

# **The Impact of a Science Qualification Emphasising Scientific Literacy on Post-compulsory Science Participation: An analysis using national data**

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In 2006 in England an innovative suite of science qualifications for 14–16-year-olds called Twenty-First Century Science (21CS) was introduced. These qualifications have a strong focus on developing scientific literacy in all students whilst simultaneously providing preparation for the study of post-compulsory science for a smaller proportion of students. Claims have been made that such an innovative qualification would impact significantly on post-compulsory science participation—either positively or negatively. Using national data in England to track one cohort of students over 2007–2011, this study compares progression rates to post-compulsory science qualifications in England between 21CS qualifications and more traditional non-21CS qualifications. Methods employed include simple comparisons of proportions progressing from each qualification, and more complex multi-level modelling approaches that take account of both students clustered in schools, and potentially differing demographic and achievement profiles of students in the 2 groups of qualifications. A simple descriptive analysis shows that there is very little difference in overall progression rates between the 2 types of 14–16 science qualification. More fine-grained descriptive analyses show that there are some important differences, based in particular on the interaction between the amount of science studied at ages 14–16, and on the post-16 science qualification chosen (biology, chemistry or physics). Furthermore, sophisticated modelling analyses indicate a consistently negative small to moderate impact on progression from the 21CS qualification. Overall, our findings suggest that the emphasis on scientific literacy within the 21CS qualification suite has not had a major impact on the uptake of post-compulsory science qualifications.

**Keywords:** *Scientific Literacy; Curriculum Reform; Post-compulsory Participation*

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## Introduction

There are many distinct aims ascribed to the compulsory school science curriculum by a broad range of stakeholders (Fensham, 2009; Ryder & Banner, 2011). These aims include promoting the goals of scientific literacy for all students (Roberts & Bybee, 2014, Chapter 7), preparation for post-compulsory science qualifications (The Royal Society, 2008), increasing the future employability of students and increasing social mobility (DfES, 2005). This multiplicity of aims has been captured neatly by Roberts's seven 'curriculum emphases': (1) everyday coping; (2) structure of science; (3) science, technology, decisions; (4) scientific skill development; (5) correct explanations; (6) self as explainer and (7) solid foundation (Roberts, 1988). For each emphasis, Roberts identifies distinct views of science, learner, teacher and society. Thus, each emphasis is likely to result in school science with distinct content, pedagogy and assessment. For example, it has been argued that a school science curriculum that focuses on the goal of scientific literacy needs to emphasise a small number of 'big ideas' in science (Harlen, 2010) alongside teaching and learning about the nature of science and social issues with a science dimension (Ryder, 2001).

Given the multiplicity of aims ascribed to school science education, a key question is the extent to which increasing the emphasis of one aim within the curriculum might result in a curriculum that is less effective at achieving other aims. Two of these aims, in particular, have a strong presence within curriculum policy pronouncements: scientific literacy for all students, and preparation for future science study for a minority of students. This paper focuses on these two aims and the potential tension between them. There has been concern expressed that qualifications emphasising scientific literacy would have a negative impact on enrolment into more academically focussed post-compulsory science qualifications (Henderson, Alex, & Blair, 2006; Perks, Gilland, Institute of Ideas, & Pfizer Inc, 2006). In contrast, a study using in-school, teacher-reported longitudinal data, presents striking evidence of a significant *enhancement* in post-compulsory science qualification participation, above the national trend, as a result of such a qualification (Millar, 2010). Our study uses national data sets in England to examine the impact of a compulsory school science curriculum with a strong emphasis on the goal of scientific literacy on the number of students progressing to more academically focussed science qualifications in post-compulsory schooling.

### *The Significance of Curriculum Content for Future Post-compulsory Qualification 'Choices'*

There has been considerable research examining the range of influences on students' subject choices for post-compulsory schooling. Recent reviews of this literature include Tripney et al. (2010), Wynarczyk and Hale (2009) and Boe, Henriksen, Lyons, and Schreiner (2011). An influential model of student choice has been developed by Eccles (2009). Key aspects of this model can be summarised through the following six questions that are likely to be guiding students as they make choices (Boe et al., 2011):

- Q1. Am I good enough at the subject?
- Q2. Am I really interested in the subject?
- Q3. Do I enjoy working with the subject?
- Q4. Does it match who I am? (student identity)
- Q5. Will it help me to achieve my desired future (career)?
- Q6. How much time and effort will be involved in studying the subject?

The precise relative weighting of the importance of each of these factors will, of course, vary from student to student depending upon their individual personality, values and social context.

