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Positioning Applied Science in Schools: Uncertainty, Opportunity and Risk in Curriculum Reform

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Foreword

It is likely that a unified system will appear as even more of a break with the past than GNVQs. This means that the design process will have to incorporate lessons from practice, and not just hope, as in the case of GNVQ, that teachers 'will make the best of them' whatever the problems. (Young et al. 1995: 8)

The innovation with which we are concerned in this report cannot claim to involve so grand a target as creating a 'unified system' of academic and vocational education, though it might contribute to it. Yet in the report which we offer here there is a strong resonance with the quotation above. Teachers have indeed 'made the best' of the reform with which we are concerned, in difficult circumstances. They have done so with some success, though not without casualties.

GCSE Applied Science was introduced in September 2002, as part of a suite of so-called 'GCSEs in vocational subjects'. The study on which this report is based began in November 2003, and was funded by the Economic and Social Research Council[1]. Its aim was to examine the process by which GCSE Applied Science was introduced, the form which it took in schools and its wider implications for the science curriculum. In this report we pay particular attention to the positioning of the new course within the structures and hierarchies of schooling, the place within it of the contested notion of vocationalism, and the realization which it provides of the rhetoric of student independent learning. All of this is set at a significant confluence, where two policy streams meet, but mingle only intermittently: 14-19 education reform, on the one hand, and the promotion of science education, on the other.

Our report is based on a range of datasets, including: teacher and student interviews and classroom observations in a sample of some 20 schools (conducted between 2004 and 2006); two national questionnaires sent to teachers (in 2005 and 2006); a questionnaire sent to Applied Science students (2006); and data derived from the National Pupil Database (NPD) for the 2003/4 and 2004/5 Y11 cohorts. Further methodological details of the work can be found in Appendix 4, including the key to the school names, which are of course anonymized. Appendix 3 offers two case studies, of relatively successful and unsuccessful courses.

We must record our gratitude to the many teachers, schools, awarding body officers and other colleagues who allowed us to interview them or attend teaching or other activities with which they were associated. We are particularly grateful to the teachers who joined a consultative group which we set up during the project. All must of course remain anonymous. We also thank staff at QCA and the DfES, who facilitated aspects of our work. Finally we are grateful for help with statistical analysis of data from the National Pupil Database given by our colleagues Matt Homer and Godfrey Pell in the School of Education at the University of Leeds.

For simplicity's sake, we have generally used the term 'Applied Science' to refer to GCSE Double Award Applied Science and 'Science' to refer to the single and double award science GCSEs which were available during the period of the study.

[1] Grant No.: RES000230229

Abbreviations

DfES	Department for Education and Skills
GNVQ	General National Vocational Qualification
IFP	Increased Flexibility Programme
KS	Key Stage
NPD	National Pupil Database
NQ	National Questionnaire
Ofsted	Office for Standards in Education
PLASC	Pupil Level Annual Schools Census
QCA	Qualifications and Curriculum Authority
SEMTA	Science, Engineering and Manufacturing Technologies Alliance
SMT	Senior Management Team
SQ	Student Questionnaire
SSAT	Specialist Schools and Academies Trust

1. Introduction

In policy terms, the late secondary curriculum has come to be dominated by a relatively small number of themes. Among the most important of these are:

- the view that the curriculum does not meet the needs of the economy;
- the perception that a significant proportion of students find their school studies of marginal relevance;
- the perceived fracture between so-called 'academic' and 'vocational' studies.

The last statement in particular is a shorthand for a complex and politically sensitive issue. It invokes a tension between so-called 'academic' and 'vocational' subjects. The distinction is by no means simple (one need only think of law or medicine), but the former are commonly thought to be judged more favourably by higher status universities and to be pursued by higher attaining young people. Vocational[2] courses of study relate more clearly to workplaces, or at least certain kinds of workplace, and their position is perhaps summed up by a recent commentator with the observation they are often thought to be a good idea 'for other peoples' children' (Wolf 2002). In schools the sharpest manifestation of this tension in recent decades has been the relationship between A-levels and GNVQ. The demise of Advanced GNVQ, and the rapid transformation of its successor, the Vocational Certificate in Education, into 'A-levels in applied subjects'[3] derives from the difficulties which the attempt to create a distinctively vocational post-16 curriculum has experienced. The effort to resolve the issue was central to the deliberations of the Tomlinson Committee, and its aftermath in the 14-19 Education and Skills White Paper. The phrase 'parity of esteem' is no longer common, but the question of how vocational courses are judged in terms of status and progression by all of those concerned remains central.

This report is concerned with a development within the KS4 school science curriculum which brings the themes identified above into sharp focus: the introduction of GCSE Double Award Applied Science (Applied Science, as we will usually call it). This case is distinctive in that it involves an attempt to create an at least nominally vocationalized version of a high status academic subject within the compulsory, indeed the core, school curriculum. It can be seen as a test-case for the attempt to integrate vocational and academic versions of schooling, albeit in the very distinctive circumstances of science. It embodies important questions, including:

- in what sense can science as a school subject be termed vocational?
- which students are likely to follow a vocationalized science curriculum, and what benefits does it offer them?
- what is the relationship of the subject to other (academic) versions of school science?

We will give attention to these questions, and to others, such as teachers' judgements of the success and impact of the new specification, and to student performance. We will not give extensive definitional attention to the heavily-loaded word vocational, which others have explored much more systematically than we can hope to do here (see e.g. Pring 1995).

[2] We will hereinafter avoid using scare quotes for these terms, taking them to be sufficiently problematized.
[3] http://www.qca.org.uk/10379.html

We have examined its current significance in the context of school science education elsewhere (Bell and Donnelly 2006). In this report our aim is rather to examine how the idea of a vocational science curriculum has been employed and realized, and the issues to which that process has given rise, in a context for which we have empirical evidence. We will suggest that the questions identified above (and the likely meaning of 'vocational' in the school science curriculum) are underpinned by other issues, of which perhaps the most fundamental is how educational purposes are configured and realized within the political[4] spaces of schooling. We will argue that, though GCSE Applied Science has demonstrated some success in difficult circumstances, it has also been carefully positioned within those political spaces in ways which condition, and perhaps limit, its educational possibilities. It has done little to alter how 'vocationalism' fits within those spaces.

The relentless association of the word 'vocational' with lower status, and with training for narrow and sub-professional employment is of course a key issue here. The association has continued, despite an ongoing attempt to reconcile a progressivist, Deweyan version of vocational learning with more instrumentalized accounts of the supposed 'needs' of industry, and both of these with the liberal tradition of schooling (Hodkinson 1991; Pring 1995; Bates et al. 1998) This reconciliatory project finds some echoes in GCSE Applied Science, but, we suggest, it is in an unequal competition with the powerful political structuring of the school curriculum.

[4] We are using the word 'political' here to refer to those interpenetrating judgements of subject status, student typology and likely progression which are instantiated and reproduced daily in schools' practices and structures. We are using 'structure' in a manner broadly corresponding, we hope, with that employed by Giddens, though we will not use the term 'structuration' (Giddens 1984).

2. The Policy Background

The wider policy background to this study has two main aspects. The first relates to the broad arena of post-14 (or 14-19) reform, and the second to the position of science within the post-14 curriculum. The latter is not however a sub-set of the former. There have been numerous recent policy initiatives aiming to make schooling more flexible, more work-orientated and more likely to encourage young people to stay in education and training. Examples of such initiatives within national policy, broadly contemporary with Applied Science, include the Pathfinders programme and the Increased Flexibility Programme (IFP) (Higham and Yeomans 2006; O'Donnell et al. 2006).[5] In most curricular areas these initiatives have been targeted less on students who are academically successful than on groups perceived to be underachieving, including particularly the so-called NEET[6] group. The entire policy domain has been judged sufficiently important to attract a major synoptic study, funded by the Nuffield Foundation.[7]

Science presents a different picture: government policy and rhetoric focuses on a perceived quantitative deficit in science students at level 3 and above, at least in the physical sciences. Both policy and rhetoric have rather less to say about quality. Promoting increased take-up figures in government policies and speeches, most prominently in the Science and Innovation Investment Strategy and its associated Framework (HM Treasury et al. 2004: 6.26). Reform of the science curriculum so as to make it more attractive to students has been regularly cited as part of the Strategy. Vocational qualifications have been marginal in this process: the term 'vocational' figures barely at all in the Framework document as it relates to schools (chapter 6). Indeed it has been argued elsewhere that the science curriculum is already too vocational (Millar and Osborne 1998), though it is a vocationalism of a distinctive kind: one which leads to established university courses and thence to a professional career in science, but might not address the supposed needs of the general population for what is called 'scientific literacy'.

[5] The emphasis figures in each of the White Papers which were published during the period with which this study is concerned, from Schools–achieving success (2001) to Higher Standards, Better Schools for All (2005), and numerous other interventions as e.g., 'Blunkett urges business to back ambitious new drive to bring vocational education into the educational mainstream'. http://www.dfes.gov.uk/pns/DisplayPN.cgi?pn_id=2001_0036. Accessed 21 January 2007.
[6] Not in Education, Employment or Training.
[7] http://www.nuffield14-19review.org.uk/ (accessed 7 April 2007)

Science is peculiarly partitioned across these two policy arenas, and that is particularly the case in respect of its vocational and applied aspect. It was absent from the suite of specialist diplomas proposed within the White Paper 14-19 Education and Skills (DfES 2005), but from mid-2006 an extensive consultation process about its possible inclusion has been mounted.[8] The Nuffield Review has examined the relationship between liberal and more instrumental perspectives on science in the curriculum: but again science as a distinctive vocational domain is less visible.[9]

Science had been available in the GNVQ from its commencement in the early 1990s, though take-up was poor. In 2001, towards the end of the life of Advanced GNVQ, 1,263 students were entered nationally for science (DfES 2002: Table 4.4). As utilised in schools and colleges the qualification appeared to have been judged to be for lower attaining students, in science as elsewhere in the curriculum. The accepted 'vocational' route to professional science remained through A-levels. However, while A-level sciences have had few problems of status, the physical sciences have attracted declining numbers of students. GCSE science does not have this difficulty, though it might be claimed that this is largely because science remains a compulsory subject at Key Stage 4. Pressure on schools to offer science as a double subject has been ongoing, and the Science and Innovation Investment Framework identifies as a headline target increasing the number of students entered for the 'triple award'. Nevertheless research suggests that school science is unpopular among students (Osborne and Collins 2000; Murray and Reiss 2003; Jenkins and Nelson 2005).

