10 and 15). A 30-year horizon is commonly applied to policy evaluations, and it is difficult to rule out significant changes in the labour market in 30 years' time that would impact on the wage premia. Increasing automation and AI may widen or narrow the wage premia of STEM depending on whether they evolve into substitutes or complements of human capital in science. HM Treasury's Green Book also generally discourages discounting values over a period longer than 30 years, unless they are associated with significant inter-generational impacts.

The estimated yearly wages earnt by both the control and treatment groups were discounted using the standard Green Book discount rate of 3.5%. Wages were discounted to age at which the intervention took place. This allows for the benefits to be directly compared to the costs which are generally calculated at the time of the intervention. The individual yearly benefits were then summed across all the years. The difference of the summed discounted wages represented the net present value of the intervention.

4.2.4 Wage Premia Results

The key outputs for the regression analysis are set out in Table 6. This shows the percentage wage premium at each of the six ages for the four STEM education treatment variables. It also sets out the mean age at which the different groups enter the labour market and the assumed age at the time of the intervention. Most of the estimated percentage wage premia were statistically significant at the 5% level. Even in the few cases where they were not statistically significant, regression results were retained for the analysis as they broadly aligned with the premia for the ages either side.

Table 6: Percentage wage premiums and CPD intervention/mean drop-out ages

Educational outcome	Wage Premium Percentage						Mean drop-out age	
	26	29	34	38	42	46	Group 0	Group 1
Meeting KS2 Science expectations	2%**	22%***	26%***	23%***	28%***	24%***	17	18
Taking Triple Science at GCSE	18%***	15%***	9%	24%***	27%***	26%***	19	22
Achieving at least 2 good GCSEs in Science	16%***	21%***	16%***	21%***	20%***	22%***	18	21
Taking at least 1 STEM A-level	1%	13%**	9%*	10%	20%***	8%	21	21

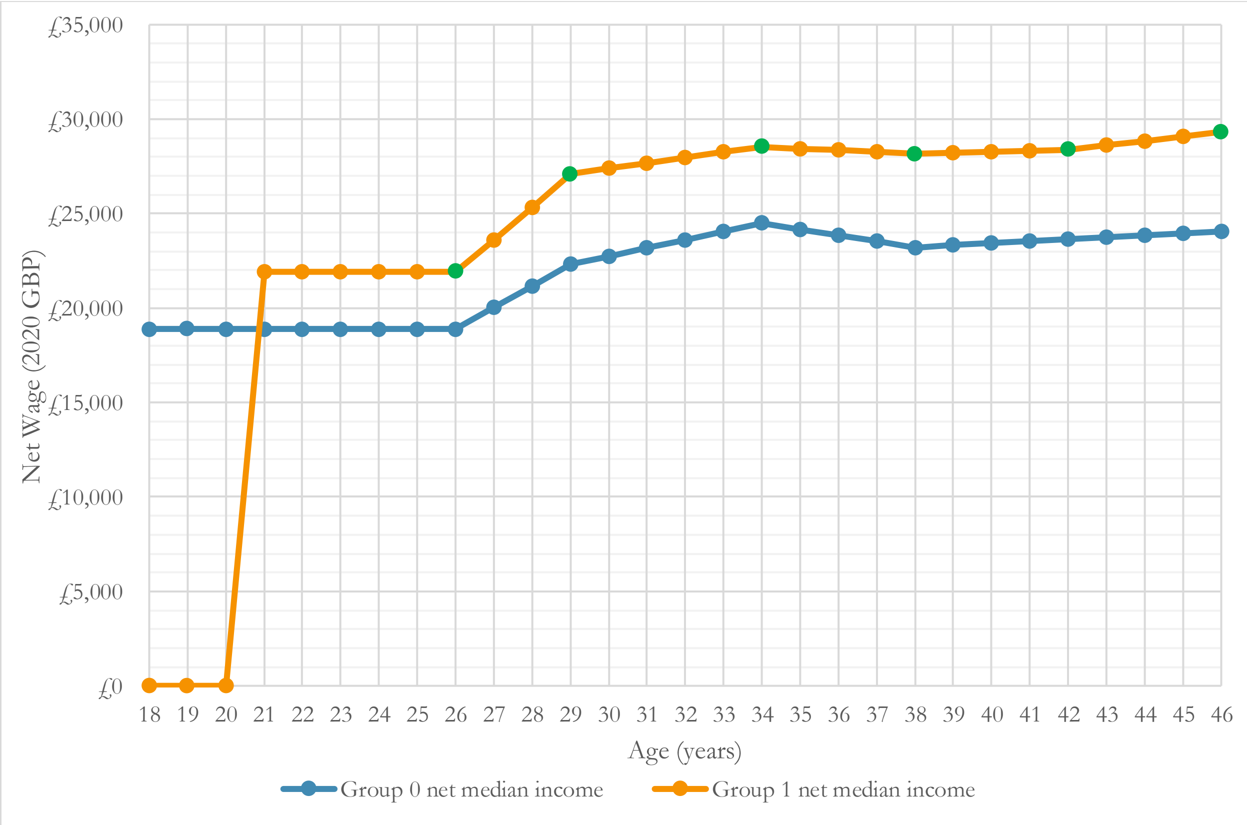
Notes:
*** Statistically significant at the 1% level
** Statistically significant at the 5% level
* Statistically significant at the 10% level

The results show that across all educational outcomes and years of estimation, there is a positive wage premium associated with increased uptake or attainment in science subjects. **The age-specific premia range from 1% to 28%.** In general, the premia increase over the early part of the career but then level off and, in some cases, fall. In a recent paper for the Department of Education (Hodge et al., 2021) similar trends can be seen in the differential between wages earnt those with different levels of highest qualification.