School-related factors, such as subject attainment, curriculum content, teaching activities and teacher relationships are likely to be significant influences within Q1 to Q3. However, particularly for Q4 and Q5, students are also likely to be influenced by factors from outside of school (Ball, Macrae, & Maguire, 2000; Foskett & Hemsley-Brown, 2001; Foskett, Dyke, & Maringe, 2008). For example, many students will receive significant parental guidance on potential future careers in addition to any professional advice provided in school. Also, issues of student identity and career aspirations are known to be heavily influenced by peer friendship groups (Archer et al., 2010; Boe, 2012).

Several studies show that some students form choices of future study within early secondary schooling or even within primary schooling (Maltese & Tai, 2010, 2011; Tai, Liu, Maltese, & Fan, 2006). Whilst students are not making qualification choice decisions at these early ages, these studies suggest that dispositions, or attitudes, towards school subjects are formed relatively early. These dispositions (positive or negative) set at an early age and then frame future qualification choices. However, other studies have shown that whilst some young people do make early commitments to not following science subjects in the future, many students are uncertain or make final commitments only in late secondary schooling (Maltese, Melki, & Wiebke, 2014). Despite the apparent rationality underlying Q1 to Q6, many studies have shown that students' subject choices tend not to be rational decisions made at a particular point in time. Rather, 'choice' is more appropriately viewed as a dynamic process that takes place, and shifts, over time. For example, in a longitudinal study of the process of choice formation for 72 students in England, only one-fifth of those students eventually following post-compulsory science qualifications had clearly expressed that 'directed trajectory' intention at ages 13–14 (Cleaves, 2005).

Our study explores the impact of school science curricula for 14–16-year-olds on subsequent qualification choices. The literature reviewed demonstrates two relevant issues. Firstly, that science curriculum content (and associated pedagogy and assessment) can be an important influence on future qualification choices, but also that this is one factor amongst many others, several of which extend beyond science lessons, and indeed schooling. Secondly, that whilst early school experiences are very important, school science experiences within the 14–16 years age range can also influence the ongoing process of future qualification choices.

*Research Context*

This study is set in the context of differing qualifications available to 14–16-year-olds in England. The study of science is compulsory in England until the age of 16, but thereafter becomes optional. In the final two years of compulsory science study, students typically follow either a dual award (DA) or a triple award (TA) route. DA takes nominally 20% of curriculum time and includes study of all three main sciences, but which is recognised as equivalent to qualifications in two subjects. TA takes nominally 30% of curriculum time (although in practice often less) and comprises a separate qualification in each of physics, chemistry and biology. It is usually expected that students following the TA route will be high attaining in science. However, high attaining students from both routes can progress to post-compulsory science qualifications.

Our comparative analysis capitalises on the existence in England of a distinct suite of qualifications, taken by a significant proportion of students, that emphasises the goal of scientific literacy: Twenty-First Century Science (21CS; Millar, 2006). These are available alongside other qualifications available in England that tend to place more emphasis on traditional academic content. Both DA and TA are available in 21CS and non-21CS versions. The 21CS curriculum project is a significant and sustained attempt to provide a system-wide qualification suite that addresses the ‘dual goals’ of scientific literacy (for all students) and preparation for future science study (for a minority of students). One of the distinctive features of the 21CS suite of qualifications is the focus on ‘ideas about science’. Other elements within the 21CS suite focus more on traditional science knowledge and understanding. ‘Ideas about science’ in the 21CS curriculum includes consideration of science issues with an ethical and social dimension, for example, health issues around air quality, greener energy sources. This could provide the potential for more discussion within the science classroom compared to more traditional approaches, and more opportunities for students to voice their opinions and hear those of other students (Morris, 2013; Sadler, Amirshokohi, Kazempour, & Allspaw, 2006). Looking back to the student post-compulsory choice model discussed earlier (Eccles, 2009), we note that the 21CS curriculum is intended to make students more likely to answer in the affirmative for at least the first five of the six listed questions making up the model (Millar, 2006). Furthermore, whilst a simplistic approach might characterise the differences between 21CS and non-21CS courses as essentially based on ‘content’, a more nuanced view would be that the new courses require different pedagogic approaches, and, perhaps, a broader range of modes of assessment, including for example, more discursive elements.

The wider literature shows that factors linked to positive impacts on students’ attitudes towards science and ultimately choice of science qualifications include a more diverse school science curriculum, an emphasis on a less teacher-led pedagogy, and more space for the ‘students’ voice’ (Bennett, Lubben, & Hampden-Thompson, 2013). For example, Ametller and Ryder (2014) examined the extent to which an emphasis on teaching about socio-scientific issues and the nature of science had encouraged students to choose science qualifications within post-compulsory schooling. On the basis of self-reporting of impact, the inclusion of teaching and learning about socio-scientific issues

within the school science curriculum (such as the potential dangers of mobile phone masts, ethical issues related to genetic testing, and climate change) had a positive impact on encouraging these students to choose, or consider choosing, science qualifications beyond post-compulsory education. The evidence suggests that the distinctive curriculum focus within 21CS on ‘ideas about science’ might result in a positive 21CS effect on post-compulsory science participation.