Despite the ambivalent position of a vocationalized science curriculum within these various policy domains, the decision to create a new GCSE in Applied Science derives in part from both. However, identifying the precise circumstances of its birth, how it was intended to fit within science provision at Key Stage 4, or even what its specific purposes were, has proved problematic.

[8] http://www.qca.org.uk/18217.html (accessed 7 April 2007).
[9] Nuffield Review Annual Report 2005-06, p.215 (http://www.nuffield14-19review.org.uk/cgi/documents/documents.cgi?t=template.htm&a=129 accessed 7 April 2007).
[10] A small number of schools has used the Intermediate GNVQ, often in IT, to enable students to gain the equivalent of 4 'good' GCSEs, and in recent years this has spread to science. Many teachers view this approach with scepticism, judging to be driven by the league table position rather than the educational interests of students. In 2003/4 4,900 15 year-olds gained Intermediate GNVQs in Science (DfES 2005)
[11] It is significant that these educational targets for science in schools were announced in connection with the Budget, by the Treasury. http://www.hm-treasury.gov.uk/media/D2E/4B/bud06_science_332v1.pdf, section 6.25, accessed 25 March 2007.

3. Creating the Framework for Applied Science

GCSE Applied Science was born out of the demise of GNVQ. As part of its aim of introducing a more vocational strand to the Key Stage 4 curriculum, the Conservative government had introduced what were called Part One GNVQs (Ofsted 1996; Ofsted 1997). They were intended to be equivalent in demand to two GCSEs. After a pilot, which ran from 1995, the qualification was introduced nationally in September 1999. It included the following subjects: art and design, business, ICT, engineering, health and social care, leisure and tourism and manufacturing. This list demonstrates both the occupational mapping of the qualification and its orientation to non-traditional school subjects. As the withdrawal of Advanced GNVQ was announced, and the qualification began its transition to Applied A-levels, it was announced in 2000 that the Part One qualification would be replaced by what were first to be called 'vocational GCSEs' (see Appendix 1). The name was later changed to 'GCSEs in vocational subjects'. Each was to be a double award GCSE. Most significantly for this study, science was added to the list of subjects to be offered.

The sources of this decision have proved impossible to identify, though it is clear from extant correspondence that the idea of incorporating science into the suite of Part One qualifications was already in train before they were phased out. The pattern is peculiarly reminiscent of the post hoc attention given to science in connection with the specialized diploma in 2006-7.
It has not proved possible to identify whether the decision to create GCSE Applied Science had any clear rationale or aims. It seems more likely to have been simply an ad hoc response to the perceived importance of science, when placed in the context of the broader KS4 reform. The publicly stated rationale for the new specifications (which were sometimes generically called 'applied') showed some variation. They were of course integrated into the wider government discourse of increasing relevance to the workplace, greater institutional flexibility in the post-14 curriculum, and so on. Their aims and purposes as represented in public documents have gradually widened. The first announcement stressed 'craft and technician-type jobs', and went on:

Vocational GCSEs … will enable young people to move on to apprenticeships and into jobs. They will also help in the drive to tackle truancy among disaffected young people. (DfES 2000)

The emphasis on disaffection was quickly dropped. Later guidance offered to students by the DfES broadened the emphasis, referring to the possibility of further study in 'an 'AS' or an 'A' level in a closely-related subject' (Department for Education and Skills 2003). Later guidance from the Qualifications and Curriculum Authority (QCA) presented the new qualification in a yet broader light: as an alternative version of the established science curriculum, offering a different teaching and learning style. Students were told that 'GCSEs in vocational subjects keep your options open… They can lead to any of the courses or qualifications that are available to you after year 11' (Qualifications and Curriculum Authority 2004). In the view of many teachers and, it appears, Ofsted (Ofsted 2003; Ofsted 2004) this is a generous judgement.[12]

[12] Applied Science was also ambivalently related to the statutory curriculum. Thus, while it 'can be used to meet the statutory requirements for science', it 'does not meet the full National Curriculum programme of study'. http://www.qca.org.uk/nq/framework/vgcse/information.asp (accessed 9 September 2002).

Though the new GCSEs were derived from GNVQ, politically important adjustments were made. The new courses were to be assessed using the same grading system as established GCSEs courses, and they were to offer the full range of grades. To signal the distinctive character of the new science GCSE it had the word 'Applied' added to its title, as did those others which paralleled established school subjects. The term 'applied science' is in fact no more innocent than the word 'vocational': but it is less politically sensitive and has fewer obvious status associations, though it does have some (Donnelly 1986; Bell and Donnelly 2006). The term 'applied science' was uncommon in the context of the secondary school and its meaning was relatively open: it needed to be converted into a set of concrete practices in classrooms, in the assessment regime and in the curricular structure of schools. In doing so it would need to be positioned within the hierarchies and culture of schools and of their science departments.

These processes and their outcome are a central theme of this report. We will argue that the meaning and positioning of the new course, while deriving in part from what might be called educational arguments about students' learning needs and possible learning outcomes, was conditioned equally by political issues of status and curriculum provision. However the process of realizing applied science began, not in schools, but within the procedures and committee structures of the Qualifications and Curriculum Authority.

The Criteria

QCA commissioned Ken Gadd, a consultant with extensive experience of GNVQ, to create a draft set of Criteria for the GCSE Applied Science. The term 'Criteria' refers to the broad regulatory text under which the specifications would be developed by the awarding bodies. Gadd's draft Criteria derived largely from GNVQ Science. They incorporated some of the key elements for which GNVQ was known: a strong emphasis on portfolios of students' work as a major assessment mechanism, a reduced emphasis on scientific knowledge (with this knowledge being assessed through a formal examination, weighted at one-third of the total) and an effort to focus on science in the workplace. The draft was reviewed and revised by a committee consisting of a small group of science education stakeholders together with officers from within QCA. Awarding body representatives were also involved. Drafts of the material were sent to a wider group including professional scientific bodies, employer representatives and so on.

The detail of this process is less significant to our argument than the fact that this very low key process created a resource from which a novel account of school science was to be created. The committee was creating a possible future trajectory for the science curriculum at KS4, yet the process was largely unheeded by the wider science education community. Partly because of pressure of time the committee appears to have drawn relatively little on this wider community (or at least received limited response from it), including academic science educators and teachers themselves. The criteria which resulted (see Appendix 2) were structurally close to those which Gadd had devised, consisting of three equally weighted Units:

- *Unit 1: Developing Scientific Skills (assessed through specified activities within a portfolio)*
- *Unit 2: Science for the Needs of Society (assessed through an external examination)*
- *Unit 3: Science at Work (assessed through specified activities within a portfolio)*

This structure had a number of professional consequences. First, and reflecting the characteristics to be found within GNVQ, it combined prescription with flexibility. To teach the course, with the exception of the subject knowledge assessed through the Unit 2 examination, science departments in schools only needed to ensure that their students produced portfolios which met the assessment requirements of the specification. This mode of curriculum formation provides a relatively abstract framework, within which teachers work: as a corollary, they are apparently allowed a large amount of professional freedom. What this freedom amounted to in practice we will discuss in a later section. Also embedded within the emphasis on portfolios in Units 1 and 3 was the possibility of freedom for students: it appealed to the idea of students working, and learning, with a degree of independence unheard of within the stereotypical investigations and examinations of established double award Science.

The second characteristic of the Criteria derived from their vocational emphasis. The Criteria began by stating that the specifications 'should enable students to develop a broad knowledge and understanding of the science sector' (Qualifications and Curriculum Authority 2002: 1). The question of whether science can be understood as a 'sector' may seem an arcane one, but it has continued to trouble those seeking to reform the science curriculum along these lines, up to and including the exploration at the time of writing (Spring 2007) of the possibility of creating a specialized diploma. The opening section of the Criteria invites a number of important questions such as: which form of (scientific?) employment is the specification meant to be related to, and, critically, how, if at all, does it differ from the employment for which the established science curriculum and specifications prepare students? Is this specification intended for students who are likely to pursue progression routes different from those associated with traditional courses? Or is it mainly about motivation, attitude and a distinctive approach to learning, so that students might still go on to pursue the full range of scientific courses, and, eventually, occupations, both scientific and serviced by the sciences? These questions may seem remote from the day-to-day concerns of teachers of Applied Science in classrooms. Yet they were and remain critical to the positioning and meaning of Applied Science in schools.

The specifications

The specifications produced by the awarding bodies needed to relate very closely to the national Criteria. There was some variation in the detail of how portfolios were to be developed and assessed within schools, but these differences were subtle, if occasionally significant for the practicalities and grading of portfolios. As discussed elsewhere (Bell and Donnelly 2005), the major difference was the manner in which awarding bodies assessed Unit 1. Approaches ranged from considering a student's best-ever marks, to schemes that were more representative of a pupil's typical work. AQA, for example, adopted a 'best mark' policy. It was described at training events and by its personnel in interview, as allowing students' development over the course to be recognised, and thus as a 'selling point'.