It is important to note that the control group generally enter the labour market earlier (because they do not spend so long in education) and hence start earning sooner. As such, the treatment group start with a 'negative' premium, but this is then overcome once they enter the labour market and earn a premium.

An example of this is shown in Figure 2 comparing those who achieve at least two good Science GCSEs and those who did not. The green markers represent the years for which wage premia have been calculated. Straight line interpolation is used to calculate the premia for the intermediate years. In this case, the treatment group do not, on average, enter the labour market until 21, three years later than the control group. As such, the control group has accumulated three years' worth of earnings. Once in the labour market, the treatment group earns a premium throughout their career. Accounting for this difference in length of time in the labour market is an important aspect of ensuring that the calculated wage premia are robust.

Figure 2: Estimated net income for those achieving 2 good STEM GCSEs (Group 1) and those achieving 1 or no good STEM GCSEs (Group 0)



The monetary values of the discounted lifetime wage benefits are presented in Table 7. Taking the first example, the calculation shows that those **children who succeeded at early science (age 10) are expected to earn a premium of £22,462 from the ages of 18 to 46 compared to those who did not.**

4.3 Indirect Benefits Analysis

In addition to the additional net wages earnt, the additional taxes paid by the STEM-educated individual to the government were calculated. The net annual wage figures were used to recover the gross amounts based upon current tax/national insurance rates and the relevant tax-free allowances. As with the wage premia, these additional amounts were discounted back to the age at the time of the intervention and summed. These figures are included in Table 7.

It is noticeable that for the two GCSE-related premia, the direct lifetime wage premia are lower than the equivalent Exchequer benefits. This is the result of the treatment group entering the labour market three years later than the control group and the fact that the tax-free allowance means that there is a differential in the effective tax rate on this initial negative wage differential and the subsequent positive wage differentials once both groups are in the labour market.

Table 7: Discounted lifetime wage premia and additional exchequer tax benefits

Educational Outcome	Discounted lifetime direct wage premia	Discounted lifetime additional income tax and national insurance contributions
Meeting KS2 Science expectations	£22,462	£14,786
Taking Triple Science at GCSE	£6,845	£15,875
Achieving at least 2 good GCSEs in Science	£8,474	£18,017
Taking at least 1 STEM A-level	£31,435	£14,793

4.4 Comparison to Literature

As a test of convergent validity, the wage premia were compared to the literature. While the isolated premium percentages identified at each age level are generally somewhat higher than the figures seen in the literature, when account is taken of the difference in mean age at which the two groups enter the labour market, the figures are broadly aligned. Table 8 sets out how the figures compare to the literature.

One of the key differences in the approach taken here and some of the literature is that the wage premia is estimated at six separate intervals in the same cohort's careers. This provides a more flexible approach to assessing the impact of education across an individual's career and highlights that the premia vary across the career, making it harder to draw conclusions from research that only shows wage premia at a specific age. However, it does also mean that it is assumed that no wage premium is earned beyond age 46. This is a limitation of the dataset used in this study, but such an approach ensures that the figures presented are conservative.

4.5 Aggregation of Pupil-related Benefits

The per pupil estimated wage premia and additional tax payments were combined with the estimates for the numbers of additional pupils achieving the relevant outcome from the CPD programmes. The resultant estimated benefits to pupils of the programmes are set out in Table 9. The **estimated total pupil-related benefits were highest for the KS5 Progression activity at slightly over £210m, with figures of between £40m and £85m for the other three sets of activity.**

Table 8: Overall calculated premium against comparable figures in literature

Educational Outcome	Overall net wage premium	Overall gross wage premium	Literature findings
Meeting KS2 Science expectations	8.9%	12.8%	No literature available
Taking Triple Science at GCSE	2.0%	5.5%	Hodge et al. (2021) find 30% net lifetime wage premium for those taking Triple Science compared to those taking Double Science but without controlling for ability.
Achieving at least 2 good GCSEs in Science	2.4%	6.0%	Hodge et al. (2021) find approximately £20,000 (3.8%) net lifetime wage premium for shifting across C-D grade boundary in Double Science. Wider literature finds returns of 6.5%-18% for a wider set of good GCSEs/O-levels.
Taking at least 1 STEM A-level	8.9%	10.4%	Range of findings of returns of 5%-11% for returns to A-levels more generally. Estimate of 6% for return to passing at least 1 STEM A-level.