We compare post-compulsory participation of students taking 21CS qualifications with those taking a range of other available qualifications (i.e. non-21CS). All qualifications (21CS and non-21CS) are, however, required to follow the National Curriculum for Science in England,<sup>1</sup> and the associated awarding body criteria. Analysis of qualification content shows that the 21CS suite has far stronger emphasis on the goals of scientific literacy (21st Century Science Project Team, 2003). Although there are modules on socio-scientific issues and the nature of science within many of the non-21CS qualifications, as a whole they reflect a much more academic focus than 21CS; emphasising in Robert’s terminology mentioned earlier: scientific skill development, *correct explanations* and *solid foundation* over *structure of science*, and *science*, *technology*, and *decisions* (Roberts, 1988).

## Data and Methods of Analysis

Student-level data on all students within state-funded schools and 16–18 colleges is held in England in the National Pupil Database (NPD).<sup>2</sup> These data include individual attainment grades/scores in nationally recognised assessments at ages 11, 14, 16 and 18 as well as student characteristics, such as gender, ethnicity and measures of, or proxies for, socio-economic status, and include approximately 92% of all children of school age in England (Ryan & Sibiet, 2010). The remaining 8% or so are in privately funded schools and are not included in this research since student characteristics are not available for these students. Under certain conditions related to guarantees of anonymity for students and schools, NPD data are made freely available to researchers.

In this study, we use the NPD to track a single cohort of students from the age of 14 to the age of 18 in order to compare progression rates to post-compulsory science between students who followed 21CS qualifications at ages 14–16 and students following other science qualifications over this period. When we refer in this paper to progression to a particular post-16 qualification, this is synonymous with qualification completion—in other words, sitting the final examination(s) and being awarded a grade (including fail grades). Table 1 summarises student options in science across the age range 14–18 that are the focus of this paper.

The majority (~60%) of students studying science at 14–16 are studying either DA or TA and these are the usual pathways into the study of science post-16. We do not consider other science qualifications at 14–16 in this paper. Similarly, whilst there are other science options available at 16–18, we do not consider these in this work since we have decided to focus only on the most popular post-16 qualifications, biology, chemistry and physics. For more details on these and other science qualifications in England at ages 14–18, see Homer, Ryder, and Donnelly (2013).

Table 1. Main science options at 14–16 and 16–18 in England

14–16 main science qualifications <sup>a</sup> (science is compulsory)		16–18 main science qualifications <sup>b</sup> (science is not compulsory)	
Students do either 2 or 3 qualifications in science These are usually referred to Dual award (DA) and Triple award (TA) respectively. Both of these options cover biology, chemistry and physics in equal proportions	There is a 21CS version and a non-21CS version of each of these two options	Biology	Students can do 0, 1, 2 or all three of these separate qualifications
		Chemistry	
		Physics	

<sup>a</sup>Formally, these are General Certificate of Secondary Education (GCSEs).

<sup>b</sup>Formally, these are General Certificate of Education Advanced Level (A-levels).

Our main aim is to compare the progression rates from 21CS and non-21CS qualifications into post-16 sciences. In exploring these differences, we have found that the results for TA qualifications are quite distinct from those of DA qualification. Similarly, we shall show that there are important differences in results when comparing between the three separate post-compulsory sciences given in Table 1. Hence, our main analysis comprises six comparisons of progression: within DA, one for each of the three post-compulsory sciences, and similarly within TA.

For each of the six pathways, we compare ‘raw’ progression rates between 21CS students and non-21CS students (i.e. the proportion from the full cohort progressing and completing the qualification). We also adjust for different student profiles by modelling progression to each post-16 qualification using multi-level logistic regression with 2 levels, student (level 1) and 14–16 school (level 2) (Goldstein, 1995). We include a range of co-variables in these models, including science attainment at 16, attainment in science, maths and English at 14, gender and measures of socio-economic status (see Table A1 for full details). The inclusion of these allows for a more accurate estimate of the independent 21CS ‘effect’ on progression rates. We acknowledge, however, that as researchers we have not manipulated student qualification choice at ages 14–16 as we would have in a controlled experiment—in the language of experimental design, this study is observational rather than a randomised experiment. Therefore, causation cannot be directly inferred from our analysis (Shadish, Cook, & Campbell, 2001). In other words, we cannot be completely sure that our estimates of the ‘impact’ of 21CS on progression are not due to other unmeasured confounding characteristics that differ across the two groups being compared (21CS and non-21CS).