Each of the three major English awarding bodies (AQA, OCR and Edexcel) offered a range of training (supported, as we will see, by DfES), which extended well beyond a narrow focus on assessment. This reflected an acknowledgement that the degree of support offered is an important marketing aspect of awarding bodies' work. Overall, responses to our second national questionnaire (see Appendix 4) demonstrated no significant differences in teachers' judgements on the quality of this training, in respect of its relevance either to teaching or assessing the course. Most respondents rated the training of some value in both areas.
Nationally, schools were distributed unevenly across the four groups offering the specification, with about half following AQA, about one-third OCR and just over 10% Edexcel. It seems unlikely that this reflected anything other than schools' historical preferences, though a few seemed to have looked systematically at the possibilities, as in the following quotation from a Course Leader in one of the fieldwork schools:

I thought the assessment criteria for AQA were better […] I thought it was an easier assessment than the other two […] also I though it was easier to deal with one examining board. (Einstein School, CL)[13]

The new specifications were developed, assembled and submitted to QCA by relatively small teams within the awarding bodies. Like everyone else, these teams had little idea of how the specifications would be employed in schools, or located within schools' other science provision, though they no doubt could make a shrewd guess about their likely positioning. Generally speaking the teams' formulations of the aims and rationale of the new specifications embodied the same language (e.g., of vocational relevance and independent learning) as that employed by the DfES and QCA.

[13] All school names are anonymized, with interviewees coded as: Course Leader (CL: may or may not be Head of Department); Teacher (T1, T2 etc).; Senior Management member (SMT); Head of Science (HoS).

4. Schools' Take-up and Interpretation of the Course

The growth of Applied Science during its first three years was steady if not dramatic.

Table 1: numbers of schools in England offering Applied Science and students entered for the examination, 2004-6

Year of assessment	Number of schools	Number of students
2004	238	8916
2005	477	18,184
2006	not available	27,471

Sources: Joint Council for Qualifications: *http://www.jcq.org.uk/attachments/published/287/GCSENEW%20(9).pdf* (accessed 15 January 2007) and National Pupil Database.

In this report one of the key themes is the 'positioning' of GCSE Applied Science within schools. That positioning was manifested first through the characteristics of the schools which did or did not adopt the specification. The specification was not heavily publicized, and it appears that the process by which schools learned of its existence was haphazard. Schools that had adopted the course and responded to our first national questionnaire (NQ1: see Appendix 4) were heavily biased in favour of comprehensive and specialist colleges. Only three out of 113 maintained selective or independent schools that responded had adopted the course, compared with a take up nationally which we estimate from National Pupil Database returns to be about 14% (477 schools) in the maintained sector at that time.

Schools which chose not to offer the course and responded to NQ1 (n=333) gave a wide variety of reasons, and usually more than one. In broadly decreasing order these were: the time pressures of setting it up (42%); lack of relevant teacher experience (38%); dissatisfaction with the perceived emphasis of the course (37%); and the cost and availability of resources (32%). In free response answers a number of schools suggested that a heavy emphasis on coursework would be to the disadvantage of their students. About one-quarter of schools had never considered Applied Science. Cluster analysis [14] suggested that most schools offered a broad combination of these reasons, but a significant minority (about 20%) focused on issues of status and lack of a clear progression route. Independent and selective schools were heavily represented in this group.

Among schools which had taken up Applied Science the decision had often been conditioned by wider developments within school policy, although usually a link was made between these and the perceived needs of students. In only about 13% of the schools which responded did the Head of Science see the decision as having emanated from the school's senior management. Again, cluster analysis of the data suggests that these schools tended to form a distinct group. Their representation in the questionnaire responses (about one in ten) corresponds broadly with that in our fieldwork schools.[15] A large proportion of respondents (nearly 60% in NQ1) suggested that the decision fitted a broader school policy, to offer a more vocational route through the KS4 curriculum, a practice which appears to be growing (Ofsted 2005: 1; Higham and Yeomans 2006: 31). In most cases, however, the judgement, and the decision to take up the course appeared to be conditioned by the views of staff in the department. An example of the type of account offered by science staff in our fieldwork schools, crossing a range of issues, is given below:

We felt that […] the traditional type of science course, didn't really meet the needs or interests of the kids, and the applied courses provided greater scope for…learning which was directly relevant to the real world, in terms of science technologies. It was also as a result of our science college bid that a lot of the sort of impetus and advice is to look at those types of courses. […] and also the style of assessment, I think it lends itself much more to sort of short-term targets, rather than, you know, one end-of-year, end-of-Key-Stage examination and so the kids could work steadily throughout two years. (Crick, SMT)

From the perspective of a Senior Management Team (SMT) member (in a different school) the situation appeared as follows:

[…] we are really looking at land based studies as a possibility, alongside the Engineering, and Health and Social Care, for the least able, and that's where we will be looking for the science department. There's already a great deal of experience and expertise there, and that hopefully will be able to build on some of the work they are doing in Applied Science. (Feynman, SMT)

The early coding of the specification towards lower-attaining students is usually apparent in these comments.

In a perhaps predictable pattern, schools where the decision to offer the course had closely involved the Science Department appeared generally to have had greater success than those where the decision had been essentially taken by management. However this kind of generalization does not capture the varied dynamics of the process. One questionnaire respondent offered the following commentary:

[We] lunged into it under specialist status. It's taken 3 years to convince SMT that we should choose students. It's injected enthusiasm into some staff and the community links are invaluable. It's underpinning our resubmission for specialist status. (Respondent's emphasis)

In sum, a linkage to a broader school policy was common: 59% of schools which had adopted Applied Science identified such a link in NQ1. However it was not necessarily helpful if it meant that science staff involvement was not wholehearted. Moreover, it could also reinforce the position of the qualification as targeted on lower attaining students, a perspective which barely needed reinforcement.

Despite such broader policy linkages from within SMT, and wider evidence cited above that schools are adopting more or less explicit 'routes' through the curriculum, science staff interviewed during the fieldwork rarely communicated any strong sense that their course fitted within a wider vocational agenda. Responses to both national questionnaires demonstrated a focus among science departments on a specifically science curriculum reform, in approximately equal

[14] SPSS two stage analysis, with schools' responses numerically dichotomized.
[15] In several fieldwork schools accounts were vague or conflicted, but in a two cases (Bunsen and Faraday) it seemed fairly clear that SMT pressure had been critical.

balance with the hope of better examination results. An emphasis on preparation for the workplace was less common both in questionnaire and interview responses. As we will see below, where it occurred, its meaning as articulated by teachers in the fieldwork in schools was commonly very broad.

Table 2: schools' reasons* for offering Applied Science

Aim	Percentage agreeing with this aim
relating the science curriculum to everyday life	85
better examination results	81
encouraging independent learning	60
preparing students for employment	54
encouraging assessment for learning	30
attracting more science students post-16	22
other aims	12

n=149

* this question offered a fixed set of responses, derived from those offered by schools in our fieldwork

In our view this pattern of interpretation of the course was equally visible across the fieldwork in schools, interviews, classroom observations and schools' schemes of work. There was, if anything, rather less emphasis on preparation for employment in these latter sources. A small minority of teachers identified the specification as clearly work-related, though with an orientation towards more routine technical work:

Well I could see that it is a very good base for anyone who is going into like, into this technician style role because quite a lot of the things, say like titrations, if they're making up standards or checking, doing stability work, or anything like that, quite a lot of the skills from what I've seen in industry could be really easily applied. (Bunsen, T)

There is a mixture of complex and sort of simple instructions they need to follow. They are not encouraged to write plans because that's not part of what a scientist would necessarily do in the workplace, but they are encouraged to follow standard procedures. (Rutherford, CL)

Whether such comments reflect either an important aspect of the reality of the industrial role of science, or the likely future progression of the students involved are more problematic questions. In some cases the school was part of a Pathfinder or IFP scheme (Davy, Pathfinder; Einstein, IFP). In such schemes the applied subjects more broadly were often of particular significance for disaffected students (Holland et al. 2003). The types of employment which students identified in the evaluation of the IFP (O'Donnell et al. 2006: 52), or in the focus group discussions with students which we held, did not include science in its more established sense. Thus, within a group of Y10 and Y11 students at Halley School, members planned to become a physiotherapist, a beautician, a car mechanic, a musician and a chef.

More generally, however, science departments tended to redirect the notion of vocationalism, or 'science as a vocational subject' towards a well-established science education agenda, using it as a code for a reformed science curriculum:

Well I think all the vocational stuff making it relevant is […] there's a massive resource out there, you know, the real world, that we're having to engage with and use to help us to teach them. (Hodgkin, T)

Within these comments Applied Science can look like a resource for teachers, in the sense of an opportunity to develop their own perspectives, rather than a clear policy shift towards a vocational curriculum. The specification might even be seen as what Ball termed a 'readerly text' (Ball 1990), enabling creative interpretation: though whether it was intended in this way is another matter.

These are of course teachers' broad comments on the specification. It needed to be converted into a workable reality within school policies and departmental practices. It was within this process that 'Applied Science' as a set of possibilities was realized and positioned within schools. The following sections give an account of this more detailed realization, and its impact on the meaning and significance of the specification.

