The enactment and impact of Key Stage 4 science education reforms: Case for Support

Introduction
In September 2006 the Key Stage 4 (KS4) science curriculum experienced its most radical reform since the introduction of the National Curriculum. The aim was to improve the flexibility of provision, and its capacity both to motivate students to study science and to improve scientific literacy. The motivation for the reforms derives from the widespread evidence that the science curriculum is not optimally fit for purpose (Angell et al., 2004; Jenkins, 2006; Jenkins & Nelson, 2005; Murray & Reiss, 2003; Osborne & Collins, 2001). A particular concern exists over falling recruitment to physical science courses at post-16 (Royal Society, 2006; Smithers & Robinson, 2007). The government’s urgent intention is to address these matters, as part of its STEM agenda (H.M. Treasury et al., 2004).

Yet, despite the outcomes of the Twenty First Century science evaluation (Burden et al., 2007), these reforms are in large measure untried, and their likely impact unknown. The aim of the present proposal is to understand how this new flexibility is employed within schools, and the meaning and impact (most probably the differential impact) of the reforms in pedagogy and curriculum content for both students and teachers. The study will establish whether the forms of provision available are differentially deployed within the student cohort (across such variables as student attainment, gender and ethnicity). It will provide longitudinal evidence about their impact, in terms of: attainment, in both absolute and value added terms; students’ judgements about the interest, importance and relevance of school science; and students’ future intentions, including the criteria against which such intentions develop (Science and Mathematics Initiative (SMI), research question 1). Yet it is critical that any assessment of the impact of the reforms gives attention to how they are realized in schools. The project will therefore also examine that realization and schools interpretation of the aims of the reforms (SMI, research question 2).

Our study will pay particular attention to the enactment and impact of two distinctive aspects of the 2006 reforms. Teaching about How Science Works forms a central feature of the single award GCSE Science specifications. Such teaching addresses epistemic, ethical and political aspects of science often through the use of historical case studies and/or debates about socio-scientific issues (Levinson, 2006; Ratcliffe & Grace, 2003; Sadler et al., 2006). Previous studies conducted in the initial stages of implementation of such teaching suggest that this is a particularly challenging area for teachers, but also one with the potential for a significant impact on the student experience (Bartholomew et al., 2004; Burden et al., 2007; Leach et al., 2003; Millar, 2006; Ryder et al., 2005; Ryder & Leach, in press). The 2006 reforms also place a strong emphasis on Applied specifications at KS4. These specifications include two major innovations: heavy reliance on coursework within formal course assessment and significant use of workplace contexts to enrich the science curriculum (Bell & Donnelly, 2006). Again, these innovations involve significant changes for teachers but have the potential to impact strongly on the student experience. In sum, the proposed research aims both to evaluate the meaning and impact of current reforms, and to provide guidance for future policy directions.

Research Questions
The proposed study will address the following research questions.

RQ1 How are the 2006 policy reforms being implemented in schools?
1.1 What are the patterns of uptake of the new science specifications at KS4?
1.2 Are these specifications being targeted differentially towards particular ‘types’ of student (by KS3 attainment, gender, ethnicity, social background), and if so how?

1.3 How does the enactment of the reforms within schools relate to the documented intentions of course designers, policy makers, regulatory bodies and awarding bodies, and how might the relationship be theorised?

RQ2 How are teachers and departments responding to the 2006 reforms?
2.1 What are teachers’ perceptions of the educational rationale of the new specifications and do they see students with particular characteristics as suited to each specification? How are these perceptions developing over time?

2.2 What innovative classroom activities are being developed in response to the reformed science specifications (with a focus on How Science Works and Applied Science)? What affordances and challenges arise from these innovative activities?

2.3 What professional development needs can be identified within schools in response to the 2006 science specifications? Are these being met, and if so how?

RQ3 What is the impact of the 2006 reforms on students’ participation, attitudes and attainment?
3.1 How are the reformed KS4 science specifications influencing the uptake of post-16 science courses?

3.2 How are students’ attitudes towards school science influenced by the reformed KS4 science specifications?

3.3 What are the relationships, on a value-added basis, between the science specifications undertaken at KS4 and student achievement, including A-level?

3.4 Are gender, ethnicity and social background influencing the impact of the 2006 reforms on students’ participation, attitudes and attainment? If so, how?