## Research Findings

Table 2 shows a summary of the number of students studying the main science qualification options at ages 14–16 over 2007–2009.

The total cohort is of the order of 600,000 with over half (52%) studying DA and 11% TA with the remainder (37%) taking other science qualifications that are not generally intended for students considering the study of academic science qualifications post-16. The percentage of students taking a 21CS version within each 14–16 qualification is quite uniform at just over 20% in each case.

*Descriptive Analyses*

If we simply compare overall progression rates to at least one post-16 science qualification (A-level biology, physics or chemistry) from 21CS and non-21CS qualifications (TA and DA combined), we find that these are very similar at 15.66% and 15.67% of the respective cohorts. In other words, there is almost no overall difference in progression rates when looking at the cohort as a whole. However, we recognise that it is important to use more nuanced comparisons including type of 14–16 qualification (TA and DA) and the three different post-16 options.

We summarise these detailed progression analyses graphically in [Figure 1](#) (for DA students) and [Figure 2](#) (TA)—complete figures are given in [Table A3](#). The error bars show 95% confidence intervals for the true percentage progressing.

A chi-square test for difference in percentages progressing from 21CS compared to non-21CS indicates that these differences are all statistically significant at the 5% level with the exception of chemistry from DA. However, the effect size as measured by phi is always small (less than 0.04 in all cases) and the statistical significance is in part an artefact of the large sample sizes in these data (Cohen, 1988).

We see that there are differences between rates of progression, and that within each 14–16 qualification (TA or DA) the 21CS ‘effect’ varies between 16–18 science subject (biology, chemistry or physics). Whilst all of these effects are quite small, they can be characterised as broadly positive from DA, and negative from TA. However, comparing the vertical scales in [Figures 1](#) and [2](#), we see that the most important

Table 2. Summary of numbers studying 14–16 qualifications

14–16 Science qualification	Number studying 21CS qualification	Percentage following 21CS option within 14–16 qualification	Number studying non-21CS qualification	Total
Two qualifications (DA)	63,972	21.00	240,721	304,693
Three qualifications (TA)	13,906	21.02	52,257	66,163
Other science <sup>a</sup>	44,736	20.46	173,880	218,616
Total	122,614	20.80	466,858	589,472

<sup>a</sup>These are generally applied science qualifications taken typically by lower attaining students. These qualifications will not be considered further in this paper.



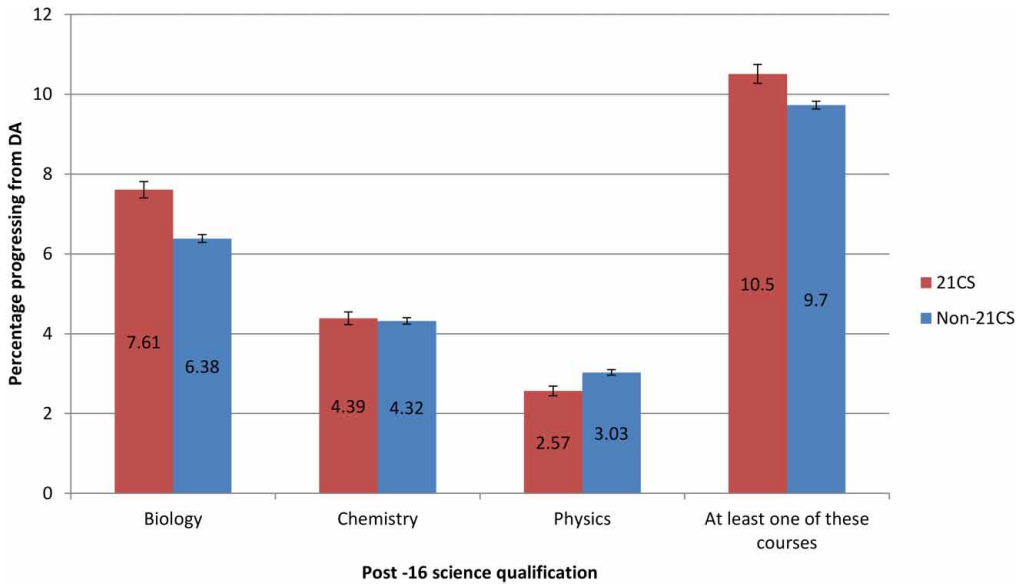


Figure 1. Percentages progressing from DA to post-16 science by 14–16 qualification

factor contributing to differential progression rates into the post-compulsory sciences is not the 21CS/non-21CS option, but TA/DA qualification option, with rates from the former typically 3–6 times higher than from the latter. Of course, students, parents and schools are all involved in deciding which particular qualifications option to take

