Measuring the impact of GCSE Twenty First Century Science on progression to post-compulsory science courses

Matt Homer and Jim Ryder
Centre for Studies in Science and Mathematics Education
School of Education
University of Leeds

Contents

The Nuffield Foundation is an endowed charitable trust that aims to improve social well-being in the widest sense. It funds research and innovation in education and social policy and also works to build capacity in education, science and social science research. The Nuffield Foundation has funded this project, but the views expressed are those of the authors and not necessarily those of the Foundation. More information is available at www.nuffieldfoundation.org.

The Nuffield Foundation, 28 Bedford Square, London WC1B 3JS

Foreword

This report presents the findings from a detailed analysis of the relationship between participation in *Twenty First Century Science* (21CS), a suite of GCSE courses, and student progression to science A levels.

Twenty First Century Science aims to provide scientific literacy for all students, as well as solid preparation for further science study for those that will continue to A level. It was developed by the Nuffield Foundation in partnership with the University of York Science Education Group, published by Oxford University Press and awarded by OCR. When it was introduced in 2006, concerns were expressed in some quarters that 21CS would have a negative effect on student progression to A level sciences.

This study shows those fears were unfounded. Commissioned by the Foundation, Dr Matt Homer and Professor Jim Ryder of the University of Leeds examined the impact of 21CS on A level progression using data from 3,000 schools and two cohorts of students. In the first cohort they found slightly higher rates of progression from 21CS but in the second there was no difference in overall progression to post-compulsory science courses between students following 21CS and non-21CS science courses.

They did however identify some small effects within cohorts. For example girls who studied 21CS were slightly more likely to complete A level sciences than those who had studied a different GCSE science course, but for boys, this effect was reversed. And students with Dual Award 21CS were more likely to progress to A level biology than their non-21CS counterparts, but less likely to go on to study physics. It should be emphasised that these differences, whilst statistically significant, were small.

These findings appear to contradict those from an initial survey, published in 2010, which reported a significant increase in the number of students progressing to AS levels in science following the introduction of 21CS. As the authors explain, that initial survey was relatively small, involving 155 schools, and relied on teacher-reports of progression to AS level. The study reported here is much larger, using National Pupil Database (NPD) data from over 3,000 schools. It also uses data from two cohorts, which wasn’t available in the earlier study, and compares A level *completion* data between 21CS and non-21CS groups, rather than comparing progression to AS level for pre- and post-21CS cohorts.

GCSEs are now subject to reform, with first teaching of new science courses currently scheduled for September 2016. The University of York team will be working with OCR and OUP to revise the 21CS suite of courses in response to the new specifications. They remain committed to the original ideals behind 21CS: that science education at Key Stage 4 should be structured in such a way as to serve the needs of, and engage all young people, both those who will go on to further study and those who will not.

Josh Hillman

Josh Hillman
Director of Education

Executive Summary

What is Twenty First Century Science?

Twenty First Century Science (21CS) is a system-wide suite of GCSE courses focusing on the ‘dual goals’ of scientific literacy (for all students) and preparation for future science study (for a minority of students). The suite includes science courses with a strong emphasis on teaching about contemporary socio-scientific issues, often with a strong ethical dimension. Teaching such courses can involve radical and distinctive classroom activities within a science context (e.g. role play and debates). Other courses within the 21CS suite focus more on traditional science knowledge and understanding.

Aim of study

This study examines whether 21CS has an impact on the proportion of students proceeding to post-compulsory science courses (A levels) in England.

Main finding

Our analysis shows that there is no large difference in overall progression to post-compulsory science courses between students following 21CS and non-21CS science courses.

At a finer level of analysis, we find some small ‘ripples’ in this overall message. These are evident when 21CS and non-21CS student cohorts are broken down by: gender; progression to physics, chemistry or biology post-compulsory science courses; and Triple or Dual Award GCSE routes. These more nuanced findings are summarised below.

Overview of detailed findings

1. Any overall effect of 21CS on progression to A level is small. For example, in 2011 (i.e. for the 21CS second cohort), 15.7% of students from 21CS completed at least one A level in biology, chemistry or physics. The corresponding percentage amongst non-21CS students is exactly the same (page 10).
2. Following 21CS courses has a different effect on participation in A level sciences for boys and girls. The impact on boys is negative (**Table 4**), whilst the impact on girls is mostly positive (**Table 5**).
3. Students following Dual Award 21CS courses are more likely to progress to A level biology than are Dual Award non-21CS students (**Tables 2**, **3** and **6**).
4. Students following Triple Award 21CS course are less likely to progress to A level physics than are Triple Award non-21CS students (**Tables 2**, **3** and **6**).

5. There is good and consistent evidence that 21CS students following Dual Award attain more highly at KS4 than do non-21CS students although this effect is strongest in earlier cohorts (**Figure 2**).
6. Once differences in prior attainment and other factors are accounted for, students who followed 21CS courses are less likely to participate in A level sciences compared to non-21CS students. However, the size of these effects is generally small (**Table 7**). By way of exemplification, if, for example, 20% of a particular 'type' of student (e.g. boys with a certain level of attainment and certain socio-economic background…) typically progress from non-21CS to Chemistry A-level, then the modelling suggests that in an equivalent group doing 21CS, the progression rate would be approximately 16%.
7. There are some small but statistically significant differences, some positive and some negative, in attainment at A level (**Table 8**) between 21CS and non-21CS students.
8. Once differences in prior attainment and other factors are accounted for, the value-added effect of 21CS on A level outcomes is generally small and negative across the sciences (**Tables 9** and **10**).

Implications

When the 21CS suite was proposed and piloted there was concern expressed by some that such courses would have a negative impact on enrolment into post-compulsory science courses (Perks et al, 2006 (p9-33); Henderson & Blair, 2006). Our analysis demonstrates that, overall, these concerns have not been realised.

Alongside other work (Ryder & Banner, 2013), our study shows the feasibility 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.

However, monitoring the impact on post compulsory science participation should be an important part of the piloting and evaluation of such courses. The 'ripples' in the overall message that we have identified in this report need to be monitored over time to ensure that the 21CS suite does not lead to unwanted shifts within A-level science participation.

We have drawn upon the available literature to explore potential mechanisms for this enhanced participation, and its differential play across Double Award/Triple Award routes and physics/chemistry/biology disciplines. However, studies that follow more qualitative methodologies are needed if we are to understand what lies behind these 21CS participation effects. Such studies will examine in-school practices and how these are experienced by young people over time. Crucially, these studies will also need to attend to broader out-of-classroom, and out-of-school, experiences of young people.

Introduction

The principal aim of 21CS is to address the dual goals of enhancing the school science experiences of those students who do not pursue post-compulsory science courses whilst also providing an appropriate foundation for further science study (Millar, 2006).[1] This report addresses aspects of the second of these goals: patterns of participation and attainment within post-compulsory science courses (A-levels in Biology, Chemistry and Physics).

A recent study, using in-school, teacher-reported longitudinal data, provides evidence of a significant enhancement in post-compulsory science course participation, above the national trend, within 21CS schools (Millar, 2010). Our analysis uses national datasets (within England) to examine and compare patterns of participation and attainment within post-compulsory science courses for students completing 21CS and non-21CS specifications at KS4.

Since attainment at KS4 to some extent 'drives' progression to courses at KS5, this study also investigates the impact of 21CS on attainment at KS4.

Methods

We used GCSE and A level data available within the National Pupil Database (NPD) as our sole data source. This allowed us to explore patterns of participation and attainment for the entire GCSE 21CS student population within the maintained sector in England and to track progression or otherwise into the A level sciences. We also compare attainment and progression rates for 21CS against non-21CS students.

This study investigates KS4 attainment for the first four 21CS cohorts (beginning in September 2006), and compares this attainment to that of the corresponding non-21CS students. It also investigates A level attainment and participation patterns for the first two 21CS cohorts. An overview of the cohorts included in the study is shown in Table 1.