Table 9: Total discounted pupil-related benefits

Activity	Additional pupils achieving outcome	Per pupil		Overall		Total
		Direct benefits	Indirect benefits	Direct benefits	Indirect benefits	
KS2	1112	£22,462	£14,786	£25.0m	£16.4m	£41.4m
KS4	3175	£6,845	£15,875	£26.9m	£57.2m	£84.1m
Triple Science	3530	£8,474	£18.017	£24.2m	£56.0m	£80.2m
KS5 Progression	4669	£31,435	£14,793	£143.3m	£67.4m	£210.8m

5 Valuing Teacher-related Benefits

Estimation of the teacher-related benefits of CPD interventions included two channels through which increased teacher retention benefits society. Firstly, benefits to the teachers themselves in terms of improved wellbeing from remaining in the profession were estimated and monetised. Secondly, the reduced cost to the Exchequer from avoided training costs were also calculated.

5.1 Literature Review

The literature on the impact of CPD on teacher retention is relatively limited. Van den Brande and Zuccollo (2021) provide a recent overview of findings in this area and identify a lack of data from randomised control trials on the impact of teacher retention. The only quantitative research that they identify is Allen and Sims (2017) whose findings are used as the basis for the calculations in Section 3. Van den Brande and Zuccollo (2021) do not apply these findings to monetise impacts as they do not feel the findings are generalisable across all teachers given that they are derived from an outcome aimed solely at STEM subjects in secondary schools. In contrast, as the analysis presented here is focused on the teaching of STEM subjects, and is primarily concerned with secondary schools, it is reasonable to make use of Allen and Sims (2017) findings to estimate this element of the value of CPD.

No formal literature was identified explicitly looking at the wellbeing of teachers as a profession compared to other sectors. However, the What Works Centre for Wellbeing (2016) provides limited data suggesting that, relative to the average salary in the sector, the teaching professions enjoy relatively high levels of job satisfaction and sense of having a worthwhile life. However, their research also shows that this may be somewhat offset by higher-than-average levels of anxiety.

5.2 Direct Benefits Analysis

5.2.1 Data

The wellbeing analysis was conducted using data from Understanding Society (USoc), a long-running, nationally representative survey of the UK population from approximately 40,000 households at Wave 1. The adult survey is completed by respondents aged 16 and over and has been conducted over ten waves to date.

An unbalanced panel dataset from 2009 to 2020 was used, containing 42,771 observations. The key variables are set out in Table 10.

Table 10: Understanding Society survey variables used in wellbeing analysis

Variable	Description
Life satisfaction	Respondents are asked to rate their satisfaction with life overall on a seven-point scale, from completely, mostly and somewhat dissatisfied, neither satisfied nor dissatisfied to somewhat, mostly and completely satisfied.
Income	Defined as a natural logarithm of household income.
Teacher	Defined as a dummy variable which is 1 for respondents whose current job is categorised as 'teaching and educational professionals' and 0 otherwise.
Hours	The number of hours normally worked per week.
Control variables	Standard set of control variables based upon those recommended in Fujiwara and Campbell (2011) including age, gender, ethnicity, marital status, education, physical health and region.

This dataset is also used to estimate the median tenure for teaching.

The longitudinal nature of the dataset allows for the observation of individuals moving out of teaching (either state funded or private school) to pursue a different profession. In total 568 individuals are observed as leaving teaching within the USoc sample. Table 11 highlights the professions into which the largest number of former teachers moved within the dataset. It can be seen that the largest proportion of those leaving the teaching profession within the dataset move on to jobs classified as 'childcare and related professional services'[8].

Table 11: Most popular destination professions of those leaving teaching within USoc dataset

Destination Sector	Percentage of those leaving teaching
Childcare and Related Personal Services	4.8%
Public Services and Other Associate Professionals	2.6%
Functional Managers and Directors	2.3%
Artistic, Literary and Media Occupations	1.6%
Business, Research and Administrative Professionals	1.4%
Welfare and Housing Associate Professionals	1.4%
Managers and Proprietors in Other Services	1.2%
Sales Assistants and Retail Cashiers	1.2%
Sales, Marketing and Related Associate Professionals	1.0%

5.2.2 Methodology

The wellbeing analysis applied the three-stage valuation approach set out in Fujiwara (2013). The approach requires estimation of:

- The causal impact of income on life satisfaction,
- The causal impact of the non-market good (in this case teaching) on life satisfaction,
- The monetary equivalent value of the non-market good.

[8] Classification based upon Standard Occupational Classification 2010 condensed 3-digit version.

This research focused on the second of these three stages, making use of the approach set out in Fujiwara (2013) for the first and third stage of the process.

Pooled OLS estimation was used to model the wellbeing of current teachers compared to the reference group of individuals in the most popular professional destinations for those teachers leaving the profession. The equation estimated was:

$$LS_{it} = \alpha + \beta_1 Teacher_{it} + \beta_2 Hours_{it} + \beta_3 X_{it} + \varepsilon_{it}$$

$$i = individual, t = time\ period$$

Where LS_{it} represents life satisfaction for person i at time t and X_{it} includes a list of control variables. The estimation contains sampling weights per wave and robust standard errors are reported to account for heteroskedasticity.