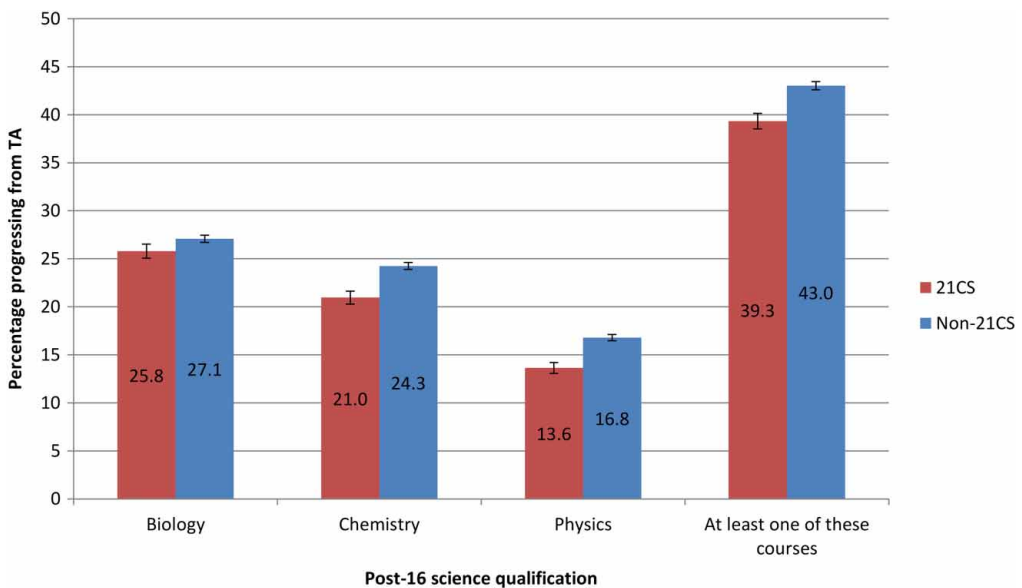


Figure 2. Percentages progressing from TA to post-16 science by 14–16 qualification



at 14–16, so we cannot infer here that the particular qualification choice (TA or DA) is, in a technical sense, causing the difference in participation rates post-16. We know that the profiles of the students in the two types of qualification are different, with TA students generally higher achieving at 16 and hence more likely to progress to post-16 sciences.

Overall, our descriptive analyses show no *large* impact of distinct science curriculum content on future science qualification choices. These findings challenge claims that a curriculum focusing on scientific literacy would have a negative impact on enrolment into post-compulsory science qualifications (Henderson et al., 2006; Perks et al., 2006, pp. 9–33). Furthermore, they also run counter to Millar’s study suggesting that the 21CS qualification suite results in a *significant enhancement* in post-compulsory science qualification participation, above the national trend, within 21CS schools (Millar, 2010).

### *Modelling Participation*

The descriptive analysis does not take account of the possibility that different types of students tend to follow 21CS qualifications compared to those following non-21CS qualifications. For example, there might be systematic differences in prior attainment between the two groups which might then impact on progression rates to post-16 science qualifications. To allow for such differences, we model progression to the post-16 science qualifications and report in Table 3 the more refined 21CS ‘effect’ on progression resulting from this modelling taking into account student characteristics including attainment in science at 14 and 16, maths and English at 14, gender, socio-economic status (see Table A2 for full details). We base our choice of these predictors on existing literature on the key influences on progression to post-compulsory science that are available in national data (Homer et al., 2013). We recognise that any choice of predictors is to an extent a subjective one (the national data set we use contains hundreds of potential predictors). We are, however, confident that the results we present here of the 21CS ‘effect’ from our models would not change substantially in other research-informed models using available national data.

Technically, we use multi-level logistic regression (Goldstein, 1995) with participation (or not) in each of the science A-levels as the dichotomous outcome variable. A positive value of the regression coefficient for the 21CS variable, or equivalently an odds ratio greater than 1 (Field, 2013, p. 767), indicates that the 21CS effect on progression is positive (i.e. students’ progress at a higher rate), having controlled for the other predictors in the model.

We see that there is a consistently negative effect of 21CS on progression once all other factors have been accounted for. For example, the odds of progressing to chemistry from 21CS DA are 0.78 of the odds of progressing from non-21CS DA courses, and the same value coincidentally holds for 21CS TA. Leaving aside biology from DA, these effects are statistically significant at the 5% level but all could be characterised as ‘small’ or, arguably, ‘moderate’ (Chinn, 2000; Cohen, 1988).