Cohort	GCSE	A level
1	2006-2008	2008-2010
2	2007-2009	2009-2011
3	2008-2010	
4	2009-2011	

Table 1: KS4 and A level cohorts included in this study

[1] Further information on the course (structure of courses within the suite, and course content and assessment), can be found on 21CS-Nuffield website: http://www.nuffieldfoundation.org/twenty-first-century-science

The NPD, incorporating the Pupil Level Annual School Census dataset (PLASC), includes science attainment data and individual student information (e.g. gender, ethnicity and free school meal eligibility) for all students within maintained schools, sixth form colleges and FE colleges in England. The NPD does not include data for students within the independent school sector.[2]

The NPD provides details of qualifications/grades awarded, i.e. award completion, and so provides no information about students who started KS5 specifications but did not complete them. So when we talk about ‘progression’ to A level sciences we are actually talking about ‘progression and completion’ of these courses. We also use the phrases ‘participation in’ and ‘progression to’ interchangeably.

A small but significant proportion of AS awards are never registered in the NPD due to differing school practice with regard to the ‘cashing in’ of these qualifications. A high proportion of schools, but not all, 'cash-in' AS levels after one year, although it is believed that guidance on this from the DfE to schools is changing. Based on DfE information,[3] we estimate missing AS data to be around 25% in the cohorts we have studied and we have therefore decided not to include any AS level analysis in this final report.

We carried out a range of descriptive and modelling work that informs the overall results provided here, but we have not included all the details in this report. Over the course of the study we have consistently found important differences in the 21CS ‘effect’ on GCSE attainment when comparing between students studying dual award and triple award at KS4. Because of this, we have treated these two potential routes into post-16 sciences separately throughout our analysis, and we treat GCSE Additional Science as our proxy for dual award.

Similarly, the impact of 21CS on progression or otherwise to post-16 sciences varies across the three main science A levels. Again, we therefore treat them separately in our analysis.

In short, at KS4 we compare:

- raw attainment by calculating the difference in the mean grade of 21CS and non-21CS students and then expressing this as a percentage of a grade.

At A level we compare:

- progression rates to A level by expressing the difference in the percentage progressing from 21CS to that of non-21CS as a percentage of the latter.

We also use more complex multilevel modelling techniques to model progression to, and attainment in, A level sciences. These allow control to be made for additional background variables (e.g. gender, socio-economic status and prior attainment) and thereby provide a more accurate estimate of the independent 21CS ‘effect’ on A-level participation and attainment. They also take account of the clustering of students in schools that simpler techniques such as ordinary regression do not.

---

[2] Approximately 13% of students participating in AS/A levels in England and Wales are studying in independent schools and their progression from KS4 is not considered in this report.
[3] Personal communication to the authors.

Our analysis is essentially descriptive (or correlational) in the sense that we cannot necessarily infer from our methods the singular causative effect of 21CS on progression to and attainment in post-16 sciences. It is always possible that other factors that we have not included (or are unmeasured) are also important. However, we have taken care, where appropriate, to include all those factors available in the NPD that are well-known influences on our key outcomes.

Results

KS4 participation

For completeness we give a breakdown in **Figure 1** of the number of students (in thousands) following 21CS courses over the period 2008-2011.

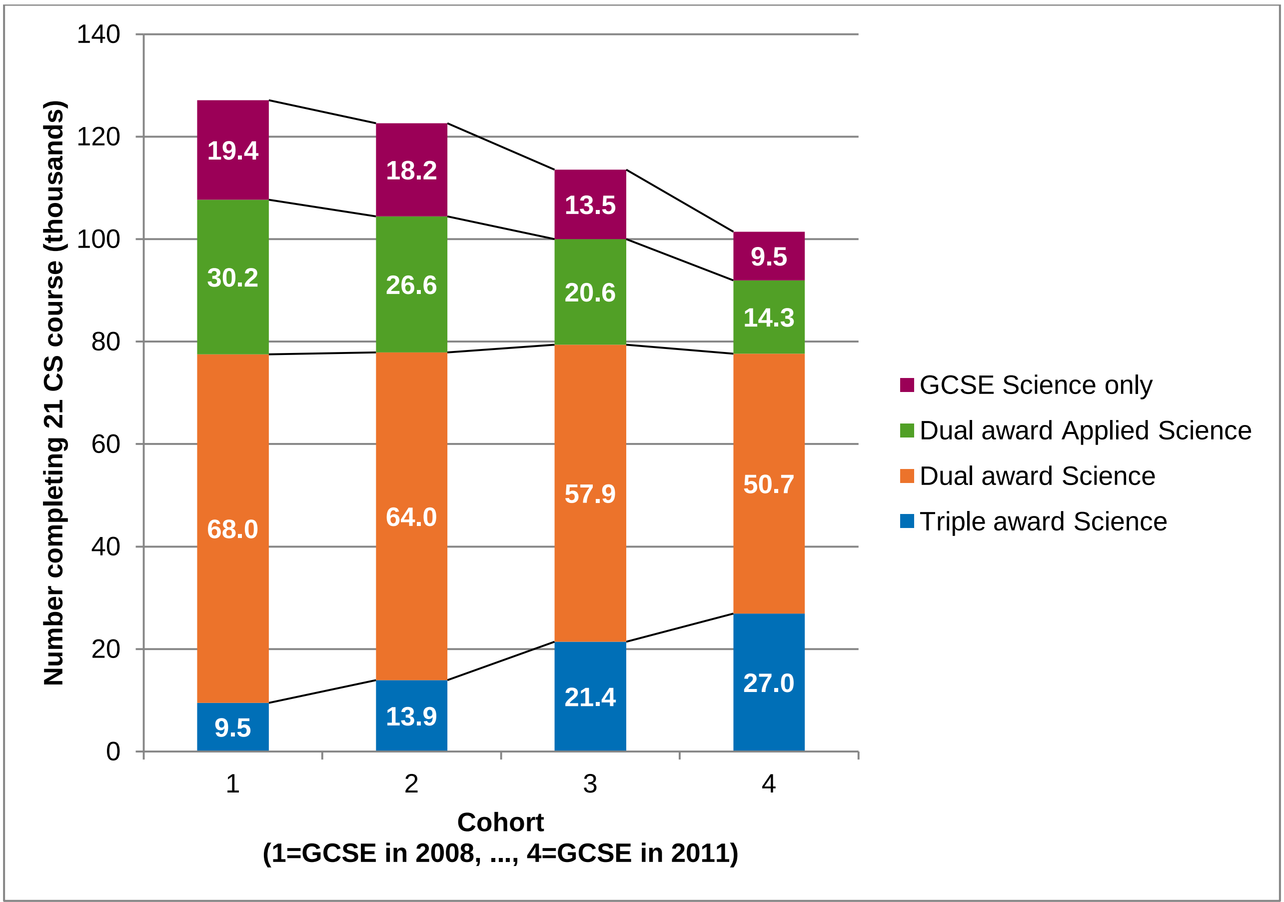

Figure 1: Pattern of participation of 21CS students (2008-2011)

Figure 1 indicates that whilst the absolute number on 21CS courses has declined over the period, the number doing triple award 21CS has increased over that time. This mirrors the overall growth in triple award over that time (Homer et al, 2013a).

KS4 attainment

Figure 2 shows that in the early years following its introduction, 21CS students achieved more highly on average in Dual award (i.e. GCSE Additional) compared to their non-21CS peers. For example, in the first cohort (GCSEs 2006-2008) the mean attainment in GCSE Additional was 32.8% of a grade higher in the 21CS group. However, these differences tail off in the more recent cohorts. This narrowing over time of any apparent 'benefit' due to 21CS might at least in part be attributed to work done by the Awarding Organisations in collaboration with the regulator aligning the standards across GCSE science specifications following the publication of Ofqual's report on the monitoring of these new specifications (Ofqual, 2009).