A reference income of £30,000 per year was used to calculate the monetary equivalent of the yearly wellbeing differential for teachers against their counterparts in the most popular career destination.

5.2.3 Results

Full regression results are available in Annex B. The coefficient β_1 was estimated to be 0.054. This implies that the annual wellbeing differential for teachers against their counterparts in most popular destination jobs was equivalent to the impact of £ 1,431 on wellbeing.

The median tenure for teaching was estimated to be five years compared to just two years for those who leave the profession. As such, the wellbeing benefit was calculated as a discounted flow of this annual benefit across three years, starting two years after the intervention. A discount rate of 3.5% was used, in line with HM Treasury Green Book guidance.

On this basis, the overall lifetime wellbeing benefits for teachers who do not leave the profession as a result of CPD was calculated as equivalent to £3,874 per teacher.

5.3 Indirect Benefits Analysis

Cost data for teacher training were taken from Allen et al. (2016). This estimated the average cost of training a teacher to be £23,005 across all Initial Teacher Training routes, across primary and secondary school.

This estimate includes central costs (direct funding to ITT providers, grants to schools, provision of student finance and provision of student bursaries) and school costs (fees and salaries paid to trainees, net of the value of their contribution to teaching).

The cost estimate was updated to 2019/20 prices to reflect inflation. The updated aggregate average cost of initial teacher training was calculated as £25,527 per teacher.

5.4 Aggregation of Teacher-related Benefits

Bringing together the estimated direct benefits (in terms of wellbeing for teachers) and indirect benefits (avoided costs for government and schools), the total calculated teacher-related benefits for the four sets of activity was as set out in Table 12. **The estimated teacher-**

related benefits associated with each set of activity were, overall, substantially smaller than those related to pupils. They ranged from less than £1m to slightly over £10m for each se of CPD interventions.

Table 12: Total discounted teacher-related benefits

Activity	Additional teachers retained	Per teacher		Overall		Total
		Direct benefits	Indirect benefits	Direct benefits	Indirect benefits	
KS2	357	£3,874	£25,527	£1.4m	£9.1m	£10.5m
KS4	356	£3,874	£25,527	£1.4m	£9.1m	£10.5m
Triple Science	24	£3,874	£25,527	£0.1m	£0.6m	£0.7m
KS5 Progression	105	£3,874	£25,527	£0.4m	£2.7m	£3.1m

6 Aggregated Results

Bringing together the pupil-related and teacher-related benefits, allows for an overall estimate of the value of the CPD intervention outcomes. These are set out in Table 13 where the figures illustrate the significant positive impact of STEM Learning's Science CPD programmes on society through both the pupils and the teachers impacted.

Table 13: Overall estimated benefits of Science CPD activities

Activity	Pupil-related benefits		Teacher-related benefits		Total
	Direct	Indirect	Direct	Indirect	
KS2	£25.0m	£16.4m	£1.4m	£9.1m	£51.9m
KS4	£26.9m	£57.2m	£1.4m	£9.1m	£94.6m
Triple Science	£24.2m	£56.0m	£0.1m	£0.6m	£80.9m
KS5 Progression	£143.3m	£67.4m	£0.4m	£2.7m	£213.8m

As the activities being considered here ran at different times, it is best to consider the results on an activity-by-activity basis. The KS2 and KS4 can be considered together and are the best representation of the impact of core science CPD provided by STEM Learning.

6.1 Triangulation of Results

One way to consider these estimates would be to compare them to costs. As set out in Can den Brande and Zuccollo (2021), a full cost estimate would need to include:

- Costs of provision of CPD training outcomes
- Set up costs related to developing outcomes that are certified
- Travel costs to and from training centres if not received within school
- Staff cover costs for when teachers need to go on training courses during school times.
- Opportunity cost of time for teachers and all involved from reduced teacher contact time.

It was out of scope of this report to establish a cost for these outcomes. However, STEM Learning have indicated that their income linked to core science CPD was of the order of £20.9m for the period from 2016-2018. The KS2 and KS4 outcomes can be considered the best counterpart to this figure as they are the most recent core science CPD training programmes and ran during these three years. The total estimated benefits for these two outcomes were £146.5m. The cost benefit ratio this implies (slightly over 7:1) is lower than the figure found by Van den Brande and Fuccollo (2021) but is still highly positive. However, it should be considered in light of the caveats and limitations discussed below.

Particular care should be exercised when considering the Triple Science outcome. The estimated total benefits of £80.9m appear large when compared an estimated direct cost of provision of only £3.2m provided by STEM Learning.

As highlighted previously, this programme is targeted at schools with historically low take up of Triple Science. It is observed that for the first two cohorts of schools on this outcome, the average take-up of Triple Science prior to the programme was just 4.8%. This compares to a national average of 23.2%. The number of schools remaining with such low take up of Triple Science is now much lower. By the time of the third cohort of schools to enter this programme, the average Triple Science take up in the treatment schools had already risen significantly to 16.2%.