Table 3. Summary of model for the 21CS ‘effect’ on participation in science A-levels

14–16 qualification		21CS ‘effect’ on post-16 science participation		
		Biology	Chemistry	Physics
DA	Regression coefficient	−0.06 (NS) <sup>a</sup>	−0.25	−0.35
	Odds ratio	0.95	0.78	0.71
	(95% confidence interval)	(0.88, 1.01)	(0.71, 0.85)	(0.65, 0.77)
TA	Regression coefficient	−0.08	−0.25	−0.26
	Odds ratio	0.92	0.78	0.77
	(95% confidence interval)	(0.86, 0.99)	(0.72, 0.85)	(0.70, 0.84)

<sup>a</sup>NS, not statistically different from 0 at the standard 5% level.

Interpreting the outcomes in Table 3 in terms of a projected impact on actual student numbers requires additional assumptions, for example, that the statistical model is correctly predicting outcomes for individual cases in sufficiently high proportions. We have decided not to include such projections here but broadly estimate that the drop in student progression numbers if all non-21CS students switched to 21CS would be of the order of 15%. We argue that this figure should be treated with caution since in addition to the assumptions about the veracity of the model, it also assumes that we have accurately identified the causal impact on progression of 21CS—as already stated, we cannot be sure that additional confounding factors exist that are not present in the available data sets.

Whilst the focus of this study is very much on the 21CS effect on progression, we feel that comment on other findings from the modelling (detailed in Table A2) is informative.<sup>3</sup> First, the ‘size’ of the 21CS effect is smaller in magnitude than for some other effects—for example, it is smaller than that for gender for progression to both biology and physics (but not for chemistry). Another interesting, if perhaps not unexpected finding, is that higher attainment in English at age 14 is a consistently negative independent predictor of progression to post-16 sciences, whereas science attainment at 14 is positive in this regard. So students who attain highly in English at 14 are less likely to take science post-16 compared to other students similar in all other respects but who attain less highly in English. For mathematics attainment at 14, there are clear differences between the post-16 sciences: in physics and to a lesser extent chemistry, higher attainment in mathematics at 14 is a positive predictor of progression, whereas in biology it is negative. The picture with regard to measures of socio-economic status is mixed, but generally the analysis indicates that students from lower socio-economic groups are more likely to progress to post-16 sciences once other factors have been accounted for. Finally, whether or not the school that the students studies in at ages 14–16 also teaches to age 18 has little effect on progression, the exception being physics from TA where the effect is positive. For more on a detailed study of general influences on post-16 participation in science in a similar context, see Homer et al. (2013).

To summarise our key findings, the basic descriptive analysis shows that there is no difference in overall progression rates between 21CS and non-21CS qualifications.

More fine-grained descriptive analyses show there are some ‘ripples’ within this null result, based in particular on the interaction between TA/DA and on the specific post-16 science qualification (biology, chemistry or physics; [Figures 1 and 2](#)). The more sophisticated modelling analyses that account for differences in student characteristics between the two groups (21CS vs. non-21CS) indicate a consistently negative, but small to moderate, impact on progression from the 21CS qualification ([Table 3](#) or [Table A2](#) for full details).

## Discussion

Our review of previous studies on the factors and processes underpinning student participation in post-compulsory science qualifications suggests that whilst early experiences of science are significant, experiences within the 14–16 age range can also play an important role in choice processes. Furthermore, science curriculum content matters, but is only one of a wide range of factors many of which extend beyond schooling. The review also identifies some evidence that a more diverse school science curriculum that includes student engagement with the nature of science and socio-scientific issues encourages many young people to consider choosing post-compulsory science qualifications. These findings underline the potential for 21CS to have a strong, positive, impact on post-compulsory science participation. Indeed, Millar (2010) suggests that 21CS has a considerable impact on post-compulsory science participation, reporting increases of between 24% and 38% in the reported numbers of students beginning post-compulsory science qualifications, following adoption of the 21CS qualification suite within schools.

However, the descriptive and modelling analyses presented here do not replicate the striking findings reported by Millar (2010). Indeed, more sophisticated modelling analyses indicate a consistently negative impact on progression from the 21CS qualifications. On the other hand, our findings also provide evidence that the concern expressed by some that qualifications such as 21CS would have a large negative impact on enrolment into post-compulsory science qualifications appears unfounded (Henderson et al., 2006; Perks et al., 2006, pp. 9–33). We argue that, from the existing literature, given the multiplicity of factors that impact on student choice, and the undoubted significance of early-middle school year experiences and out-of-school factors, it would have been surprising to have found a nationwide shift on the scale reported by Millar (2010).