For the separate science GCSEs, there is a smaller 21CS 'effect' on GCSE attainment, and by Cohort 4 (2010) any differences are quite small.

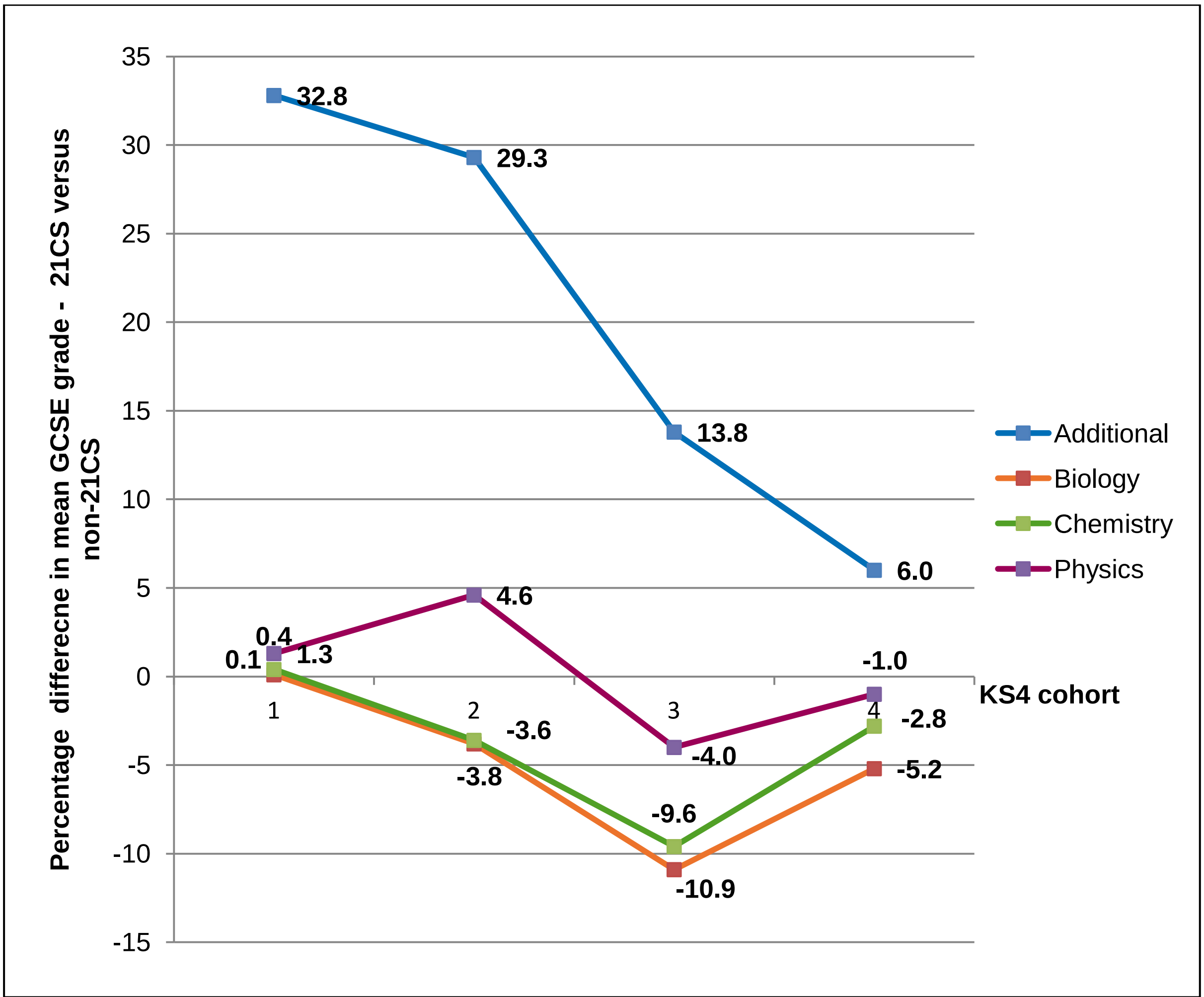

Figure 2: The differences in mean KS4 performance as a percentage of a GCSE grade

A-level participation

The overall effect of 21CS on progression to A level is small. For example in 2011 (i.e. for the 21CS second cohort), 15.7% of students from 21CS completed at least one A level in biology, chemistry or physics. The corresponding percentage amongst non-21CS students is exactly the same, 15.7%.[4]

However, further investigation shows that this un-differentiated analysis masks some variations in participation effects according to the type of KS4 course students had followed, and the science A level in question. A comparison between the proportion of 21CS and non-21CS students completing each of the three science A levels is shown in **Figure 3** (for Dual Award) and **Figure 4** (Triple Award).

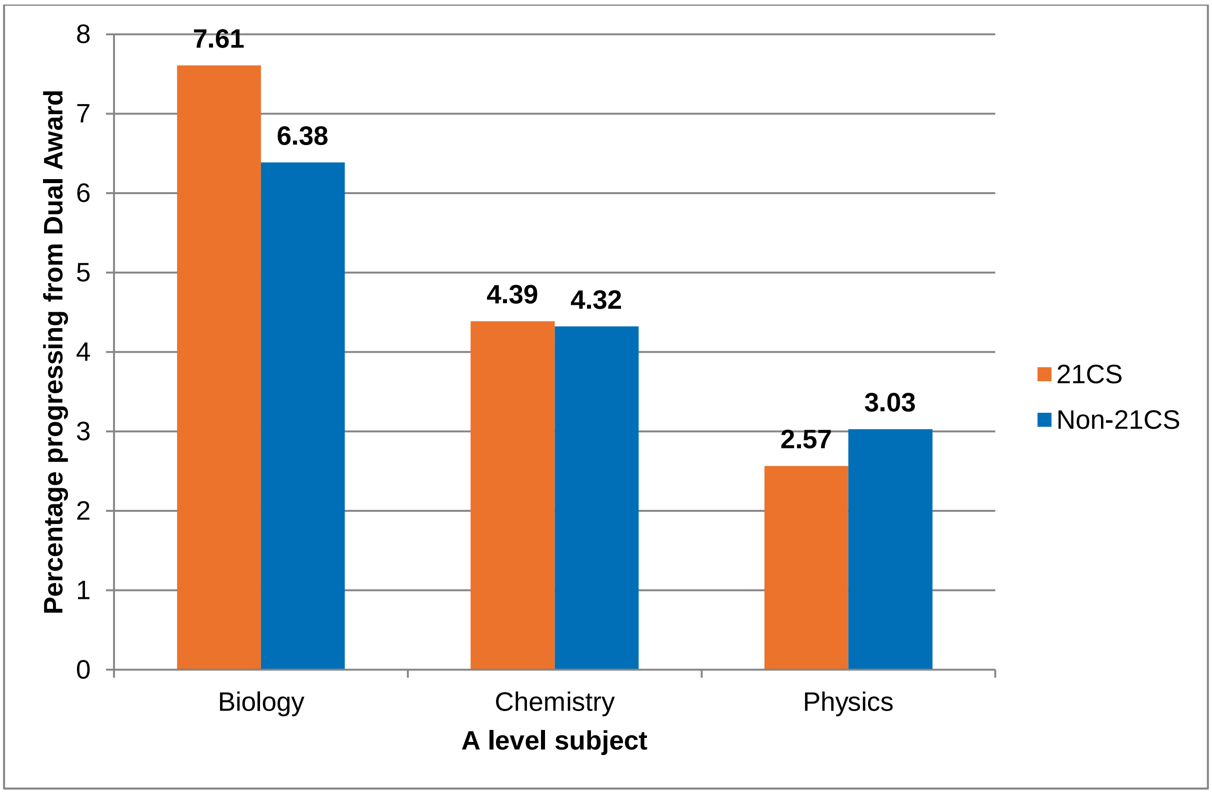

Figure 3: Differences in progression rates from Dual Award across biology, chemistry and physics Alevels (2011)

So **Figure 3** indicates, for example, that amongst Dual Award students following 21CS, 7.61% went on to complete A level biology in 2011. The corresponding percentage for non-21CS students is 6.38%.