Research Methods
We will use available national datasets and custom-designed national surveys to generate statistically robust, nationally-representative findings. In addition we will conduct longitudinal school-based case studies to examine more deeply specific aspects of the enactment of the reforms and their impacts on students. Each dataset will be used to address several research questions (Annex, p.1). See Annex (p.2) for a timetable of data collection, and other activities.

DS1 National datasets (RQ1.1, 1.2, 3.3, 3.4)
The National Pupil Database (NPD), incorporating the Pupil Level Annual School Census dataset (PLASC), includes science attainment data and information on student gender, ethnicity and free school meal eligibility. The use of these powerful datasets for research purposes is growing (Bell et al., in press; Burgess et al., 2005; Schagen & Schagen, 2005). Within the timescale of the proposed study KS3/KS4 data will become available for the first three cohorts of students following the revised specifications (Annex, p.3-4). Post-16 data will be available for two student cohorts. Given the complete national coverage of the databases sampling is not strictly an issue, although the size of the data files and associated demands on computing power may require some degree of sampling whilst maintaining high levels of representativeness.

School-based case studies (RQ2, RQ3)
The proposed staffing would enable us to conduct intensive, longitudinal case studies within 15-20 schools. We will begin with a sample of 20 schools to allow for dropout. Given the range of school, teacher and student characteristics and the variety of reformed science specifications available at KS4 a sample of this size cannot be considered as nationally representative. Nevertheless we will ensure inclusion of a broad range of school types (comprehensive,
‘grammar’; presence or absence of sixth form), student backgrounds and KS4 science specifications.

Data collection within schools will involve interviews with teachers, focus group discussions with students and student questionnaires. To support analysis these discussions will be transcribed. Wherever possible data collection will be preceded by observation of a lesson involving these teachers and students. Observed lessons will be chosen to exemplify teaching about How Science Works and coursework and workplace-related aspects of Applied Science courses. The purpose of classroom observations will be to provide a shared starting point for broader discussions with teachers and students about their experiences of these novel aspects of the reforms. We are also applying for a PhD studentship examining the nature of classroom interactions during the teaching of novel aspects of the reforms.

DS2 Interviews with teachers (RQ2.1, 2.2, 2.3)
In each school 2-3 teachers will be identified. To provide a strategic overview of the departmental response to the 2006 reforms one of these teachers will be the Head of Science. We will also include at least one specialist physical sciences teacher. These teachers will be interviewed individually in each year of the project. A semi-structured interview protocol will be used to explore the development of teachers’ responses to the 2006 reforms.

DS3 Student focus groups (RQ3.1, 3.2, 3.4)
In each school two groups of approximately six students will be identified. These student groups will be chosen to reflect the range of specifications followed, student achievement, gender, ethnicity and social background. Student groups will take part in focus group discussions in Y10 and again in Y11. We will consider the use of single gender groups to allow for a full exploration of the impact of gender on student perspectives. Focus group discussions will explore students’ responses to coursework and workplace-related activities within Applied Science courses, and classroom activities addressing How Science Works. Discussions will also address broader contextual issues that impact on student choice, such as careers advice, family background and institutional influences. The term ‘attitudes towards school science’ encompasses a wide range of distinct components (Osborne et al., 2003). Focus group discussions will address students’ interest in school science, their enjoyment of the subject, and the extent to which they consider school science as relevant to their lives. At the end of each focus group discussion students will be asked to complete a written questionnaire. These open response questions will help provide access to the views of individual students within the group.

DS4 National teacher questionnaire (RQ2.1, 2.2, 2.3)
We will commission NFER to draw a random sample of around 1000 schools stratified across key school variables such as school type, presence or absence of sixth form and geographical region. Past experience suggests a likely response rate of around 50% giving a sample of 10-15% of schools nationally. A combination of closed and open response questions will probe teachers’ views of the aims of the 2006 reforms, their experiences of developing innovative classroom activities and identified professional development needs. The timing of the national teacher (and student) questionnaire in the final year of the study will enable hypotheses arising from the school-based case studies to be tested nationally.

DS5 National student questionnaire (RQ3.1, 3.2, 3.4)
A sample of 30 schools stratified across key school variables will be asked to distribute the student survey to their entire Y11 cohort. We anticipate that this will result in around 1500 completed student surveys. A combination of open and closed response questions will explore the impact of the 2006 reforms on students’ attitudes and choices with respect to science.
Review of available datasets
We will make full use of the NPD and PLASC datasets. We are aware of initial evaluation studies that have been conducted on science courses associated with the reforms, e.g. Twenty First Century Science (Burden et al., 2007; Millar, 2006) and uptake of science specifications in the first year of reforms (Donnelly et al., 2007). These initial findings will inform the design of research instruments. However, the datasets developed in these studies are not suitable for the proposed longitudinal study.