5. Positioning Applied Science in Schools

Identifying students for the course

Well, we try to stress that in Year 9, when they do their options, that they have to do 14 pieces of coursework over 2 years, but then, we sold it to them as well in that they only have to do one exam, which they could re-sit. And we said that it was obviously for those people who weren't thinking of doing science as a science, that it was more diluted down. And we did stress: don't – this is not the course for you if you're not interested in doing 14 pieces of coursework. (Davy, T)

I think really we have got to–and we do look at specific students, in which ones we actually target to do the course. The students aren't given the overall choice, we choose the students and I think we have got to do it like that because if you get someone who is a bad attender and they are missing the coursework obviously they get penalised because it's not done. (Boyle, CL)

The first cohort we had through [asked], 'Is this the Noddy science that stupid people do?' […] But that hasn't happened in the [current] Year 10. It's quite the opposite, you know, it's more, 'Why can't I do this, because it's far more me?' you know. But initially there was a, 'Why are we doing this?' (Crick, T)

Arguably the single most important element of the process of positioning the course involved decisions about how it was to be made available to students. Parents were 'reflexively' involved in this decision: that is, they were rarely involved actively, but their anticipated, and in some cases observed, responses were important. We will discuss this aspect of the process in the following section. Schools were asked in NQ2 about their approach to identifying students for Applied Science, using fixed response options derived from fieldwork, and their responses are shown in Table 3.

Table 3: How students were identified for Applied Science

Criterion	%
Selected by staff: students who might move across the D/C borderline	58
Selected by staff: students with particular aptitude for coursework	50
Selected by staff: students disaffected by traditional/ double award science	34
Selected by staff: students with good attendance	30
Free choice by students/ parents	25
Other	13

n=149

Schools adopted a range of approaches, but future attainment through examination performance was a central theme around which the issue was configured. The likely impact on students' expected grades was of course a highly judgemental process in the first instance, and might even be thought a self-fulfilling prophecy. Targetting the C/D boundary, with the aim of enabling students to pass through it, was particularly characteristic of the selection process: the significance of this for the specifications' positioning within schools can hardly be overstated. The group of students involved was distinctive in terms of attainment levels, but also in some behavioural and attitudinal characteristics.

There were of course differences in emphasis, and changes over time, in teachers' and schools' responses. Thus, in one school, Applied Science students were said to be chosen on the basis of those who would 'freeze' in exams, or could have coursework 'nagged' out of them (Maxwell, CL). A questionnaire respondent described the course as follows: 'The ideas behind it are sound and it allows students who would have found 6 modular tests in Year 10 an effort a chance to succeed'. One of the schools which ultimately abandoned the course had employed a different tactic:

We recognised that we were very definitely going to do this as a pilot and we said: 'Okay, who are the kids who aren't going to do well on the other course but who should be able to get a C? Let's try them on this other course.' […] By having a whole group of disaffecteds, they've loved doing the practical work, they've hated doing any writing up. (Bunsen, CL)

This school entered students who had performed relatively well at KS3. However their eventual performance at GCSE was well below target, and indeed what was achieved by schools nationally (see section 9 below). The tactic of targeting disaffected students, which might be thought to have been encouraged by the government's early rhetoric, was rare and in this case ultimately unproductive, though in other settings it appears to have been effective (Holland et al. 2003). Applied Science required above all else a degree of co-operation on the part of students in producing coursework. Bunsen School found itself in difficulties in this respect, a circumstance not helped by a delay before addressing the difficulty.

The emphasis on attainment level was often linked to comments on students' approaches to work:

It has a very distinct student type I think, and I think you can have very able students doing it, […] They would prefer to do practical type work and are much better at working continuously through the year, rather than cramming for an exam. But they are bothered enough to go back and re-do things, they don't mind re-looking, re-assessing their own work. (Faraday, T)

In a number of cases schools expressed the rationale for the course in terms of catering for students' supposed 'learning styles' (a notion in vogue at the time of the specifications' introduction), while making little reference to academic attainment. For example, the SMT member at one school who was also a science teacher and a Lead Practitioner within the Specialist Schools and Academy Trust (SSAT) described the reasoning behind taking up Applied Science as:

[…] an attempt to meet the needs of different pupils, both in terms of ability, but more in terms of learning styles […] What we were determined to do is, we wanted a course that was for the whole ability range, and you know,

in some schools, the Applied Science course has become the course for the least able, and we definitely didn't want to do that. (Davy, SMT)

But the link with attainment was not easily avoided, in part because of the anticipated influence of the knowledge and expectations of parents. In particular, though teachers' views showed some variation, a large majority, including the person just quoted, judged that the course was not an adequate preparation for traditional A-level sciences:

With the nature of Applied Science at the moment we felt that we had to say to pupils who were considering doing A level sciences that maybe this wasn't yet sufficient preparation, there wasn't the obvious progression there. (Davy, SMT)

However this interviewee offered a fairly relaxed view of the course for those judged unlikely to pursue science further, whatever their attainment:

But for those pupils who were good at science, but they were already clear that they didn't want to study science post-sixteen, … it was an entirely appropriate course for them. (Davy, SMT)

This was by no means a universal view: the SMT member at Feynman School clearly indicated that high attaining students, whatever their likely progression post-16, would not be allowed to study Applied Science. A further variant of the linkage with pupil attainment was found in Halley School which had deployed the course with its lowest attaining students. However, despite an ongoing improvement in student performance, beyond predictions, the teacher in charge of the course felt that staff and student efforts to achieve the best grades possible were not being recognised, since the grades gained were below the critical C threshold.

With so much coursework involved, good attendance was often judged to be a pre-requisite. In some cases, this could lead to somewhat paradoxical decisions. In Crick School all students whose other courses took them out of school at times which would mean they would miss science lessons were excluded from the course. This had the effect of barring all students on 14-19 Pathfinder programmes.

Other influences, while powerful, were more localized. Thus, in Curie School where the course was introduced as an option after initial trialling, the teacher running the course waited to see who opted for it, then 'weeded out' students considered to be 'time wasters and trouble makers'. She only entered students predicted to get below a D grade if they were 'good practical scientists'. Again however, anyone thought likely to wish to study science after compulsory schooling was not included. Perhaps because of this careful management of the group, this school succeeded in obtaining results which, on a value-added basis, were substantially better than the national pattern (see section 9 below).

Fieldwork schools displayed changes in approach over time, but on the whole, they adapted rather than transformed student selection criteria. For example, at Boyle School the first year's intake was based on judgements of the suitability of the assessment regime, to which was added, in the second year, students' attendance records.

In some schools where the course was judged a success, critically in terms of students obtaining grades above those predicted from KS3 attainment and other targeting systems, the course was extended to students of higher attainment (Feynman, Halley, Boyle, Rutherford). While largely appearing to be driven by pressures to improve GCSE grades, this could be combined with teachers' positive judgements about the educational and motivational quality of the course. Distinguishing these different judgements and pressures is however difficult. Some modifications were carefully targeted. In Maxwell School the staff reassessed the level of demand posed by the course and excluded the lowest attaining set. Rutherford, a school visited in the first and third rounds, in part because of its success with the course, was distinctive in that it had both begun to include some students likely to attain a B grade at GCSE and extended the course to lower attaining students, who had previously taken a Modular course at Foundation level.

Schools soon found that practical considerations, such as class size, were critically important to the course. A member of SMT at Hooke School, suggested that two classes of eighteen were manageable; a larger class size was described as 'absolutely impossible' by a Head of Department elsewhere:

There is no way at all that I could deliver the style of lesson to a class of thirty. I mean thirty pupils doing different things in a room would be a nightmare. (Crick, CL)

Even if class sizes remained small, pressures remained: numbers could be problematic in terms of visiting workplaces where there were strict rules about small visitor groups.

Overall, and despite these variations across schools, the two key elements in the process remained, first, raising attainment in the critical C/D area, and, second, articulation with future post-16 possibilities. This latter element involved attention both to possible progression routes and, where appropriate, not undermining the viability of traditional post-16 science courses. Despite some tendency to raise the upper ceiling in several schools, potential students on traditional A-level sciences remained an absolute horizon. The issue was, however, not immutable from the student point of view: in a few schools where the course was successfully deployed and had the effect of raising attainment, some Applied Science students were found, against expectations, to be showing an interest in studying A-level science. They had also achieved the grades, albeit Applied Science grades, to do so. This could evidently raise issues of comparability with traditional Double Award. We will return to this point as part of our discussion of progression below (see footnote 33 below).

Managing students' and parents' choices

The kinds of judgements quoted above did not of course occur in isolation: schools needed to take account of the views of students and parents. One-quarter of schools, in responses to NQ2, claimed to operate a policy of free parental or pupil choice. However, we did not find any school in our fieldwork where such a policy appeared to be clearly in operation.

In most cases the science department selected a number of students who were thought to be suited to the course, and usually contacted parents. There were no reports of extensive objections: we will qualify this point below. There are indeed examples where after a careful rationale had been explained, and if the course was perceived as going well, parents appeared quite supportive of the innovation. Rutherford School, decided to trial the course with a class of 25, and a number of parents were consulted at parents' evening. More were enthusiastic than expected, leading to an initial cohort of 39 students divided into two groups. Schools reported a steady trickle of discussions and responses to parental concerns which needed to be allayed: but few appear to have led to serious problems. Schools rarely seemed to press the point against resistance, and were generally willing to adjust students' courses if necessary. All of this was facilitated by the position of science as a core subject, and the relatively uncomplicated timetabling arrangements which the introduction of Applied Science usually required. According to a member of SMT at Maxwell School, echoed elsewhere, parents were strongly reassured when told that the course had progression opportunities and that it had the value of two GCSEs.