[4] The corresponding percentages in the first cohort were 12.8% (21CS) and 12.2% non-21CS), implying a 5.2% higher progression rate from 21CS compared to non-21CS (100 × (12.8-12.2) / 12.2)..

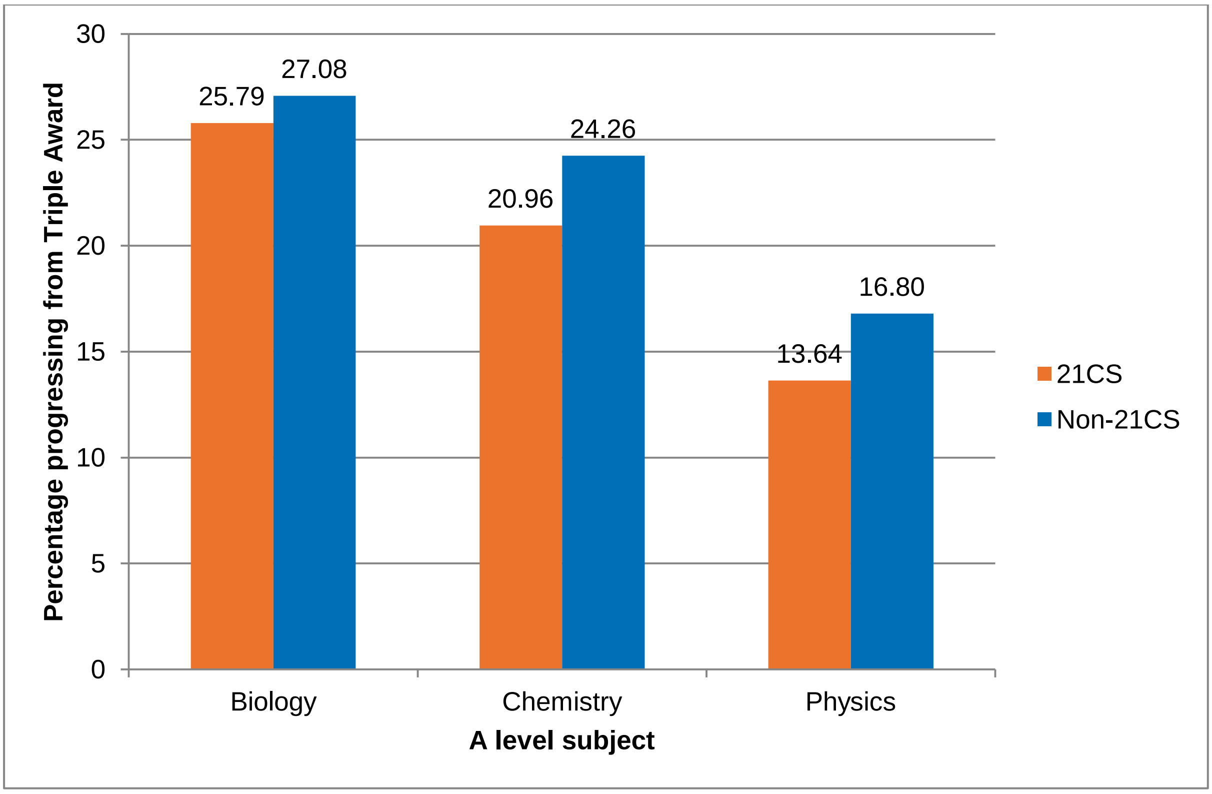

Figure 4: Differences in progression rates from Triple Award across biology, chemistry and physics A-levels (2011)

Figure 4 indicates that the amongst Triple Award students, the percentage progressing from 21CS is lower across all three A levels in comparison to non-21CS students.

In **Table 2**, we summarise the data in **Figure 3** and **Figure 4** by calculating the difference between the percentage progressing from 21CS and non-21CS expressed as a percentage of the latter. Green shading in each table indicates a positive difference in participation rates in favour of students who followed a 21CS specification at KS4. In later tables (8-10) any highlighted differences will be for A-level attainment.

Cohort 2		**Difference in A-level participation rates**		
		Biology	**Chemistry**	**Physics**
A-levels in 2011	**Triple Award**	-4.8	-13.6	-18.8
	Dual Award	+19.1[5]	+1.6	-15.3

Table 2: Summary of 21CS participation effects (percentage) across TA/DA routes and biology, chemistry and physics A-levels (2011)

Table 2 indicates that the subject showing the largest 21CS 'effect' (i.e. the difference between 21CS and non-21CS students – we will use this shorthand throughout) amongst

5 For example, 100 ×(7.61-6.38)/6.38 = 19.1

Dual Award students is biology – the progression rate from 21CS is 19.1% higher than it is from non-21CS courses. Applying this higher progression rate to the full Dual Award cohort of approximately 300,000 students would have the effect of increasing from 20,000 to 23,000 the number of students studying A level biology from this KS4 route.

By contrast, **Table 2** also shows that students following 21CS Triple Award specifications are less likely across the board to progress to A levels in science compared to their non-21CS peers.

The figures corresponding to **Table 2**, but for the first cohort (A-levels in 2010), are shown in **Table 3**:

Cohort 1		**Difference in A-level participation rates**		
		Biology	**Chemistry**	**Physics**
A-levels in 2010	**Triple Award**	+5.0	-6.5	-10.9
	Dual Award	+24.3	+5.6	-3.1

Table 3: Summary of 21CS participation effects (percentage) across TA/DA routes and biology, chemistry and physics A-levels (2010)

A comparison between **Table 2** and **Table 3** shows a broadly similar patterning effect in the 2011 cohort, but that generally the 21CS effect in 2011 is reduced in comparison to that in the 2010 cohort.

We note that these findings do not match those of Millar (Millar, 2010), who in a study of around 150 schools, found a large increase in the numbers studying (rather than completing) AS levels in science following the introduction of 21CS. This increase was of the order of 30% *and was present in all three A-level sciences*.

If we breakdown **Table 2** by gender we obtain **Table 4** and **Table 5**:

Cohort 2 (males only)		**Difference in A-level participation rates - males**		
		Biology	**Chemistry**	**Physics**
A-levels in 2011	**Triple Award**	-6.9	-13.1	-16.2
	Dual Award	-3.6	-14.1	-25.1

Table 4: Summary of 21CS participation effects (percentage) on males across Triple Award/Dual Award routes and biology, chemistry and physics A-levels (2011)

Cohort 2 (females only)		Difference in A-level participation rates - females		
		Biology	Chemistry	Physics
A-levels in 2011	Triple Award	+11.8	-3.5	-13.3
	Dual Award	+22.9	+6.4	-17.6

Table 5: Summary of 21CS participation effects (percentage) on females across Triple Award/Dual Award routes and biology, chemistry and physics A-levels (2011)

Table 4 shows that the 21CS effect on participation is negative across the board for males, whereas **Table 5** shows a positive 21CS effect for females in biology from both Triple and Dual Award (11.8% and 22.9% respectively). In other words, there is evidence of differences by gender in the impact on progression to A-level sciences of 21CS courses at KS4.

In order to account to an extent for potentially confounding variables,[6] we modelled participation or otherwise in A-levels in biology, physics and chemistry separately using two types of model, one simple ('model 1') and one more complex ('model 2'):

- Model 1 includes: 21CS (Yes/No) at KS4 for each student as the only predictor of participation in each of the A-levels in science.
- Model 2 includes as predictors: 21CS (Yes/No) at KS4, KS4 science points, KS3 English, Maths and Science (fine) levels, gender, FSM-eligibility, IDACI[7] score (all of these measured at the student level) and whether or not the KS4 school teaches to 18 (at the school level).