Our study provides some confidence that suites of science qualifications such as 21CS, addressing the dual goals of science education, are unlikely to have a large negative impact on post-compulsory science participation. Alongside other work (Ryder & Banner, 2012), we argue that this study shows the feasibility and importance of maintaining a broad and varied curriculum provision in compulsory school science. Such provision enables teachers to match the differing needs of their students, leading to broader positive engagement in science study within compulsory schooling. Indeed, it has been argued that providing curriculum space for courses that emphasise scientific literacy is a benefit in itself, regardless of any impact, positive or negative, this

might have on progression to post-compulsory sciences (UNESCO, 1999; see also Layton, Jenkins, & Donnelly, 1994). If more students have learned more science and/or gained a better scientific understanding of their world through such taking such courses, then this is obviously a positive thing. However, in our study, we have no data on such issues and we would argue that there is an urgent need for more longitudinal studies that investigate the impact of courses that claim to teach scientific literacy on students' long-term engagement with scientific issues, and on any science-related decision-making that they might have to make in later life.

Our modelling analyses do indicate a small to moderate negative impact on post-compulsory science participation. We argue that the scale and nature of such effects needs to be monitored and explored. Estimating the impact of new qualifications on post-compulsory subject choices should be an important part of the piloting and evaluation of their introduction. There is a growing availability to researchers of secondary educational data sets, not just in England but more widely (Smith, 2008a, 2008b), and we would argue strongly that such data should be used more widely to monitor and compare participation and attainment patterns, particularly following important curricula reform. Furthermore, studies that follow more qualitative methodologies are needed if we are to better understand what lies behind any participation effects arising from specific school science curricula. Ideally, such studies would examine in-school practices and how these are experienced by young people over time. Crucially, these studies would also need to attend to broader out-of-classroom, and out-of-school, experiences of young people.

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## **Notes**

1. <https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study>.
2. <http://www.education.gov.uk/researchandstatistics/national-pupil-database>.

3. Recall that any estimated effect is independent of all other effects. In other words, the estimates are interpreted as if all other predictors are controlled for.

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## Appendix

For each of the main 14–16 science qualifications (DA and TA), there are three multi-level random intercept logistic regression models (as per Table 1) predicting participation (1) or not (0) in each of biology, chemistry and physics.

Each of these six (“full”) models uses the same set of predictors as detailed in Table A1.

Table A1. Predictors used in the multi-level logistic regression modelling

Predictor	Type of variable	Further details
21CS	Dichotomous	This is whether or not the student studies 21CS at 14–16 (0 = no, 1 = yes)
Gender (male)	Dichotomous	The reference group (coded 0) is female so the effect in the model is for male (1)
Free school meal (FSM) eligibility	Dichotomous	This is a measure of socio-economic status based on whether the student is eligible and in receipt of free school meals (0 = not eligible, 1 = eligible)
Income deprivation affecting children index (IDACI)	Continuous	This is a second, distinct, measure of socio-economic status on a scale from 0.0 to 1.0 indicating the proportion of children under age 16 in the local area living in low income households. Lower values of this index relate to wealthier areas, and higher values to poorer areas
English attainment at 14	Continuous	This are national test results at 14 in the respective subjects (on a scale from 0 to 8)
Mathematics attainment at 14	Continuous	
Science attainment at 14	Continuous	
Attainment in science at 16	Continuous	This is the mean points score the student achieved in science (on a scale from 0 to 58)
14–16 school teaches up to age 18	Dichotomous	This indicates whether the 14–16 school also provides post-compulsory education up to age 18 (0 = no, 1 = yes)



Table A2. Model estimates (log(odds ratio)) for predicting participation in post-compulsory biology, chemistry and physics