As such, it is unlikely that the programme will be able to deliver such large returns in the future. An alternative estimate for the number of pupils achieving the outcome as a result of the programme was calculated. This was done by comparing those schools who engaged with the Triple Science programme for activities relating to Key Stage 3 (when choices around the uptake of Triple Science are made) and those that engaged only at Key Stage 4 (i.e., working with teachers of pupils who have already made such choices). Schools in both of these groups generally have similarly low levels of Triple Science uptake. This alternative estimate is that 1319 pupils took up Triple Science as a result of the programme. If this lower figure is used, the overall estimated benefits would fall to £30.7m.

This figure can likely be considered as an underestimate of the impact of the programme historically. In particular, those teachers working at Key Stage 4 often also work at Key Stage 3 and may apply learnings from the CPD to their wider teaching even if it is aimed solely at Key Stage 4. However, it may be a better estimate of the *potential* of the programme going forward.

The KS5 Progression activity has the highest estimated impact at over £200m. This estimate can be compared to the KS4 activity as both are effectively measuring an impact of CPD interventions with teachers working at Key Stage 4 but measured using different outcome metrics (one is attainment at GCSE and the other is uptake at A-level). The KS5 Progression activity pre-dates the KS4 activity. This means that more years of data is available to estimate the impact. Specifically, three years of impact was available for all schools in the programmes, whereas for the KS4 outcome, Cohorts 2 and 3 of schools only had data on two and one year of impact respectively. This likely explains a significant amount of the difference in the estimates between these two similar outcomes.

6.2 Caveats and Limitations

The estimated benefits presented in this report represent a best estimate of monetary value of the impacts of STEM Learning's science CPD programmes. As with any study, there are areas that cannot be included or that could be considered further if the data were to become available.

Overall, the figures can be considered a conservative, robust estimate of the outcomes' impact for a number of reasons. Firstly, the routes through which STEM Learning CPD generates social value are multiple, and the current analysis cannot be seen as capturing their full extent. It is also clear, for example, that the subset of pupils for which benefits are calculated does not capture the full impact of the CPD programmes. No account is taken of improvements in grades for other students aside from those achieving the specific outcome. For the KS4 outcome, for example, the approach taken effectively values the impact on those pupils who shift from a 3 to 4 at GCSE (D to C in previous grading system) but assigns no value to those students who move from a 6 to 7 as a result of the improved teaching.

Wider Exchequer benefits have not been considered in terms of reductions in state benefit contributions and savings to the government. For example, Lochner and Moretti (2011) find that, in general, increased education is correlated with reductions in incarceration rates and hence can be linked to lower costs for policing. Similarly, it would be expected that there would be reductions in claims for other state benefits if education levels were raised. Neither of these elements are considered but it provides further evidence regarding the conservative approach taken in the estimation presented here.

In addition, the benefits produced by STEM Learning CPD are assumed to be zero for those years during which beneficiaries are still in education. There is no attempt to calculate the wider benefits to the pupil of having a better teacher beyond the specific impact on achievement/uptake of outcomes. There may be other positive outcomes associated with CPD, such as reduction in dropout rates and improved confidence.

Furthermore, the wage premia are only calculated to age 46. The BCS70 dataset continues to be updated. The current BCS70 sweep is underway and is due to finish in late 2022. This update would allow the wage premia to be calculated for an additional 5 years. As discussed previously, it is not, however, clear that extending the wage premia beyond the 30-year horizon is a robust approach in the light of rapidly changing technology and general uncertainty over the returns to education in the future.

These factors all mean that the value estimated in this research is likely to understate the overall benefits. Conversely, there are some assumptions made that could, in theory, mean that certain elements are overstated.

Firstly, those pupils who do achieve the relevant outcome as a result of the intervention are assumed to then achieve the same wage trajectory as others who would have achieved that outcome anyway. In other words, it is assumed that it is not the case that these pupils are just moved marginally across a boundary at one stage but then fail to achieve thereafter. While this is a concern, STEM Learning have some evidence to support this assumption from their Triple Science programme. It shows that the programme not only raises *uptake* of Triple Science in the schools engaged but also leads to *attainment* in Triple Science in those schools that are in line with the wider sector.

Secondly, the estimate for the number of teachers retained as a result of CPD may be an over-estimate. This would be the case if teachers who obtain CPD are not representative of the wider population and were less likely to leave the profession even in the absence of the CPD intervention. A better causal estimate would require some form of randomised control trial to estimate the impact. While a concern, it is noticeable that the significant majority of the values estimated in this research are driven by the pupil-related benefits rather than those related to the teachers.

There are other factors that may be considered as adding some uncertainty to the figures presented but for which it is unclear the direction of any imprecision. Firstly, the wage premia estimates are, necessarily, based upon a dataset that represents a cohort of individuals born in 1970 who completed their education in the late 1980s. The value of education obtained in the later 1980s may not reflect the impact of improved STEM education on the current cohort of young people. However, use of this dataset allows for the estimation of a flexible wage premium that varies at different points in the individual's career. This provides a more accurate representation of the trajectory of wage premia earnt but, as a result, this research must rely on a dataset that is, to some extent, historic in nature. The more recent Millennium Cohort Study is available but, as it tracks children born in 2000, there is not yet significant data on the individual's careers.