The choice of which predictors to include from the many available in the NPD is based on existing literature on key influences on progression to post-compulsory sciences (see for example, Homer et al., 2013b). We acknowledge that different variable selections could be made, but are confident that the estimate we present of the 21CS effect from our models would not change substantially in other models. We have included the key known predictors of post-compulsory participation in science that are available in the NPD (based on previous research: gender, prior attainment and socio-economic status).

Model 1 gives the 'raw' 21CS effect on participation, whereas model 2 gives the independent 21CS effect having controlled for other factors (prior attainment, gender, socio-economic status and so on). Technically, we are using multi-level logistic regression with participation (or not) in each of the science A levels as the dichotomous outcome variable. For more details on these two models see Appendix A.

[6] In other words, take account of differences in the profiles of students doing and not doing 21CS
[7] The Income Deprivation Affecting Children Index, a second measure of socio-economic status available in the NPD.

Table 6 and **Table 7** summarise the 21CS effect on participation as estimated by these models. A positive value indicates that the 21CS effect on progression is positive, having controlled for any of the other predictors in the model.[8]

Cohort 2		21CS effect on A-level participation – model 1		
		Biology	**Chemistry**	**Physics**
A-levels in 2011	**Triple Award**	-0.06 (ns[9])	-0.14	-0.19
	Dual Award	0.18	0.04 (ns)	-0.15

Table 6: Summary of simple model of the 21CS effect on participation in science A levels (2011)

Cohort 2		21CS effect on A-level participation – model 2		
		Biology	**Chemistry**	**Physics**
A-levels in 2011	**Triple Award**	-0.08	-0.25	-0.26
	Dual Award	-0.06 (ns)	-0.25	-0.35

Table 7: Summary of more complex model of the 21CS effect on participation in science A levels (2011)

In terms of formal statistical effect sizes (i.e. a standardised measure of the size of the 21CS ‘effect’ on progression), all the estimates in **Table 6** and **Table 7** should probably be considered ‘small’.

As expected, the pattern of results for model 1 in **Table 6** corresponds to the descriptive analysis shown in **Table 2**.[10]

From the results for model 2 in **Table 7**, it is clear that once prior attainment and other student and school level factors are accounted for, students from 21CS are generally less likely to progress to science A levels than are their non-21CS peers. However, the effects sizes are generally small, with the largest (negative) effect that for physics from Dual Award.

Hence, one could argue that the apparently positive effects on participation in A level sciences as witnessed in **Table 2**, particularly for biology from Dual Award, are largely, if not

[8] The numbers themselves are (logistic) regression coefficients for the 21CS variable. See Appendix A for more details, including corresponding odds ratios.
[9] (ns) means non-statistically significant (at the 5% level).
[10] Effectively, these are different ways of estimating the same thing and so should match.

entirely, driven by the higher attainment of 21CS students at KS4 (as per Figure 2, cohorts 1 and 2).

A level attainment

In a parallel analysis to that of *participation* in A levels summarised in **Table 6** and **Table 7**, we can also model *attainment* at A level in order to estimate the 21CS effect on A level outcomes using the same set of predictors as before. Again, for each A level subject we can use a simple model ('model 3') and a more complex model ('model 4') as follows:

> Model 3 includes 21CS (Yes/No) at KS4 for each student as the only predictor of A level attainment.
>
> Model 4 includes 21CS (Yes/No) at KS4, KS4 science points, KS3 English, Maths and Science levels, gender, FSM-eligibility, IDACI score (all of these measures at the student level) and whether or not the KS4 school teaches to 18 (at the school level).

These models use multi-level ordinary regression, with A level points in each of the three science A levels as the outcome variable. Note that in contrast to progression to A level, where the outcome being predicted is a dichotomous variable, in the case of attainment at A level we are now modelling a continuous outcome. For more details on these two models see Appendix B.

For these models, the differences in mean performance between 21CS and non-21CS students (as a percentage of an A level grade) are summarised in **Table 8** and **Table 9**:

Cohort 2		**21CS effect on A-level attainment – model 3**		
		Biology	**Chemistry**	**Physics**
A-levels in 2011	**Triple Award**	-13.0	-9.0	-4.1 (ns)
	Dual Award	-10.1	5.3 (ns)	3.2 (ns)

Table 8: Summary of simple model of the 21CS effect on attainment (percentage of a grade) in science A-levels (2011)

Cohort 2		**21CS effect on A-level attainment – model 4**		
		Biology	**Chemistry**	**Physics**
A-levels in 2011	**Triple Award**	-8.1	-7.8	-3.0 (ns)
	Dual Award	-13.8	1.5 (ns)	-3.2 (ns)

Table 9: Summary of more complex model of the 21CS effect on attainment (percentage of a grade) in science A-levels (2011)

From **Table 8**, one can see that whilst the 21CS effect on attainment from Triple Award is negative in all three A level sciences, there are small positive 21CS effects on attainment in chemistry and physics A levels for Dual Award students.

However, **Table 9** shows that having accounted in model 4 for prior attainment in science and other student and school characteristics, there is a negative effect on A level attainment of having followed 21CS at KS4, with the possible exception of chemistry from Dual Award.

A broadly similar analysis in the first cohort (A levels in 2010) to that of model 4 is summarised in **Table 10**:

Cohort 1		**21CS effect on A-level attainment (analysis similar to model 4)**		
		Biology	**Chemistry**	**Physics**
A-levels in 2010	**Triple Award**	-7.8	-5.2 (ns)	-16.2
	Dual Award	-6.8	-3.5 (ns)	0.5 (ns)

Table 10: Summary of modelling the 21CS effect on attainment (percentage of a grade) in A-level sciences (2010)

The pattern is similar, with perhaps the largest change between successive cohorts being in physics from Triple Award – in the earlier cohort there is a significantly negative value-added effect for 21CS, but in the second (2011) cohort this becomes non-significant.

Discussion

Our analysis shows that there is no large difference in overall progression to post-compulsory science courses between students following 21CS and non-21CS science courses. However, at a finer level of analysis, we find some 'ripples' in this overall message when 21CS and non-21CS student cohorts are broken by gender; progression to physics, chemistry or biology, and Triple or Dual Award GCSE routes. In this section we draw upon international studies of the factors that impact on students' subject choices to account for any 21CS participation effect. In particular we explore *potential mechanisms* through which 21CS might be impacting on students' post-compulsory science participation.

A wide range of influences that go beyond schooling

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 & Hale (2009) and Boe et al. (2011). Here we provide an overview of findings from a selection of these studies. The overall message of this brief review is that the school science curriculum is one of many distinct influences on students' subject choices.

An influential model of student choice has been developed by Jacquelynne Eccles and colleagues (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? (subject attainment in school)
- 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?

School-related factors such as subject attainment, teaching activities and teacher relationships are likely to be significant influences on student attitudes related to Q1-Q3 above. However, in reflecting on all of the above questions, and particularly Q4 and Q5, students are also likely to be influenced by factors from outside of school (Ball, Maguire, & Macrae, 2000; Foskett, Dyke, & Maringe, 2008; Foskett & Hemsley-Brown, 2001). For example, many students will receive significant parental guidance on potential future careers. Also, issues of student identity and career aspirations are known to be heavily influenced by peer friendship groups (Archer et al., 2010; Boe, 2012). This range of influences on student choice was summarised and used to frame discussions with young people about their subject choices in a recent study involving 16-18 year olds.[11]

How and when do students make choices?