		Fixed parameter estimate (standard error)													Level 2 (school) residual variance estimate (standard error), percentage of residual variance at school level			
		Null model		Simple model (single predictor 21CS)		Full model (multiple predictors—see Table A1 for further details)												
								Measures of socio-economic status		Attainment at 14(KS3 fine level)								
KS4 route	Post-16 qualification	Constant	Constant	21CS	Constant	21CS	Gender (Male)	FSM-eligible	IDACI	English	Maths	Science	Science attainment at 16 (KS4 points)	14–16 school teaches to 18	Null model	Simple model	Full model	
DA	Biology	−2.656 (0.018)	−2.700 (0.020)	0.184 (0.041)	−13.095 (0.111)	−0.056 (0.035)	−0.442 (0.019)	0.065 (0.038)	0.412 (0.065)	−0.260 (0.018)	−0.182 (0.017)	0.661 (0.026)	0.201 (0.002)	0.000 (0.002)	0.754 (0.025), 18.6%	0.750 (0.025), 18.6%	0.327 (0.015), 9.0%	
	Chemistry	−3.100 (0.022)	−3.109 (0.025)	0.040 (0.051)	−16.613 (0.152)	−0.250 (0.044)	0.042 (0.024)	0.264 (0.045)	1.276 (0.079)	−0.532 (0.022)	0.349 (0.023)	0.429 (0.033)	0.24 (0.003)	0.002 (0.002)	1.122 (0.037), 25.4%	1.124 (0.037), 25.5%	0.517 (0.025), 13.6%	
	Physics	−3.545 (0.022)	−3.514 (0.025)	−0.146 (0.052)	−20.617 (0.205)	−0.348 (0.045)	1.806 (0.034)	0.041 (0.061)	0.097 (0.098)	−0.721 (0.026)	1.141 (0.03)	0.574 (0.041)	0.176 (0.003)	0.001 (0.002)	0.972 (0.036), 22.8%	0.956 (0.036), 22.5%	0.315 (0.022), 8.7%	
TA	Biology	−0.997 (0.017)	−0.984 (0.019)	−0.060 (0.041)	−8.451 (0.179)	−0.081 (0.037)	−0.502 (0.023)	−0.016 (0.055)	0.386 (0.083)	−0.24 (0.022)	−0.308 (0.022)	0.504 (0.037)	0.161 (0.003)	0.065 (0.034)	0.3 (0.016), 8.4%	0.299 (0.016), 8.3%	0.170 (0.012), 4.9%	
	Chemistry	−1.157 (0.020)	−1.127 (0.022)	−0.142 (0.047)	−12.876 (0.222)	−0.246 (0.045)	0.021 (0.026)	0.152 (0.061)	0.700 (0.094)	−0.544 (0.024)	0.127 (0.027)	0.404 (0.043)	0.226 (0.003)	−0.026 (0.041)	0.424 (0.021), 11.4%	0.419 (0.021), 11.3%	0.271 (0.018), 7.6%	
	Physics	−1.661 (0.020)	−1.621 (0.022)	−0.191 (0.047)	−17.051 (0.287)	−0.263 (0.047)	1.500 (0.034)	−0.057 (0.080)	−0.047 (0.111)	−0.710 (0.027)	0.920 (0.034)	0.497 (0.053)	0.162 (0.003)	0.242 (0.043)	0.396 (0.019), 10.7%	0.357 (0.021), 9.8%	0.218 (0.018), 6.2%	

Notes: *Sample sizes*—schools, students. DA: null and simple models: 3,065 schools, 304,693 students; full model: 3,017 schools, 281,765 students; TA: null and simple models: 1,662 schools, 66,163 students; full model: 1,607 schools, 60,170 students. Student numbers are smaller than the corresponding figures in Table 2 due to a small amount of missing data on some predictors. Unshaded cells indicate coefficients significantly different from 0 at the 5% level, whilst shaded cells indicate non-significant effects.

Table A3. Summary of progression to 16–18 qualifications

14–16 qualification		16–18 qualification	Number progressing to 16–18 qualification within group	Percentage progressing to 16–18 qualification within group	Chi-square test of difference in percentages progressing: <i>p</i> -value and effect size (phi)	Total number of students within group
DA	21CS	Biology	4,866	7.61	< 0.001	63,972
	Non-21CS		15,369	6.38	0.020	240,721
	21CS	Chemistry	2,807	4.39	0.460	63,972
	Non-21CS		10,400	4.32	0.001	240,721
	21CS	Physics	1,641	2.57	< 0.001	63,972
	Non-21CS		7,290	3.03	0.011	240,721
	21CS	At least one of these	6,724	10.5	< 0.001	23,420
	Non-21CS	qualifications	23,420	9.7	0.011	240,721
TA	21CS	Biology	3,587	25.8	< 0.001	13,906
	Non-21CS		14,152	27.1	0.012	52,257
	21CS	Chemistry	2,915	21.0	< 0.001	13,906
	Non-21CS		12,675	24.3	0.032	52,257
	21CS	Physics	1,897	13.6	< 0.001	13,906
	Non-21CS		8,780	16.8	0.035	52,257
	21CS	At least one of these	5,471	39.3	< 0.001	13,906
	Non-21CS	qualifications	22,485	43.0	0.030	52,257

For completeness, in addition to the full model, we also report results for the null model (where no predictors are included) and the ‘simple’ model which includes 21CS as sole predictor—see [Table A2](#).

In [Table A2](#), we also report the percentage of residual variance at the school level.

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