In addition, this is the first time that wellbeing values have been incorporated into an analysis of CPD outcomes. It is also the first time that the Understanding Society dataset has been used to identify the destination of teachers leaving the profession. This provides a data-driven approach to comparing the wellbeing of teachers and ex-teachers. However, it should be noted that this approach is not able to identify those teachers who would have stayed under a counterfactual of receiving CPD. Future research may seek to track cohorts of teachers within a randomised control trial setting.

Furthermore, USoc data also does not distinguish between STEM and non-STEM teachers. As such, for the purpose of this analysis, the value estimated applies to teacher retention in general rather than specifically to STEM teachers. More generally, wellbeing values are proxies. It is not possible to observe what individual's life satisfaction would have been if they had decided to stay. However, the analysis presented is the most advanced analysis that could be undertaken using observational data collected in large national household surveys.

7 Conclusions

The research presented here strengthens the case that high quality CPD interventions such as those provided by STEM Learning have a significant value to society. **The overall estimated value of the four sets of activities ranged from £51.9m to £213.8m**. The **majority of these benefits were derived from pupil-related benefits as a result of future wages** accruing to those pupils or through the additional taxes paid by those individuals. A smaller proportion of total benefits, ranging from less than **£1m to £10.5m are estimated as resulting from the increased retention of teachers as a result of CPD**. Most of these benefits represent avoided training costs from improved retention.

The estimates made in this research represent a robust and conservative estimate of the benefits of such activities. The figures are likely to understate the full value of such set of activities because i) wage premia are only calculated until age 46 (whereas several papers estimate them until age 67) and ii) a number of additional channels through which STEM Learning's Science CPD programmes generate value were not assessed due to a lack of adequate data. In particular, the impact of such CPD outcomes on improving the grades of those students who were already likely to achieve the relevant standard (for example, Science EBacc) was not assessed.

Further research should look to extend the range of benefits calculated by assessing additional benefits to a wider range of pupils. Estimation of Teacher-related benefits could be strengthened through randomised control trials to examine the impact of CPD on teacher wellbeing and retention across different Key Stages.

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Annex A: Establishing the Number of Pupils Affected

In order to apply the wage premia derived, it was necessary to assess the number of pupils who are positively impacted by the CPD activities conducted by STEM Learning. Data was assessed for each of the four activities in turn.

In each case a difference-in-difference approach was taken to ensure that the growth in achievement/uptake seen following the CPD activity was not just indicative of wider trends. Changes in the percentage of pupils achieving the relevant standard/taking the relevant subject in schools that engaged with corresponding CPD activity were compared against the equivalent changes in non-engaged schools. The difference was then used alongside the population of pupils in the engaged schools to calculate the number of children who benefited from the activity.

Key Stage 2

Data was available on two cohorts of schools where teachers had undertaken CPD relevant to Key Stage 2. Cohort 1 consisted of 1953 schools where a teacher(s) had completed the training in 2015/16 while Cohort 2 consisted of a further 1445 schools where training had been completed in 2016/17.

The outcome measure of interest was the percentage of children reaching the expected standard in Key Stage 2 science. For Cohort 1 such data was available for 2016, 2017 and 2018 while for Cohort 2 data was available for 2017 and 2018. Data was restricted to those schools for which matched data was available for the relevant period. For Cohort 1, this provided a population of 1880 schools for 2016/2017 and 1854 schools for 2016/18. For Cohort 2, this provided a population of 1381 schools for 2017/18.

Aggregated data on the numbers achieving the expected standard was provided by STEM Learning for those schools that did not engage with the Key Stage 2 CPD activity in this period.

Table A1 summarises the calculations. Non-engaged schools saw increases in the percentage of pupils meeting the required standard. Cohort 1 schools saw larger positive increases in this percentage for the equivalent periods (e.g. +1.6% versus +0.8% in non-engaged schools). Cohort 2 schools saw an increase in the percentage meeting the required standard. However, this was lower than the percentage increase in non-engaged schools.

The excess change relative to the non-engaged schools was multiplied by the cohort population of pupils for the relevant year to calculate the number of pupils impacted by the CPD. The estimated total number of pupils who met the required standard in Key Stage 2 science as a result of the CPD provision was 1112.

Table A1: Percentage change across 2016 to 2018 of schools engaged in KS2 Science CPD and pupils impacted

Measure	Period	School Group		
		Non-engaged	Cohort 1	Cohort 2
Change in percentage of pupils meeting the required standard for science at Key Stage 2	2016 to 2017	+0.8%	+1.6%	
	2016 to 2018	+1.7%	+2.4%	
	2017 to 2018	+0.9%		+0.7%
Excess change relative to non-engaged schools	2016 to 2017		+0.8%	
	2016 to 2018		+0.7%	
	2017 to 2018			-0.2%
Estimated number of pupils impacted	2017		618	
	2018		597	-103

Key Stage 4

Data was available on three cohorts of schools where teachers had undertaken CPD relevant to Key Stage 4. Cohort 1 consisted of 1416 schools where a teacher(s) had completed the training in 2015/16. Cohort 2 consisted of a further 468 schools where training had been completed in 2016/17 and Cohort 3 consisted of a further 378 schools where training had been completed in 2017/18.