The set of six questions presented above might imply that students make decisions about subject choice following rational consideration of each of these questions at the time when they need to make decisions about future subjects. However, many previous studies have shown that students' subject choices are not necessarily rational decisions made at a particular point in time. Rather, 'choice' is viewed as a dynamic process that takes place, and shifts, over time (Cleaves, 2005).

The 'decision point' for AS/A level options within schools is typically part way though Year 11. However, studies show that many students actually make choices of future study (or more specifically, choices not to follow post-compulsory science courses) at ages much earlier than this; early secondary schooling or even within primary schooling (Maltese & Tai, 2010, 2011; Tai, Qi Liu, Maltese, & Fan, 2006). Whilst students are not making course choice decisions at these early ages, these studies suggest that dispositions, or attitudes, towards school subjects are formed early. These dispositions (positive or negative) set at an early age then frame future course choices. Such findings have significant implications for our study of the impact of 21CS; a course first experienced by students in the latter years of schooling. If choices are actually formed in late primary/early secondary, then we would not expect any significant differential impact on progression to post-16 sciences from distinct GCSE science courses or specifications.

[11] Interests and Recruitment in Science (IRIS) project:
http://www.education.leeds.ac.uk/research/projects/interests-and-recruitment-in-science-iris

However, other studies, typically employing longitudinal methodologies, have shown that while some young people do make early commitments not to follow science subjects in the future, many students are uncertain or make final commitments in late secondary schooling. 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 courses had clearly expressed that intention in Y9 (‘directed trajectory’) (Cleaves, 2005). Furthermore, a longitudinal study by Tai et al. (2006) in the US is often cited as showing that students with expectations for a science-related career at age 13 are many times more likely to complete a physical science or engineering degree than students without such expectations. However, our own examination of the data in Tai et al. (2006) shows that only 17% of students who had completed a science or engineering degree by age 25 had stated that they wanted a science-related career in Y8. Thus, even though expressing an early interest in a science career makes it more likely that a student will complete a science-related degree, there are still many students who do finally follow a science route who did not express this firm commitment at an early age. These analyses challenge the claim that the majority of students who pursue science courses within post-compulsory schooling develop this commitment early in their school experience. Thus, we believe that there is an opportunity for science courses in later secondary school to have significant impact on students’ post-compulsory school subject choices.

The potential impact of GCSE Twenty First Century Science

Our study shows there is no large difference in overall progression to post-compulsory science courses between students following 21CS and non-21CS science courses. However, at a finer level of analysis, we do find some ‘ripples’ in this overall message within different student gender; progression to physics, chemistry or biology, and triple or dual award GCSE routes. As noted earlier (page 13), stronger 21CS effects on progression have been reported by Robin Millar (2010). Given the wide range of influences on young people’s subject choices, and the time span over which these influences are in play, any claim of a significant impact of 21CS on progression is striking. Here we explore mechanisms through which specific aspects of GCSE 21CS might enhance elements of post-compulsory science participation.

Student attainment

A key factor influencing young people’s subject choices is their attainment in the subject (Q1: Am I good enough?). Thus, if the GCSE science attainment of students differs between 21CS and other GCSEs this could be behind any differential uptake. Specifically, if 21CS students attain higher grades than non-21CS students within GCSE then this would explain, at least partly, the reported positive 21CS participation effect.

Our analysis shows that 21CS students following Dual Award attain more highly at KS4 than do non-21CS students with this effect strongest in earlier cohorts (**Figure 2**). Differences within Triple Award are much smaller.

Thus, higher 21CS attainment might, at least in part, account for some of the enhanced participation effects from Dual Award. However, it is notable that the enhanced KS4 progression rates for Dual Award 21CS students is identified mainly in progression to biology

A level, and is not evident in progression to chemistry or physics. Thus, attainment at KS4 is certainly not the only factor behind the A level science participation effects. Furthermore, the more complex modelling analysis, which controls for prior attainment, shows a non-significant or slightly negative participation effect (**Table 6** and **Table 7**).

Curriculum content

One of the distinctive features of the 21CS suite of courses is the focus on 'ideas about science'. This area of the 21CS curriculum includes consideration of science issues with an ethical and social dimension, e.g. responding to climate change or the use of genetic engineering. This provides the potential for more discussion within the science classroom, and more opportunities for students to voice their opinions and hear those of other students. Whilst such issues are included in non-21CS specifications (driven by the inclusion of 'How Science Works' within the National Curriculum for science) they are more prevalent in the specifications and associated textbooks of the 21CS suite.

A more diverse school science curriculum, an emphasis on less didactic teaching styles, and more space for the 'students' voice', are all factors linked to positive impacts on students' attitudes towards science and ultimately choice of science courses (Bennett, Lubben, & Hampden-Thompson, 2011; Lyons, 2006). A recent EU-funded study has examined the extent to which an emphasis on teaching about socio-scientific issues and the nature of science had encouraged students to choose science courses within post-compulsory schooling (Ametller & Ryder, 2012).

This study included a questionnaire completed by Y12 students from two secondary schools. These two schools were known to include many science teachers who were enthusiastic advocates of the 21CS course. Y12 students (both science and non-science choosers) were asked to reflect back on the choices they had made before starting Y12. As part of this questionnaire, in closed responses, students indicated their experiences of science lessons (e.g. interest, enjoyment, usefulness), the influences on their choices of subject (e.g. attainment, curriculum content, teaching activities, teachers), and when they had first considered following science courses. Overall, on the basis of this 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 courses beyond post-compulsory education. Science choosers indicate that learning science facts had a more positive impact on their choice (84% agree or strongly agree), compared to having discussions about socio-scientific issues (65% agree or strongly agree). Non-science choosers indicate that learning science facts had a *less* positive impact on their choice (55% agree or strongly agree), compared to having discussions about socio-scientific issues (73% agree or strongly agree). Overall, responses to the questionnaire suggest that for many students, both science and non-science choosers, teaching about socio-scientific issues and the nature of science within compulsory science schooling had encouraged them to consider choosing post-compulsory science courses.

The evidence above suggests that the distinctive curriculum focus within 21CS on 'ideas about science' might account, at least partly, for some of the 21CS effects on A-level sciences participation reported here.[12] This curriculum focus could result in students following 21CS courses being more engaged with science lessons, and hence potentially more predisposed to choose post-compulsory science courses (impacting on Q2: Am I really interested in the subject? Q3: Do I enjoy working with the subject?).

The 'patterning' of the 21CS participation effect across KS4 routes and science disciplines

It is striking that positive 21CS participation effects are largely from the Dual Award, and not Triple Award route. Earlier we presented evidence that for many (but not all) students who eventually follow post-compulsory science courses, this decision is formed at an early age – at least by early secondary schooling. It is possible that such students are more heavily represented within Triple Award courses than Double Award. Those students who develop a long lasting positive disposition towards science at an early age are likely to follow through into Triple Award routes. Such students will tend to follow post-compulsory science courses *irrespective* of their experiences of KS4 science. By contrast, students within Double Award routes may be more ambivalent about post-compulsory science courses, and hence more open to be positively influenced by an engaging science course within KS4.

However, we have also shown that, looking within science disciplines, any positive 21CS participation effect is focused on biology participation, and there is actually a small negative impact on physics participation.

Comparison with Millar's earlier study

Our analysis does not replicate the findings reported by Millar (2010). In this section we explore the differences between the studies in terms of substantive findings and the methodologies employed. We then consider how these differing study outcomes might be accounted for. Finally, we present what might legitimately be concluded when taking both studies into account.

Comparison of substantive findings

Millar finds increases between successive school cohorts (pre/post 21CS) of 30%, 24% and 38% in the reported numbers of students beginning AS level biology, chemistry and physics, respectively in 2008 (i.e. the first 21CS cohort). Our within-cohort 21CS/non-21CS analysis, for A level completion, does not automatically allow for a direct comparison between our results and his. However, assuming an underlying growth rate in AS and A level sciences of 10%, Millar's findings would translate to equivalent figures of approximately 27%, 22% and 35% for a within-year study. We do not find effects of this size in our A level analyses for either cohort.