Identifying a clear horizon for the course, and largely excluding potential A level candidates, as happened in most schools, effectively removed a large group of parents and students from the process. When the course was extended up the attainment range, parents tended to want more information and reassurance. The Head of Science in Darwin School, where this had happened, commented:

This year I think because we have introduced it into set three there's been a little bit of more come back. But I mean we have a Year 9 option booklet that goes out and on its heels is a Year 9 Parents' Evening. So we spent the parents' evening explaining to those parents what Applied Science is all about and why it should be better for their kids than traditional science, and really it hasn't been a problem. (Darwin, HoS)

In Halley School which offered the course to its lowest attaining Y10 students it was in the case of the child of a teacher where the most serious debate appears to have occurred. Even here the school's judgement that this course would play to the student's strengths appears to have prevailed. The Course Leader summed up the situation:

I had a couple of kids this time who could have gone either way…and one went to the GCSE and one to the VGCSE […there are few objections] as long as people know it's A to G…* (Halley, HoS)

The final comment in this quotation, about the availability of the full range of GCSE grades, was also referred to as an important issue by several teachers, though only about 1% of Applied Science students have gained A and A* grades nationally. In one identified case a parent was recorded as appealing to governors about the placement of their child in Applied Science, though the outcome was not recorded. While most schools had something to say about parents, governors were more rarely identified as requiring reassurance. At Faraday School there was an account of a governors' committee meeting at which a good deal of reassurance and 'selling' had been required in response to a charge of 'dumbing down'.

Such formal policy processes were rarely mentioned during interviews, but status, and the means by which it was expressed within the school, were never far from the surface within teachers' accounts of the course. The exclusion of parents who might be more attuned to the issue may have contributed to the absence of debate. In a small number of cases interviewees stated explicitly that the most academically able students would not be allowed to take the course:

I don't ever see us being allowed to say to our very bright kids 'You can do Applied Science'. I just don't think parents will wear it. (Darwin, HoS)

Hodgkin School was a secondary modern[16], and had taken the decision to enter all students for Applied Science.[17] While the staff at the school considered the decision to have been justified and successful, and the school performed well by national standards, it gradually began to have repercussions for the practice of transferring students to the local grammar school post-16. By the second fieldwork visit, in round two, an increase in relatively high-attaining students at GCSE (perhaps, ironically, as a result of the new course) was becoming an issue. The SMT member interviewed suggested that one way forward might be for such students to take the course early, and then use the rest of the time pursuing more traditional academic science in preparation for A Levels. A member of the science department noted that the parents of some Y7 students had made it known that they wanted their children to take separate sciences. There was also indirect and anecdotal evidence, in relation to an unnamed school that we did not study directly:

I just know there's a school in [a nearby place], […] who moved all their kids onto Applied Science and there was an absolute uproar from parents saying it's going to restrict our children's choices, and that is true, it does if they are going to do A Levels. If they want to do A Level Science, it isn't good preparation for some of them. (Rutherford, SMT)

In sum, where Applied Science moved outside a carefully managed position in relation to those parents and students following the course, issues of status and progression quickly began to arise.

[16] This term was not used, but the school served the local area together with another, selective, school.
[17] NPD data suggest that there may have been between 20 and 30 such schools across the country. The conditions of use of these NPD data mean that we are not allowed to identify or approach schools on the basis of them.

Staffing the course

- I. *(Overall)…what do you think of Applied Science?*
- T. *The potential to be superb, that's the simple answer. It has the potential to be superb and it has the potential to be an absolute failure.*
- I. *Really?*
- T. *And the people that make the difference are the teachers. I think, at this school, we will make it superb because it's got levels of support from the top to bottom, and we genuinely care for our children.* (Crick, T)

How the course was staffed, including how it was managed and led, was a further aspect of what we have termed its 'positioning'. This issue can be interpreted in terms of the relationship between the department and SMT, and the extent to which the course had clear lines of responsibility. At the two fieldwork schools within the study which took the decision to drop the course during the lifetime of the project it had been introduced as part of management initiatives. At one a team member said,

[…] we've not been clear about who's had the overall responsibility for the administration of the course […] as opposed to it being, 'Oh, you three are teaching it. Sort it out amongst yourselves'. (Bunsen, T)

At the other (Faraday) the Head of Science remarked: 'It would have been better if we had been allowed to decide for ourselves whether to take it up'. The lead teacher responded to a question about responsibility as follows:.

- I. *…you don't have an official responsibility?*
- T. *No I don't […] It was just put out there for, if anyone was interested. I was happy to take it on, so if nobody was happy to take on, then, yes I do not know what would have happened then to be honest. And then we met at the end of last year all sat down the four us and then we sort of started to plan it and then we had different roles of looking into different areas and resourcing it or whatever and just setting it out.*

Faraday's decision to drop Applied Science was particularly associated with a reduction in students' marks during moderation. Whether or not this was a consequence of the absence of clear lines of responsibility—somebody, as it were to 'worry about the course', the standards and procedures being employed and the degree of engagement with awarding body guidance—is unclear. However it seems probable that it contributed.

In the response to NQ2, only about half of schools suggested that the course had a designated leader, and only 30% indicated that its direction attracted any salary allowance. In the fieldwork schools it was common for the Head of Science or Key Stage to take on this role:

[The Head of Department] would obviously take the lead. So he chose to do it […] So basically, what he's doing, is he's leading the way and he's getting people on board and he's just got to evaluate it and make sure the results are good. (Einstein, SMT)

I have been Head of Science, and just making sure things are on track, and you know, at the minute we have departmental meetings where we talk about Applied Science … so I mean, really, I have been in the role of kicking and shoving where necessary and just really ensuring it's on track. (Darwin, CL)

But a senior staff member was not essential to success, and at one school a relatively junior teacher had successfully taught the course single-handedly with one group of students, displaying a quite unusual degree of preparation, for example in designing all assignments before the start of the course (Joule). In another school the appointment of a relatively inexperienced but energetic teacher specifically to run the course had transformed it. The appointment could be claimed as the source of the success of Applied Science in the school, and subsequent expansion, until it dominated the school's provision outside the single sciences (Feynman). While it is difficult to generalize about how the course might be staffed, committed and identifiable leadership (though 'responsibility' would probably be a better word) was, predictably, close to a precondition for the course to be visibly successful.

Other 'critical success factors' in relation to staffing were more difficult to identify. Responses to NQ2 suggested that only 20% of schools had chosen staff on the basis of industrial or GNVQ experience. Some teachers without industrial backgrounds tended to see this lack of experience as a deficit, while teachers with such a background saw it as an advantage though not crucial to the success of the course. One Head of Department concluded:

I've heard a lot of reference to people that this course would be better taught by people who have come out of industry and who have a background in Applied Science, in actually applying Science, and I don't agree with that at all. I think the best people to do it are good teachers, who know their kids and are willing to get their heads around a new course and work out what the kids need to be taught. (Hodgkin, CL)

Good quality exposure to industrial settings also seemed to go some way to compensating for absence of work experience, though we found few examples of teachers identifying such experiences.

[The local Business and Enterprise Partnership] put on a course looking at British Sugar. We actually got the opportunity to go to British Sugar, [...] and relate it to what went on in the factory for Applied Science. So they picked out some bits on chemistry, loads of bits of biology and some bits about--for the physics, like the efficiency, and it was an amazing day because we went through loads of stuff which they prepared and then we actually went round the factory and watched it working; it was just like, it was amazing to see what happens to the sugar beet. I've never done anything other than science, than chemistry teaching, so I've never been in industry or anything, and I knew that's really what I needed to do to get some ideas, especially for this applied stuff and I think it's essential. (Hodgkin, T)

Several teachers suggested that experience of teaching GNVQ, with its emphasis on portfolios, and forms of student responsibility for portfolios, was helpful but not essential. One Head of Department said of the process by which staff were identified, 'we sort of knew we needed some people with portfolio work' (Boyle).

Classroom experience in what could be a challenging and complex environment was usually judged more important. Such teachers were described in one school as being:

Happy with the style of delivery, you know, happy with letting pupils work at their own pace, or on different assignments, all at different stages. […] I think you've got to be able to manage that situation, and I think unless you have got some experience, it's not easy. You know, by that situation, I mean twenty pupils all at different stages. (Crick, CL)

Several teachers commented on the importance of staff being able to build a long-term the student/teacher relationship:

[…] my passion is for children. I have a passion for science and I have a passion for young people and my greater passion, I have to say, is making sure young people are happy. (Crick, T)

One teacher extended this, describing a 'typical' Applied Science student as 'the sort who want reassurance, they want guidance, they are just unsure of a few things' (Einstein, T). It is of course possible that such 'typicality' may have been itself a construct of the school's approach to the course. Another teacher who discussed this aspect of Applied Science expressed the position differently, suggesting that the teacher-pupil relationship was a by-product of the course: it resulted from staff having time to talk to students during the extensive laboratory work and related portfolio activity, and contrasted it with more transmissive style of other KS4 science courses (Curie, CL). Whatever pattern of cause and effect may have been in play, several teachers commented on the distinctive quality of the teacher/student relationship which was associated with successful teaching of the course.

Within NQ2, nearly half of schools indicated that the course was staffed by volunteers, and, of course, whatever the degree of planning and choice that was attempted, for many schools the staffing simply depended on who was available when. There were few examples of reluctant teachers amongst those we interviewed though there was occasionally some allusion to this from other staff.