The outcome measure at Key Stage 4 was the percentage of the Key Stage 4 cohort who achieved the EBacc 2 Sciences measure (grades 4+ in at least 2 science GCSEs). For each school, data was available on the percentage achieving this standard in the year of intervention and subsequent year(s) up until 2019. Data was restricted to those schools for which matched data was available for the relevant period[9].

Aggregated data on the numbers achieving the standard was provided by STEM Learning for those schools that did not engage with the Key Stage 4 CPD activity in this period.

Table A2 summarises the calculations. As with Key Stage 2, it can be seen that while most of the data showed that the CPD led to a positive excess performance relative to non-engaged schools, for Cohorts 2 and 3 change in performance in the first year after the intervention was slightly behind the change in non-engaged schools.

[9] This was particularly relevant in this context as a significant number of schools, in particular in Cohort 1, appeared to drop out of the sample. It is understood that this is likely to be the result of schools switching to be academies and hence the original schools are deemed as having closed.

Table A2: Percentage change across 2016 to 2019 of schools engaged in KS4 Science CPD and pupils impacted

Measure	Period	School Group			
		Non-engaged	Cohort 1	Cohort 2	Cohort 3
Change in percentage of pupils meeting the EBacc 2 Sciences standard	2016 to 2017	-2.4%	-2.2%		
	2016 to 2018	+0.2%	+0.4%		
	2016 to 2019	+0.5%	+1.1%		
	2017 to 2018	+2.6%		+2.5%	
	2017 to 2019	+2.9%		+5.1%	
	2018 to 2019	+0.3%			-0.5%
Excess change relative to non-engaged schools	2016 to 2017		+0.2%		
	2016 to 2018		+0.2%		
	2016 to 2019		+0.6%		
	2017 to 2018			-0.1%	
	2017 to 2019			+2.2%	
	2018 to 2019				-0.8%
Estimated number of pupils impacted	2017		416		
	2018		374	-64	
	2019		1395	1527	-472

As with the previous Key Stages, the excess change relative to the non-engaged schools was multiplied by the cohort population of pupils for the relevant year to calculate the number of pupils impacted by the CPD. The estimated total number of pupils who met the EBacc 2 Sciences standard as a result of the CPD provision was 3175.

Triple Science

Data was available on three cohorts of schools where teachers had undertaken CPD relevant to Key Stage 3. Cohorts 1 and 2 consisted of 135 schools where a teacher(s) had completed the training in 2016 to 2018. In Cohort 3 they consisted of a further 120 schools where training had been completed in 2018 to 2020.

Intervention at Key Stage 3 was specifically intended to increase the number of pupils entered for Triple Science at GCSE (i.e., taking separate GCSEs in Physics, Chemistry and Biology). As such, the outcome measure of interest was taken as the percentage of the cohort who were subsequently entered for Triple Science at GCSE. For each school, data was available on the percentage who were entered for Triple Science at GCSE at the start and end of the 2-year intervention period[10].

[10] Due to Covid, school level data on exam entries has not been published. As such, self-reported data from schools on Triple Science entries for engaged schools was provided by STEM Learning.

For Cohorts 1 and 2 similar data was available for non-engaged schools to provide a counterfactual. For Cohort 3, the school level exam entry data for 2020 was not available due to the impact of Covid-19. Instead, aggregated data on exam entries data was used to calculate a counterfactual[11]. Table A3 summarises the calculations.

Table A3: Percentage change across 2016 to 2020 of schools engaged in Triple Science CPD and pupils impacted

Measure	Period	School Group		
		Non-engaged	Cohorts 1+2	Cohort 3
Change in percentage of pupils taking Triple Science at GCSE	2016 to 2018	+3.8%	+14.1%	
	2018 to 2020	-1.2%		+4.3%
Excess change relative to non-engaged schools	2016 to 2018		+10.3%	
	2017 to 2018			+5.5%
Estimated number of pupils impacted	2018		2257	
	2020			1273

The excess change relative to the non-engaged schools was multiplied by the cohort population of pupils for the relevant year, to calculate the number of pupils impacted by the CPD. The estimated total number of pupils who took Triple Science following CPD interventions at Key Stage 3 was 3530.

An alternative calculation was undertaken using those schools that engaged with the Triple Science programme but only at Key Stage 4. These schools are more similar to the cohort of schools that engaged at Key Stage 3, with relatively low take up of Triple Science at the start of the programme. As choices around which GCSEs to enter, are generally made at the end of the Key Stage 3, it may be considered that the intervention at Key Stage 4 did not impact on the uptake of Triple Science in this alternative cohort[12]. Using this alternative approach, a lower figure 1319 pupils were estimated to have been impacted.