[12] Our study has not examined the approaches followed in 21CS classrooms, and the impact of these approaches on students' experiences of science lessons, and their future aspirations. However, this has been the focus of a study by PhD student Helen Morris at the University of Leeds. Working in a single school known to include teachers who are enthusiastic advocates of 21CS, Helen has examined classroom practices and students' experiences of these. Her analysis shows that in this school, classroom practices when teaching about socio-scientific issues often follow very 'traditional' teaching approaches. Furthermore, whilst many students are attracted to teaching/learning about socio-scientific issues, some student groups resent the move away from what they see as 'real science'.

Furthermore, our analysis of the ‘ripples’ in post-16 participation within specific science subject areas shows any positive impact is strongest in biology and weakest (indeed negative) in physics. By contrast, Millar’s study shows the strongest participation impact within physics (38%), followed by biology (30%) then chemistry (24%).

In earlier work, not reported on in detail here, we identified a 17% difference in AS level science participation between 21CS and non-21CS students, for the first cohort. This figure is reported in a conference paper by Millar (2011). However, due to the known incompleteness of AS level data within the NPD this figure needs to be treated with some caution. The A-level data within the NPD is much more complete. For the first 21CS cohort, we identified a 5.2% difference in A-level science participation between 21CS and non-21CS students. However, as detailed in the current report, this difference is NOT sustained in cohort 2. We see no overall difference in progression to A-level sciences between 21CS and non-21CS students for cohort 2, reduced from a 5.2% difference for cohort 1. Thus, whilst it remains possible that there is a sustained, small, 21CS effect on *AS-only* science participation, our analysis suggests this is not the case for *A-level* science completion figures.

Methodological differences
The two studies take very different approaches to addressing the same research question. **Table 11** summarises the main methodological differences:

	Millar (2010)	**NPD study reported here**
21CS Cohorts	First 21CS cohort only	First and second 21CS cohort
Sample	A sample of 36% of 11-18 schools following 21CS (number of schools=155)	Students in all maintained schools in England studying Dual or Triple Award at KS4 (approximately 380,000 students in 3100 schools in each cohort)
Measure	Teacher-reported AS-level starting numbers	Actual A-level qualification completion
Comparison	Successive in-school cohorts; pre/post 21CS	Within cohort 21CS/non-21CS comparison

Table 11: Comparison of methodologies used by Millar (2010) and the NPD study

Millar examines participation for the first 21CS cohort only. Our NPD study analyses participation for two successive 21CS cohorts. Overall, we find that any positive 21CS effect within cohort 1 is reduced within cohort 2. This suggests that Millar’s study might provide an over-estimate of the *long term* impact of 21CS on post-16 science participation. Indeed, it may be that there something akin to a ‘Hawthorne effect’ in play here, in the initial introduction of 21CS. Schools that choose to take on an innovative course such as 21CS may be 'up for change' resulting in an increased 'buzz' and excitement in the department that feeds through to students. This is an effect of taking on 21CS, but may not necessarily be an effect caused by particular elements of the 21CS course structure. This initial take-up ‘buzz’ within the department is likely to reduce over successive years, as seen in the NPD analysis.

The NPD study uses the entire population of maintained schools within England. Millar's study focuses on a 36% sample of 11-18 schools following 21CS. However, Millar conducted a follow-up telephone survey of a sample of non-responding schools, suggesting that non-responding schools were not strongly different in terms of science participation patterns, from those schools providing a questionnaire response. This suggests that the low response rate has not biased the sample significantly. The exclusion of 11-16 schools in Millar's study is also a key difference. However, we can identify no compelling reason why students' course choices will be significantly different between 11-16 and 11-18 schools.

Millar's study relies upon teacher reporting of student participation numbers, whereas the NPD study uses actual participation (i.e. qualification) data. Furthermore, Millar's study uses a comparison between a teacher's recollection of AS level student numbers in the previous two years, with *current student numbers* in the first 1-3 months of AS level courses. There may be a natural tendency for teachers to recall, or look up, student AS-level *completion* figures instead of initial AS level *participation* in previous years. It is likely to be difficult for many teachers to accurately recall actual starting numbers on AS level courses, for previous years. If so, this difficulty in recall would naturally lead to an over-estimate of any year-on-year participation effect within 21CS schools.

However, whilst there may be some uncertainties in teachers' recollections of student numbers, we would expect teachers to be able to provide this reasonably well and without deliberate bias. A more significant distinction in the measure used is that between starting and completion figures. Millar used numbers of students starting AS level sciences (within the first few months), whereas this NPD study focuses on A level qualification completion data. Anecdotally, non-completion rates within AS level are significant. Furthermore, only approximately 65% of students gain the corresponding science A level qualification, following AS level completion.[13] In a policy context it is the number of students completing a qualification successfully that is the key measure, with A level, rather than AS level, arguably being the main policy indicator of successful science progression.

Summary of comparison between the two studies

It is difficult to account for the striking differences in the findings of these two studies. As discussed above there are no 'fatal flaws' in the methodologies of either. That said, the NPD study reported here arguably provides more robust findings given:

1. use of two successive student cohorts, rather than one;
2. actual A-level qualification completion data, rather than teacher-reported participation in the first few months of AS-level;
3. inclusion of all schools within the maintained sector (n~3100), rather than a sample of 11-18 schools following 21CS courses (n=155).

Given the methodological strengths of the NPD study identified above, we do not believe that it is legitimate to claim that participation in 21CS GCSEs results in striking increases in post-16 science participation. Indeed, our review of the international literature on factors impacting post-compulsory courses choices shows that the school science curriculum is one

[13] Personal communication to the authors from DfE in 2011.

of many distinct influences on students' subject choices. Thus, we would be surprised to have found a very significant positive or negative effect on A-level science participation arising from the 21CS suite. On balance, taking these two studies together, we believe that the following claim is well-supported: there is no consistent evidence of a large difference in overall progression to post-compulsory science courses between students following 21CS and non-21CS science courses.

Acknowledgments

We are grateful to the Nuffield Foundation for providing funds to conduct this study.

The National Pupil Database data were obtained after a request to the Data Services group at the Department for Education. We are grateful for their efficient and prompt responses to our queries.

References

Ametller, J., & Ryder, J. (2012). The impact of science curriculum content on students' subject choices in post-compulsory schooling. In E. K. Henriksen, J. Dillon & J. Ryder (Eds.), *Recruitment, retention and gender equity in science, technology, engineering and mathematics higher education*: Springer.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). 'Doing' science versus 'being' a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education, 94*(4), 617-639.

Ball, S. J., Maguire, M., & Macrae, S. (2000). *Choice, pathways and transitions post-16: New youth, new economies in the global city*. London and New York: Routledge-Falmer.

Ryder, J., & Banner, I. (2013). School Teachers' Experiences of Science Curriculum Reform. *International Journal of Science Education*, 35(3), 490–514.

Bennett, J., Lubben, F., & Hampden-Thompson, G. (2011). Schools That Make a Difference to Post-Compulsory Uptake of Physical Science Subjects: Some comparative case studies in England. *International Journal of Science Education*, 1-27.

Boe, M. V. (2012). Science choices in Norwegian upper secondary school: What matters? *Science Education, 96*(1), 1-20.

Boe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: young people's achievement-related choices in late-modern societies. *Studies in Science Education, 47*(1), 37-72.

Cleaves, A. (2005). The formation of science choices in secondary school *International Journal of Science Education, 27*(4), 471-486.

Eccles, J. (2009). Who Am I and What Am I Going to Do With My Life? Personal and Collective Identities as Motivators of Action. *Educational Psychologist, 44*(2), 78 - 89.