I *Any staffing issues?*
T. *Apart from staff not wanting to teach it?*
I. *Is that an issue?*
T. *It was at the last school, very much so, to the point where it got dropped after I left completely, because nobody wanted to teach it.*
I. *Right.*
T. *But here the people are quite enthusiastic about it.* (Feynman, CL)

This issue could also prove more significant if the course was successful, as teachers were brought in to teach a larger group of students. In these circumstances there was some, again indirect, evidence of resistance. 'The crunch', as the Head of Department in Millikan School put it in connection with changes in staffing, 'was that they did not want to teach it'. She thought this aversion was not to do with the different teaching style, nor the fact that staff would probably be teaching less highly attaining students, nor that the course was 'vocational': it was mainly to do with the amount of marking.

Teachers' disciplinary specialisms are an important cultural and intellectual feature of school science departments and were sometimes accommodated in the organization of the course. However, in response to NQ2, only about 16% of schools indicated that provision of specialist teaching had been a key issue in staffing the course. In this schools appear to adopt a somewhat different attitude to their approach to Double Award Science (Donnelly and Jenkins 1999). Boyle School moved from parallel teaching by two teachers across the specification, to teaching by subject specialists in sequence. This was thought likely to encourage a greater interest in science post-16, and to be less confusing for students, as they only saw one teacher for solid blocks of time. By contrast, in Crick School, which had also been running the course since it became available, the fourth year was to see a staffing switch from subject specialists to a pair of teachers. The senior of the two had decided in the third year of the course that Applied Science was not about separate science subjects, but about problem-solving, researching, and 'about the skilful scientist, and not the science of biology, physics or chemistry' (Crick, T).

The course made greater than normal demands on non-contact time. In some schools many administrative tasks, such as preparing portfolios for internal standardisation and external moderation were undertaken by non-teaching staff. Many teachers also spoke of the time-consuming task of contacting industries in order to set up visits or arrange visitors into school. In two specialist science schools (Ramsay, Rutherford) this was undertaken or supported by an administrator. In one case this person also developed contacts with the local Press and helped maintain and strengthen industrial links.

In some of our fieldwork schools Applied Science staff appeared to be a distinct grouping within the department, while elsewhere teaching the course was judged a whole department responsibility:

[…] so we do it as a department, so we get ideas from people. But maybe they don't want to deliver it, but maybe they have got a really good idea, or they're really imaginative and they come up with all these creative scenarios and then we can develop that further. But I think it has definitely, it has got to be a team effort. (Bunsen, T)

In the open-ended responses to NQ2 the following observations were made by two teachers: 'It is a course that needs very dedicated staff' and 'I would recommend it to as many departments as possible (as long as you have committed/enthusiastic teachers)'. These quotations clearly reflected the findings from our fieldwork.

In sum, Applied Science did not display the same clear positioning in relation to staffing as was detectable in relation to school type or the selection of pupil. The variation across schools was considerable, with a wide range of teachers and staffing arrangements observed. Enthusiasm, energy and organization were however prerequisites, not least because, as we will see, schools were to a significant degree left to their own devices in developing the courses.

6. Creating the Course

In terms of when we first started it two years ago in September, we knew very little about the course. We had no textbooks because […] no books came out on time. We didn't actually receive the books I don't think until February, so we were kind of teaching it off the top of our heads, without any resources at all, and using normal GCSE textbooks […]'teaching blind' I think, would be a good description. (Boyle, CL)

Yes, 'planning' is maybe being a bit generous. … I did roughly map it out, but I gave ownership, initially, for the Physics and the Biology sections, to the other members of staff. And then when it al went pear-shaped, we were just on fire-fighting, and it's whatever worked. (Bunsen, CL)

I love the course, but organizing it was like running through a forest at night. (Ad hoc conversation with a non-fieldwork teacher of Applied Science).

In a survey undertaken in connection with the new specifications as a whole teachers of Applied Science were among those who felt the least well prepared: nearly half (44%) suggested that they did not feel their preparation was adequate (Qualifications and Curriculum Authority 2006: 16). We judge this an optimistic figure when compared with the responses and experiences of teachers in our fieldwork schools.

Resources and support

Given the demands which the course made, including its relative novelty, support for teachers would have been very welcome in most schools. Those who started with the course in 2002 were under some pressure even at the level of laboratory equipment.: '[…] the biggest expense would actually be the quantitative Chemistry glassware. I had to use my A level stuff and I had to say, "If you break this, you're dead."' (Bunsen, HoS). But issues of material resources were (relatively) easily addressed, in some cases through resources deriving from specialist school status. Understanding how to teach the course and organize its assessment was the real challenge. Overall, the support which was provided simply did not meet the needs of schools or their staff.

This is not to say that a good deal of support was not available. DfES funded awarding bodies to extend the training which they provided, and this meant that a good deal of free provision was available. Around 80% of schools had received some training in teaching and assessing the course through this route. Teachers' responses in NQ2 suggested that this was the dominant source of training.

Table 4: the training that staff received

Training by	Teaching (%)	Assessing (%)
Examining group	79	87[18]
In-school	46	46
LEA	35	33
Other	35	22

n=149

[18] Lack of publicity for awarding body training, staff turnover and lapse of collective memory, may account for the nearly 10% of schools which claimed not to have received any such training.

However an underlying difficulty with this approach was, first, that awarding bodies were principally associated in teachers' minds with assessment and, second, that however expert their officers, they had no more experience of teaching this novel course than most teachers. Nevertheless, in their responses to NQ2 teachers judged the provision reasonably positively. Some 71% thought the examining group training had been at least of some use in teaching the course (31%, very useful), and 82% thought it at least useful in assessment (49%, very useful).

A range of other support material was available. The DfES funded the development of resources by the Centre for Education and Industry at the University of Warwick. These were made available freely on CD, and through the Learning and Skills Development Agency, as it then was.[19] The Science, Engineering and Manufacturing Technologies (SEMTA) sector skills agency established a website intended to provide a central gateway to relevant resources.[20] It is not a criticism of these resources to observe that it was very rare for any of the teachers whom we interviewed to know about them. It might however be construed as a criticism of an approach to teacher development which relied heavily on such disembodied resources, and expected them to have a significant impact in schools. A rather different web-based resource was available through the then Specialist Schools Trust: it offered case studies of effective practice. Again, however, it was rare to find schools which were aware of these materials.[21]

Most departments found it difficult to convert the specification into a teaching scheme. Some teachers made comparisons with other specifications, such as those generated by the Salters' Institute, which they had found easier (Hooke, T). The significant point here is that the Salters' specifications are not merely specifications, but adjuncts to courses, developed in conjunction with teachers and academic science educators.[22] Whatever the merits of the resources referred to above, they were created not as part of the development of a 'course' in any proper sense. Teachers seemed often to look to the awarding body documentation to provide this, but that was beyond its immediate remit:

I've looked at the schemes of work, things like that, and what we found was that because the schemes of work were received late, the initial time when we started teaching it, we didn't use because we just started and then you got into it from there. (Boyle, CL)

The challenge teachers experienced stemmed partly from the need to realize the 'vocational' aspect of the specification, but to an at least equal extent it reflected the novel (for most) portfolio-based assessment regime. Often the expression of these difficulties was linked to more detailed complaints: teachers felt that guidance was changed arbitrarily, or that they lacked explanations of how certain criteria were to be interpreted, or how to structure the awarding of five marks for three tasks.

In fact, the specification presented a major challenge for both teachers and awarding bodies, and most criticisms of the latter tended to be of the initial phase. One Head of Science commented:

[19] http://www.vocationallearning.org.uk/teachers/cei/science/ (accessed 12 January 2007).
[20] http://www.gcseinappliedscience.com/ (accessed 12 January 2007).
[21] http://www.specialistschools.org.uk/ (accessed 12 January 2007: registration required).
[22] http://www.salters.co.uk/institute/curriculum_gcse.htm (accessed 12 January 2007).

The guidance we got towards the end was brilliant, the early guidance wasn't, and I guess from the Exam Board's point of view it was experience for them, that they modified it, but it didn't help us. It would have been more helpful if that had all been sorted out before we started on the course, maybe that's not possible and maybe the people who have been starting it from the second year are going to benefit. I guess we, having gone for it right from the beginning was perhaps a disadvantage. (Crick, CL)

Assessment issues were of course more clearly within the awarding bodies' remit, and one teacher described the benefit of attending a training session very positively:

We got a very nice portfolio of how to mark coursework, and we then used it to mark our own. [It made] a huge difference. It actually made sense, yes, because the criteria for marking it is just so vague. […] Yes – 'this is worth marks 5-11', and there's just three sentences in there and you think, 'Well, how on earth do you get 5-11?' [ ] So it was nice to know how to do it, and also, we then came back and devised our own little grid and between us we said: 'Right, if they do that, they get a mark.' [ ] 'If they do that, they get a mark.' (Davy, T)

Some of the most successful schools in the fieldwork sample had ongoing awarding body connections:

We do AQA GCSE Modular […] and myself and [the Head of Science] moderates coursework for the GCSE, and also I have worked at AQA, and I also know the teacher support officer for science, and I now know the Chair of Examiners really well for science. (Rutherford, CL)

Other schools decided to develop an insider's view of the qualification by encouraging a member of staff to become an Applied Science moderator (Feynman, Darwin).