[11] Data drawn from https://www.gov.uk/government/statistics/provisional-entries-for-gcse-as-and-a-level-summer-2020-exam-series/provisional-entries-for-gcse-as-and-a-level-summer-2020-exam-series#gcse-entries and https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803906/Provisional_entries_for_GCSE__AS_and_A_level_summer_2019_exam_series.pdf with Triple Science entries represented by the minimum number of entries across the three relevant subjects and the overall cohort proxied by the average of the numbers entered for Maths and English Language.

[12] In reality, there is a substantial rise seen in take up of Triple Science in this cohort, suggesting that interventions that are related to Key Stage 4 may still influence teaching quality or pupil engagement with science at Key Stage 3 and hence lead to stronger uptake. This would mean that the figure estimated using this alternative approach is an underestimate of the true number of pupils affected.

Key Stage 5 Progression

Data was available for a cohort of 2108 schools where teachers had undertaken CPD relevant to Key Stage 4 between 2014 and 2016. The outcome measure of interest for this group was the percentage of children taking at least one STEM A-level at Key Stage 5. Data was available for both engaged and non-engaged schools for 2016, 2017 and 2018 and 2019. Table A4 summarises the calculations.

Table A4: Percentage change across 2016 to 2019 of schools engaged in KS4 CPD and pupils impacted

Measure	Period	School Group	
		Non-engaged	Cohort 1
Change in percentage of pupils taking at least 1 STEM A-level	2016 to 2017	+0.9%	+1.2%
	2016 to 2018	+2.3%	+2.7%
	2016 to 2019	+3.4%	+3.9%
Excess change relative to non-engaged schools	2016 to 2017		+0.3%
	2016 to 2018		+0.4%
	2016 to 2019		+0.5%
Estimated number of pupils impacted	2017		1220
	2018		1461
	2019		1878

The estimated total number of pupils who met the required standard in Key Stage 2 science as a result of the CPD provision was, therefore, 4560.

Annex B: Regression Outputs for Wellbeing Analysis

Variable	Coefficient	Robust standard error
Teacher	0.0538**	(-0.0255)
Hours	-0.00261***	(-0.000771)
Age	-0.0623***	(-0.0044)
Age squared	0.000670***	(-0.000053)
Male	-0.0271	(-0.0166)
Ethnicity - Irish (white)	-0.119	(-0.076)
Ethnicity - Gypsy or Irish Traveller (white)	-0.731***	(-0.177)
Ethnicity - any other white background (white)	0.0551	(-0.047)
Ethnicity - white and black Caribbean (mixed)	-0.188	(-0.116)
Ethnicity - white and black African (mixed)	-0.624***	(-0.187)
Ethnicity - white and Asian (mixed)	-0.180*	(0.107)
Ethnicity - any other mixed background (mixed)	-0.740***	(-0.207)
Ethnicity - Indian (Asian or Asian British)	0.00398	(-0.0459)
Ethnicity - Pakistani (Asian or Asian British)	0.0905	(-0.0577)
Ethnicity - Bangladeshi (Asian or Asian British)	0.05	(-0.0774)
Ethnicity - Chinese (Asian or Asian British)	-0.12	(-0.0808)
Ethnicity - any other Asian background (Asian or Asian British)	0.0541	(-0.0911)
Ethnicity - Caribbean (black or black British)	-0.261***	(-0.0683)
Ethnicity - African (black or black British)	0.0801	(-0.0584)
Ethnicity - any other black background (black or black British)	0.168	(-0.22)
Ethnicity - Arab (other ethnic group)	-0.0667	(-0.187)
Ethnicity - any other ethnic group (other ethnic group)	0.0232	(-0.154)
Marital status	-0.0938***	(-0.00565)
Number of own children in household	0.0336***	(-0.0102)
A level or GCSE qualification	-0.0619	(-0.0703)
Other Qualification	-0.106	(-0.0821)
Degree or Higher Degree	-0.00949	(-0.0707)
Missing/unknown	0.200*	(-0.115)
Log equivalised household income (+1 correction yearly)	0.300***	(-0.0171)
SF-12 Physical Component Summary (PCS)	0.0151***	(-0.00112)
Urban or rural area	-0.000631	(-0.0188)
Government office region - North West	0.0578	(-0.0444)
Government office region - Yorkshire and the Humber	0.0616	(-0.0456)
Government office region - East Midlands	0.0484	(-0.0456)
Government office region - West Midlands	0.00179	(-0.0462)
Government office region - East of England	0.0453	(-0.0446)
Government office region - London	-0.0691	(-0.0479)
Government office region - South East	0.00042	(-0.0429)
Government office region - South West	0.0306	(-0.0451)
Government office region - Wales	-0.0315	(-0.0484)
Government office region - Scotland	0.0231	(-0.0466)
Government office region - Northern Ireland	0.381***	(-0.0528)
Constant	2.918***	(-0.207)

Observations	44228	
R-squared	0.0471	

Note: Sampling weights by wave are utilised and the specification includes wave dummy variables.
** denotes significant at 10% level, ** denotes significant at 5% level and *** denotes significant at 1%.*

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