Foskett, N., Dyke, M., & Maringe, F. (2008). The influence of the school in the decision to participate in learning post-16. *British Educational Research Journal, 34*(1), 37 - 61.

Foskett, N., & Hemsley-Brown, J. (2001). *Choosing futures: Young people's decision-making in education, training and careers markets*. London and New York: Routledge-Falmer.

Henderson, M. & Blair, A. (2006). Science elite rejects new GCSE as 'fit for the pub', *The Times* (London), 11 October 2006. Available from: <http://www.thetimes.co.uk/tto/news/uk/article1944010.ece> [Accessed 30 September 2013].

Homer, M., Ryder, J. & Donnelly, J. (2013a) Sources of differential participation rates in school science: the impact of curriculum reform*. British Educational Research Journa*l, 39 (2), pp.248–265.

Homer, M., Ryder, J. & Banner, I. (2013b) Measuring determinants of post-compulsory participation in science: a comparative study using national data. *British Educational Research Journal*. doi: 10.1002/berj.3106

Lyons, T. (2006). Different Countries, Same Science Classes: Studentsâ€™ experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591 - 613.

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the Fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education, 95*(5), 877-907.

Millar. (2006). Twenty First Century Science: Insights from the design and implementation of a scientific literacy approach in school science. *International Journal of Science Education, 28*(13), 1499 - 1521.

Millar, R. (2010). Increasing participation in science beyond GCSE: The impact of Twenty First Century Science. *School Science Review, 91*(337), 67-73.

Millar, R. (2011). *Teaching for scientific literacy: Increasing participation in science in upper secondary school*. ESERA, 5-9th September, Lyon.

Ofqual (2009). The new GCSE science examinations: findings from the monitoring of the new GCSE science specifications: 2007 to 2008. Available from: <http://dera.ioe.ac.uk/327/1/ofqual-09-4148_GCSE_science_2007_2008_report.pdf> [Accessed 12 September 2013].

Perks, D., Gilland, T., Institute of Ideas & Pfizer Inc (2006). What is science education for? London, Academy of Ideas.

Tai, R. H., Qi Liu, C., Maltese, A. V., & Fan, X. (2006). Career choice: enhanced: Planning early for careers in science. *Science, 312*(5777), 1143-1144. doi: 10.1126/science.1128690

Tripney, J., Newman, M., Bangpan, M., Niza, C., MacKintosh, M., & Sinclair, J. (2010). Factors influencing young people (aged 14-19) in education about STEM subject choices: A systematic review of the UK literature: EPPI-Centre.

Wynarczyk, P., & Hale, S. (2009). Improving Take Up of Science and Technology Subjects in Schools and Colleges: A Synthesis Review: ESRC/DCSF.

Appendix A: Modelling progression to A level sciences using multi-level logistic regression

For each post-16 course (A level biology, chemistry and physics) and for each KS4 pathway (Dual Award and Triple Award), we predict student participation (or not) in the respective A levels.

We use multi-level logistic regression with two levels, student (level 1) and KS4 school (level 2). For the simple model (model 1), the single explanatory variable is 21CS (Yes=1, No=0). For the more complex model (model 2) the additional explanatory variables are listed in Table A1.

Level in model	Predictor	Further details
Student (1)	Prior attainment in science at 16	GCSE points. For Dual Award we use GCSE Additional as the KS4 prior attainment score. For Triple Award, we use the appropriate GCSE subject (i.e. for biology A level, we use biology GCSE and so on).
	Prior attainment in science at 14	KS3 fine level in science
	Prior attainment in maths at 14	KS3 fine level in maths
	Prior attainment in English at 14	KS3 fine level in English
	Gender	Gender
	Free school meal eligibility (FSM)	A measure of socio-economic status based on whether the student is eligible and in receipt of free school meals.
	Income deprivation affecting children index (IDACI)	A second measure of socio-economic status indicating the proportion of children under age 16 in the local area living in low income households.
School (2)	14-16 school also teaches up to age 18	This indicates whether the 14-16 school also provides post-compulsory education up to age 18.

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

The estimates of the independent 21CS effects on A level participation (and corresponding odds ratios) are shown in **Tables A2** and **A3** for models 1 and 2 respectively.

Cohort 2			21CS effect on A level participation – model 1		
			Biology	**Chemistry**	**Physics**
A levels in 2011	**Triple Award** Students: 66163 Schools: 1662	**Coefficient (SE)**	-0.060 (0.041)	-0.142 (0.047)	-0.191 (0.047)
		Odds ratio	0.942	0.868	0.826
	Dual Award Students: 304693 Schools: 3065	**Coefficient (SE)**	0.184 (0.041)	0.040 (0.051)	-0.146 (0.052)
		Odds ratio	1.202	1.041	0.864

Table A2: Estimate of 21CS coefficient in logistic regression model 1

Cohort 2			21CS effect on A-level participation – model 2		
			Biology	**Chemistry**	**Physics**
A levels in 2011	**Triple Award** Students: 60170 Schools: 1607	**Coefficient (SE)**	-0.081 (0.037)	-0.246 (0.045)	-0.263 (0.047)
		Odds ratio	0.922	0.782	0.769
	Dual Award Students: 281765 Schools: 3017	**Coefficient (SE)**	-0.056 (0.035)	-0.250 (0.044)	-0.348 (0.045)
		Odds ratio	0.946	0.779	0.706

Table A3: Estimate of 21CS coefficient in logistic regression model 2

Appendix B: Modelling attainment in A level sciences using multi-level ordinary regression

For each post-16 course (A level biology, chemistry and physics) and for each KS4 pathway (Dual Award and Triple Award), we predict student attainment (i.e. A level points[14]) in the respective A levels.

We use multi-level ordinary regression with two levels, student (level 1) and school (level 2). For the simple model (model 3), the single explanatory variable is 21CS (Yes=1, No=0). For the more complex model (model 4) the additional explanatory variables are as shown in **Table A1** above.

The estimates of the independent 21CS effects on A level attainment are shown in **Tables B1** and **B2** for models 3 and 4 respectively.

Cohort 2			21CS effect on A-level attainment – model 3		
			Biology	Chemistry	Physics
A levels in 2011	Triple Award	Coefficient (SE)	-3.91 (1.32)	-2.70 (1.37)	-1.23 (1.77)
		% of a grade	-13.0	-9.0	-4.1
	Dual Award	Coefficient (SE)	-3.03 (1.17)	1.60 (1.41)	0.96 (1.96)
		% of a grade	-10.1	5.3	3.2

Table B1: Estimate of 21CS coefficient in ordinary regression model 3

Cohort 2			21CS effect on A-level attainment – model 4		
			Biology	Chemistry	Physics
A levels in 2011	Triple Award	Coefficient (SE)	-2.42 (0.99)	-2.34 (1.10)	-0.91 (1.40)
		% of a grade	-8.1	-7.8	-3.0
	Dual Award	Coefficient (SE)	-4.13 (0.95)	0.46 (1.2)	-0.95 (1.61)
		% of a grade	-13.8	1.5	-3.2

Table B2: Estimate of 21CS coefficient in ordinary regression model 4

The sample sizes vary across each of the three A-level subjects and are given in Table B3.

[14] The difference between successive A level grades (e.g. A and B) is 30 points so to obtain the percentage of a grade we express the coefficient as a percentage of 30.

Cohort 2			Sample size (student, school)		
			Biology	**Chemistry**	**Physics**
A levels in 2011	**Triple Award**	**Model 3**	17739, 1476	15590, 1415	10677, 1295
		Model 4	16126, 1428	14182, 1374	9683, 1240
	Dual Award	**Model 3**	20235, 1898	13207, 1697	8931, 1523
		Model 4	18836, 1842	12319, 1641	8316, 1465

Table B3: Sample sizes for the A-level attainment ordinary regression models