Access and potential risks
We have ensured that access to NPD and PLASC datasets is granted to educational researchers. Access to schools is more problematic. However, our experience is that given consideration of the needs of teachers and students in schools, and appropriate financial inducement, schools are willing to work with us. In any case our initial school sample will allow for some dropout over the three years of the study. We have excellent contacts with QCA and DfES and have ensured that the proposed study will not duplicate existing or planned evaluation activities.

Analysis of datasets

NPD/PLASC national datasets (DS1)
Our analysis will be framed by three dimensions within the datasets: combination of KS4 science specifications undertaken (Science, Science and Applied, Science and Additional, Triple, Double Award Applied Science); outcomes (post-16 course choices, student achievement at KS3/4 and post-16); and student characteristics (gender, ethnicity and eligibility for free school meals).

Implementation in schools and student characteristics (RQ1.1, RQ1.2)
We will examine the uptake of each KS4 specification type nationally. We will also analyse the availability of each specification type within schools to explore the extent to which schools are offering a flexible suite of science specifications to their students. Analysis will also link the specification types followed by students to student achievement at KS3 and student characteristics within PLASC. This analysis will identify any targeting of specification types on different categories of students, testing existing evidence that Applied courses are targeted on less highly attaining students (Bell & Donnelly, 2007). All of these analyses will be conducted on successive student cohorts, enabling us to track changes over the first three years of the 2006 reforms. Analysis will involve the use of standard chi-square tests for comparisons across a single dimension, and logistic regression and/or discriminant analysis for comparisons across multiple dimensions.

Specification type, attainment and post-16 choices (RQ3.3)
Using KS3 achievement as a baseline, we will examine the value-added achievement at KS4 of three successive cohorts of students following different KS4 specification types. The project team already has experience of using national datasets for this kind of analysis (Bell et al., in press). We will also examine the compulsory school background (KS4 specification type and KS3/4 achievement) of students choosing post-16 science courses (particularly in physics and chemistry) for two cohorts of students. This analysis will identify any differential success across specifications and combinations of specifications in promoting post-16 course uptake. This analysis may also be extended to incorporate specific awarding body specifications if exploratory analysis suggests this to be informative. We will also examine student achievement on post-16 science courses, relating this to KS4 specification type and KS3/4 achievement. This analysis will involve standard ANOVA and multiple regression techniques.
Student characteristics, attainment and post-16 choices (RQ3.4)
We will use General Linear Models (GLM2) to investigate how student gender and ethnicity influence value-added performance within specifications. These findings will extend significantly our current understandings in these areas (Elias et al., 2006; Jones & Elias, 2005; Murphy & Whitelegg, 2006). The PLASC dataset will also enable us to examine the impact of eligibility for free school meals on student attainment (on a value added basis) and post-16 choices, though we are aware of the limitations of this variable as a measure of social background.

Technical details of statistical aspects of the analysis are provided in the Annex (p.5). Our proposal includes staffing with statistical analysis expertise to support this aspect of our work. We will also engage with other users principally through the DiIES/ESRC funded PLASC/NPD Users’ Group (PLUG) based at the University of Bristol.

Teachers’ responses to the 2006 reforms (RQ2.1, RQ2.2, RQ2.3; DS2, DS4)
The focus of this analysis will be on the ongoing interaction between teachers’ espoused beliefs, constraints (including both professional skills and classroom constraints), support mechanisms and practices, and how these change over time.

Teachers’ beliefs about the aims of innovative science education initiatives are an important influence on their classroom practice (Lumpe et al., 1999). Our analysis will identify teachers’ views of the educational rationale of specific specifications and the characteristics of students they see as suited to each specification. We will also examine how these views change as teachers gain classroom experience of such teaching. An early study of innovation in the classroom activities of teachers on the Twenty First Century Science GCSE suggested that many teachers displayed uncertainty in incorporating aspects of How Science Works (Burden et al., 2007). Where this is the case our school-based studies will identify teachers’ perspectives and priorities in this area, and that of workplace-related learning. Our focus will be on individual case studies (and if appropriate typologies) located within the context of broader departmental and school policies.