After the training provided by awarding bodies, the most common forms of support which teachers had access to were commercial resources. In 2006 89% claimed to have bought textbooks, and 54% course materials (NQ2). However, most of these had appeared close to the beginning of courses in 2002 and, to the extent that they had been trialled at all, appeared to have employed GNVQ and traditional GCSE contexts (Bell and Donnelly 2005: 117). Ambivalences about the aims and purposes of the course were visible in teachers' comments on these resources. There were some complaints that they did not stretch the more academically able students, but generally teachers commented that they thought textbooks' language was too challenging for the average candidate, and generally betrayed evidence of lack of trialling:

I think the text-based resources aren't so good. I don't think any of them are really what I would say are appropriate or particularly good. I mean they're okay, they are adequate, but not particularly good. … The issues with [a named resource] is yes, it's the level of the language, but it's also the amount: there's too many words on each work sheet, so when I re-write them, it's pruning out a lot of the stuff that's almost irrelevant to the task. [Crick, CL]

Predictably, the single most used resources, whether in terms of equipment, ideas or people were those already available in school. Sometimes this was a straightforward practical point: 'In terms of the equipment, we really developed assignments that we're equipped to be able to deliver, basically' (Einstein, CL). But it had broader significance:

The most important thing is human resourcing. […] that the teachers actually feel confident in delivering it. Also that they are, it's not something that kind of bolt-on, they haven't just got prescribed schemes of work or, you know, feel that they have to be restricted to the use of textbooks, that they actually they have some sense of ownership and it kind of grows organically if you like. Teachers actually feel that they are delivering, that they have been part of developing, rather than something that, you know, 'turn to page fifteen and this is what we are going to do today'. (Boyle, SMT)

A comment of this kind might of course be seen as a positive construal of a difficult situation. Applied Science was underconceptualized in terms of classroom practice and, which is hardly to be distinguished for this course, often also at the level of assessment. This uncertainty represented a risk to the successful introduction of the course (a risk to which some schools would eventually succumb), but it also constituted a space and an opportunity in which teachers could work. This combination of flexibility and challenge ran through Applied Science, despite the apparently constraining effects of the Criteria: the following section explores this issue further, through an examination of the creation of schemes of work.

Schemes of work

The Criteria for GCSE Applied Science are written as if addressed to students, and as if the Units are teaching Units: but this last is not necessarily or even usually the case. In planning the course schools had to make a strategic decision about how the Units were to be managed. NQ2 revealed that schools had taken advantage of this freedom. They divided approximately evenly across three approaches, as shown in Table 5.

Table 5: schools' main approaches to teaching the Units

Approach	(%)
three Units taught separately	32
Units 1 and 2 taught together, with 3 separate	26
all three Units integrated	31

n=149

Some teachers saw this decision as critical to the success of the course, given its target population. Unit 1, or Units 1 and 2 combined, were both popular ways to start the course, as was some kind of mini-introduction created by the department. These might focus on how assignments should be written, or on standard procedures to be followed, such as how to set up a microscope. One department started by teaching all of Unit 2, initially believing that students would need the scientific content knowledge before 'applying' it. Schools with the most novel approach to the course, including such ideas as clocking-in and company logos designed by each cohort, were commonly sensitive to the positioning of Unit 2, with its emphasis on more traditional science. This view tended to be predicated on a belief that Applied Science catered for a distinctive student group: 'if you start on that [Unit 2], you have lost your kids before you start' (Darwin, HoS).

Some teachers reported that students were unable to disentangle Unit 2 scientific 'content' when it was presented in a heavily vocational context. This was said to be echoed in the initial Unit 2 examination results, where students did not draw on the science they had been taught if the specific vocational context of an examination question was one with which they were unfamiliar. This led some teachers to resist combining Unit 2 with portfolio units, despite encouragement at awarding body INSET sessions.

We've now separated them to being taught as Unit 1 and Unit 2. It makes it easier for the students to identify what's for revision and what's for portfolio. (Rutherford, CL)

Experience of this kind echoes APU findings from many years ago that setting science in everyday settings requires care and can even be off-putting, if it requires a major contextual switch for students (Welford et al. 1986: chapter 8). However the quotation also indicates how the structure and language of the assessment regime could dominate how the course was understood in practice. It provides a contrast with the occasionally rhetorical emphasis on student independence and knowledge transfer to be found in other less concrete comments on the course.

Predictably, schools' approaches to planning were diverse. Those which undertook extensive division of labour tended to do so on subject specialist lines. This included Hodgkin, the one school in our sample which had taken the radical step of converting its entire KS4 curriculum to Applied Science, and so could scarcely be accused of conservatism. Even so, specialist traditions remained deep rooted:

I split it physics, biology, chemistry. I felt that when I was introducing a new course, and people had got to basically devise their own schemes of work and get their own resources, it was best done by specialists, and, of course, we are not talking about one group, we are talking about the whole year group. (Hodgkin, CL)

In other schools one individual took more or less the entire responsibility:

I have written really all the schemes of work, mainly because I am the one that goes to all the [awarding body's] meetings. I'm the one who's got the contacts now, so I'm the one who knows the ideas behind Applied Science and how to put that into practice. (Rutherford, CL)

However the work was organized, for almost all schools the process of coming to a view on how to teach the course was both problematic and extended far into the first round of teaching. One teacher described the process graphically as 'like the blind teaching the blind and you know, these kids have got to get a GCSE out if it, so it's kind of daunting' (Ramsay, CL).

The Course Leader in one of the schools which judged Applied Science a considerable success commented bluntly: 'Do you want the honest answer here? It wasn't planned.' (Boyle, CL). But after a year of what she saw as a hand-to-mouth existence, the department addressed the issue in a concentrated way:

This year I organised some INSET time when we first came back to sort out the coursework. […] So we spent a whole day with all the staff that teach Applied and we made a scenario, as it were, for every single piece of coursework that we need to cover. So every single piece is now vocationally linked.

The commercial schemes of work and textbooks discussed above attracted mixed judgements. One teacher with recent industrial experience described them as being valuable as 'a guide for a new school wanting to take it on board. You need that back-up, especially if…you haven't got an array of staff who have recently come out of industry' (Bunsen, T). Quite often though, such resources were quickly assessed as not meeting the needs of the student body, as a Head of Department in another school explained:

We have abandoned it now, we used very little of it, but it was worth its two hundred quid, or whatever it was, because it was all that was available and it had activities in there which you could do to meet the criteria for the schemes of work – for the specification … [the scheme used] was a life saver, but we have abandoned it now because we don't feel the activities are at the level of our kids. (Hodgkin, CL)

Tiering

You know which ones are going to manage the higher tier exam - that doesn't stop them doing well though, in the portfolios, you see, they can get C's on the exams, B's on the portfolios and they end up with B's overall. (Darwin, HoS)

…the nature of this course is that because sixty-six and two-thirds of a percent is based on assignments, they could be extremely intelligent, but if they haven't got the assignments in, then it's going to be a waste of time entering them for higher tier, simply because it's really not going to make a huge difference to their final grade. (Davy, CL)

…for those who have done well on the foundation, I'll give them the opportunity to do the higher exam in June, otherwise it's a case of doing the exam once again in June to try and improve their marks basically. (Einstein, CL)

Applied Science was the only member of the suite of GCSEs in vocational subjects to have a tiered examination, and this required an important structural decision: how, if at all, to introduce the higher tiered content into lessons. The approach (which usually involved limited attention to the higher tier material) can be seen as another aspect of the positioning of Applied Science in schools' hierarchies of subjects.

It was rare for schools to create separate groups for the different tiers, though arrangements of this kind were beginning to appear towards the end of the study, in schools where the course was being expanded up the attainment range. Instead schools generally adopted strategies in which the distinction between the content was not entirely transparent to the students (commonly teaching, or not teaching, the material to all students). A strategy employed in some schools was to ignore the higher tier content until the portfolio work had been improved to its limit. This was the case in Davy School, despite the view, quoted above, that the course was open to students of all attainment levels.

The course could be differently experienced by the students in consequence of this issue. In some schools the differences might be quite small: common, mixed tiered classes of students, with higher tier Unit 2 content accessible by students through outcomes. In some cases higher tier was introduced to all students. Elsewhere higher tier content was taught in separate sessions, perhaps at lunchtimes, or classes were temporarily altered so that 'content' lessons were given to higher tier sets or foundation tier sets.

The most extreme example observed was a case where two separate courses had been created based on KS3 results (Einstein). The higher set were taught in part at the local FE college. While in school they were taught by the Head of Science, who said his role was now more that of a facilitator. The lower set was taught entirely in school by an AST. In terms of the portfolio units, each set was given different assignments. Arrangements such as this highlighted the distinctive institutional positioning of the course.

7. Applied Science in the Classroom

The previous sections examined important aspects of the planning and structure of the course, and the diversity of schools' response. We have particularly sought to communicate a sense of schools struggling to come to grips with the challenges the course presented, with limited support or knowledge. In this section we look more closely at how the specification was realized in practice. We have chosen to focus on what we judge to be its three distinctive aspects:

- the emphasis on laboratory work and other practical activity;
- the management of assessed work, portfolios and students' independent work;
- the involvement with workplace contexts.

A positive construal of the situation we have so far described could present it as offering a version of professional freedom to teachers. In this section we are concerned less with giving detailed accounts of what might be called in some contexts 'effective practice', than with how teachers gave expression to this putative freedom under the three important aspects just identified.

Emphasis on laboratory work and other practical activity

This year because we're on the applied science course it makes it more fun so we're not, 'Oh we don't want to go'. So we'll go and then the work that will be set for us will be practical or coursework and practical or practical and coursework afterwards. (Rutherford, Yr 10 Girl)

It is a commonplace (not always supported by evidence) of science education that practical work is both motivating and valuable, and that the emphasis on it has declined (House of Lords. Science and Technology Committee 2006: 28). Of the 28 lessons which were observed during the course of the project some 19 (nearly 70%) involved some laboratory work. Although authoritative statistics about the extent to which KS4 science currently involve practical work are not available (and it is possible that these lessons were untypical), it seems to us probable that this is significantly greater than would be found in the majority of double award Science lessons at the time of the study. Students themselves indicated that their Applied Science lessons involved more laboratory activity than they had experienced at KS3: 58% suggested that they now did 'more' or 'a lot more' practical work (SQ). Moreover the remaining lessons were by no means 'talk and chalk', but involved such activities as a talks by a visitor, internet research and of course working on assignments and portfolios.