Classroom observations will provide important contextual information to inform teacher interviews and subsequent analysis, but we will not attempt a normative analysis of teachers’ classroom activities. Such judgements can easily diminish the challenging context in which the teacher is working or the dimensions of their professionality. Rather, our focus will be on exploring the reasons behind teachers’ activities, the challenges and affordances they experience in developing their teaching, and how they exploit these. Professional development needs, and the extent to which they are considered to have been met, will also be examined. Analysis of interview discussions with each teacher in each year of the project will probe the issue longitudinally. Analysis of responses to the national teacher survey will examine, on a national scale, key issues and patterns arising from these case study analyses.

Impacts of the 2006 reforms on students (RQ3.1, RQ3.2, RQ3.4; DS3, DS5)
Our central focus will be on identifying the impact of the reforms. However, we recognise that any such impact will be mediated strongly by aspects of students’ sense of agency and identity, and their socio-cultural environment. Our study will focus on what students identify as key influences, while recognising the limitations of such self-reporting and employing a less intensive methodology than some studies (Ball et al., 2000; Foskett & Hemsley-Brown, 2001). Analysis of post-session written reflections in addition to focus group discussions will facilitate the characterization of individual students’ perspectives. We will track the development of students’ perspectives on post-16 choices. A key issue will be how ‘choices’ are made, and the
influences, including socio-cultural influences, involved. Analysis will also examine the development of students’ attitudes towards school science, in the context of the 2006 reforms. As recognised by Morris (2007) and Osborne et al. (2003) there have been few studies within science that have taken this integrative, qualitative and developmental approach.

One outcome of our analysis will be a generalised account of factors impacting on student choice and attitudes to school science. Within the data available to us will also generate more individualized case studies. To assess the national significance of findings arising from the case studies key aspects of the analysis will be embedded in the national student survey. In all of these we will seek to take account of key student characteristics such as KS4 achievement, gender, ethnicity and social background. In conducting this aspect of the study we will be sensitive to the ethical issues involved for teachers and students (see ‘ethical information’).

Enactment of the 2006 reforms and documented intentions (RQ1.3)
Our analysis of public domain policy documents will characterise the range of aims associated with the 2006 reforms, and their ambivalences. This analysis will be compared with our interpretation of the enactment of reforms nationally, and within specific school settings. Our analysis will be informed by theoretical understandings of the processes of public policy development and implementation (Lumby & Foskett, 2005; Robitaille et al., 1993). For example, we will seek to examine whether teachers, despite their apparent position as ‘recipients’ of the reforms, are able to ‘co-produce’ them (Hill & Hupe, 2002, p.134-6). This analysis will draw on other theoretical areas including, for example, Ball’s conceptualisation of policy texts as readerly or writerly (Ball, 1990). One outcome of this analysis will be an informed understanding of how current and future school curriculum reforms can be implemented more effectively, while acknowledging the aims and realities of teachers’ professional work.

Dissemination and impact
In addition to liaising with other funded SMI projects we will engage with key potential users throughout the lifetime of the project and beyond to maximise the impact of the proposed study. We will convene a consultancy group comprising representatives from key user groups including school teachers, Ofsted, ASE, DfES, QCA, IOP, RSC, Royal Society, National and Regional Science Learning Centres and academics. In designing the proposed study we have already consulted with key individuals within several of these user groups. The consultancy group will provide guidance on the design and conduct of the research at key points in the study and advice on approaches to disseminating findings. Given the size of the group, communication will be electronically-based. The group will be sent, and asked to comment on, annual and final project reports. In the final stages of the project we will organise a dissemination conference involving key user groups to review findings in the context of ongoing policy priorities. We will also explore opportunities to extend analysis of student cohorts from post-16 and into HE beyond the lifetime of the proposed study.

Study outcomes will have significant implications for individual schools that are developing their KS4 science provision. We will present findings from our study at Annual Meetings of the Association for Science Education over the lifetime of the project. We will also publish findings in teacher journals such as School Science Review, Education in Chemistry and Physics Education. A significant innovation is the use of the NPD/PLASC databases. We will engage with the existing ESRC-funded NPD/PLASC user group at the University of Bristol to contribute to an ongoing development of methodological expertise in this area. We will also contribute to theoretical understandings of curriculum and policy change through presentations at academic conferences and publications in the academic literature.