The practical activities which students undertook were strongly orientated to the requirements of the portfolios. Indeed it was rare to find an activity which did not offer such a link. This might be thought an overstatement, since almost any activity could be judged to lend itself to some aspect of the specification: but in our view the link was usually more direct. Many of the activities appeared to be designed to provide the opportunity to complete one or other of the prescribed assignments, whether or not the intention was to employ them for this purpose. The emphasis on testing and simple instruments (in physics), preparation and analysis of materials (in chemistry) and monitoring of organisms (in biology) articulated strongly with the criteria and specifications. It is difficult to determine with any confidence whether this articulation undermined the capacity of teachers to approach their teaching creatively, though, as we have already suggested, most of those we interviewed thought that they had ample freedom and would in fact have appreciated more guidance. The assessment demands of the specifications certainly encouraged departments to focus on the identification of assessment opportunities and the structuring of practice around this. Thus, for example, slight differences in approach (notably in terms of support from teachers and support assistants) could undermine the level achievable by students. In sum, while we rarely heard teachers complain directly that their freedom or opportunities for creativity were limited, their priorities were in meeting the perceived needs of the students, and the school, in relation to maximizing formally assessed outcomes.

The course activities, while inevitably varying in the degree of creativity which the teacher displayed, were not radically novel, except perhaps when judged against the standardized approaches which have developed under the National Curriculum, and especially its assessment regime. In many cases they resembled the kinds of activities available to teachers who used schemes such as the Science at Work series, the Nuffield Secondary Science CSE-orientated course in the 1970s and 1980s and other related sources: dyeing, growing plants, fermentation, building simple machines and so on often figured in these sources. Such approaches have suffered because of their lack of orientation to the National Curriculum programme of study, with its focus on canonical science and variable-based investigation. Nevertheless they have retained a place in the collective wisdom of teachers. Some teaching resources have survived down the years and Applied Science has provided a sympathetic environment for their reintroduction, despite the statutory National Curriculum requirements.[23]

Such activities, with an everyday (though not necessarily workplace) setting were widely employed by teachers in teaching the course: the fact that they were configured so as to provide evidence within portfolios reflected the shift from the less structured world of the 1970s and early 1980s. This was how teachers (and students) 'lived' the course. Assessment requirements infiltrated and colonized practice. Forming a judgement about the significance of this reconfiguration around portfolios for the autonomy and independence of both student and teacher is not straightforward: we will now examine how these issues were realized in school.

[23] It is perhaps again worth citing the somewhat Delphic comment of QCA on Applied Science in the version before the 2006 reforms: 'Applied science can be used to meet the statutory requirements for science, although it does not meet the full national curriculum programme of study.' http://www.qca.org.uk/13192_1786.html (accessed 28 January 2006).

Management of assessment, portfolios and pupils' independent work

Probably the thing that we've learnt the most since we have started teaching the Applied Science course, which we'd thought about, but perhaps hadn't realised how important it was going to be, was that changing to a vocational course is actually about changing your whole teaching style and the learning style for the youngsters, […] and it's only really now that we are starting to come to terms with that. (Davy, SMT)

In its conscious elision of the distinction between vocational courses and a particular pedagogic approach, the preceding quotation reflects a common view of how such courses should be taught. The portfolio represented two-thirds of the assessment requirements of the course: so long as these portfolio/assessment requirements were met, teachers were free to organize and teach the course as they wished. This pattern of governance, though not radically different from GNVQ, was novel in the context of GCSE science, and for most of the teachers involved.

Student independent work was a key area of interest both within the design of Applied Science and for most of the teachers who taught the course. The issue crystallized particularly around the creation and use of the portfolio. At many levels, including such unpromising themes as following standard procedures, students were seen as displaying a degree of independence. Teachers did not readily distinguish this from the benefits of a greater emphasis on coursework generally and the reduced role of formal examinations.

Several teachers commented that formal examination was a method of assessment in which many students had already experienced failure, through the KS2 and KS3 National Curriculum Tests. In both questionnaire responses and fieldwork interviews teachers often saw the assessment shift as the major distinctive quality of the course, when organized well. One questionnaire respondent wrote:

The course gives well motivated but less academic students a better chance of attaining something. Modular double award is too content-heavy and keeps confirming lack of ability in exams. We have experienced students coming back at lunch time etc. to catch up, as they know they can control the portfolio part.

Some teachers were keen to describe themselves as 'facilitators'. They pointed out, however, that a large amount of work is required on the part of a teacher to get students to the stage where they work on their own and the teacher can afford to act in this role. One Course Leader described this as 'controlled independent learning' (Rutherford, CL).

A large majority of respondents to the second national questionnaire stated that, by the time they reached Y11, students were encouraged to work independently using the assessment criteria and other guidance ('most of the time' in 55% of the respondents' schools; 'occasionally' in 40%). According to the respondents, nearly half of the students were occasionally able to do so (47%) and over a third (37%) were able to do so for most of the time. This level of independence was said to require a great deal of preparation and on-going help from teaching staff. This aspiration was to be found even, again perhaps a little paradoxically, in such fields as following instructions. One teacher observed, of students new to the course:

…with 'following instructions', you don't just give them the instructions and say 'Follow them'. You actually teach them how to follow instructions by doing all sorts of silly other little things, but that's actually quite fun, […] and just how to build a portfolio, organisation. You, you have to give them the skills before you can actually start the science. (Crick, T)

In one 14-19 fieldwork school, where students came from a variety of feeder schools and, in the judgement of the high school staff, tended to have had insufficient experience of practical work, 'mini practicals' were devised to develop laboratory skills. Quizzes at the end of practice sessions were used to help develop pupils' approaches to evaluation (Hooke, CL).

In sum, however, the assessment regime was rarely forgotten. Typically, in most schools, students were asked to rehearse practical activities similar to the one that would be assessed. They were encouraged to seek help if they did not understand anything and were reminded that such help would carry a penalty if sought during the upcoming assessed practical. Some staff tried to address the overall assignment to the students' own peer group, for example, by explaining health and safety issues in a school leaflet to be provided to new students. The focus was on helping candidates gauge what would be relevant to include (Boyle, CL). Assignments were broken down into carefully-managed steps:

I think pupils, well certainly our pupils, need some structure to their work and I think that it's up to me [Head of Science], and up to the teacher to provide that structure. [ ] Pupils can't manage time very well, at least the majority. So I think it needs teacher--input there, to manage the process of going through it. (Crick, CL)

The comments of the above Head of Science were echoed by a member of SMT in Hodgkin School:

The students need a heck of a lot of support, whoever they are…it does require steady working, yes, but they still need lots of support and keep pushing, […] the more the assessment is a continual type of assessment, that's got to be very carefully managed for the students, particularly pre-sixteen. (Hodgkin, SMT)

Once an assignment had been handed in, teachers tended to give feedback on it, offering students the opportunity to improve their work. Several different systems were in operation. For example, one school had a first and second mark only policy, with marking, feedback and reworking done on an on-going basis (Boyle). Another first marked and then saved working on improving assignments until the end of the first year (Einstein). Across the fieldwork schools, students were helped by various forms of reminders about outstanding work, together with opportunities to complete it. A teacher at Rutherford School explained:

I think that they're not so good at multi-tasking as maybe more able kids are, so they approach it in a very kind of structured format, so if you perhaps, in one assignment, might see eight things that they've got to do, you know they'll do one, and then they'll hand it in again, and then you'll say, 'Yes that's okay. What about the other seven things?' and it can be very much like that, and that's partly because of the confidence levels. (Rutherford, T)

This might be thought an attenuated kind of independence, but this teacher focused more on the course's impact on students' self-esteem than independence narrowly understood:

If the end outcome is that they have a high level of self-confidence and self-awareness, then at the end of the day that's all it's needed for isn't it?[…] I think in terms of themselves and their motivation as to what they can do and what they can achieve. I think that's the key point to it. So it's not about the course, it's about the kids, I think, and how they feel internally about themselves and their motivation. (Rutherford, T)

Getting good marks at an early stage was considered an important motivator. Often this would be the first time students had had assessment criteria sufficiently explained so as to help them appreciate what they needed to produce. A teacher at Crick School commented:

[…] the thing is if you can get them getting an A in the first [assignment] Once they've understood that you follow the criteria and provided you have got a piece of work that matches that and evidences it you are going to get full marks, and it's a big learning curve for young people.* (Crick, T).

The Head of Science at Darwin described students' motivation as 'fantastic, absolutely fantastic':once they had had their initial success early on, 'that's what it all comes down to, is they can see success out of it'.

Separating the different processes in play here is inevitably difficult, and a recurrent theme for some teachers, when discussing systems of feedback, was the opportunity for it to have a real impact on gradings alongside its articulation with both self-esteem and students' perceived approach to learning:

I would say that it's encouraged some pupils where I think with the Modular course they would have ended up being certainly discouraged or maybe even disillusioned, because I think there is some obvious success, visible success, because they are getting marks back that suggest that you are getting a grade C. Now whether that is true or not, I don't know because they haven't been moderated, but pupils that–that need that kind of positive reinforcement all the time–get that opportunity with this kind of course, because they are getting feedback all the time about where they are up to and what kind of grades they are working at, what level they are at (Crick, CL).

One Course Leader felt that the transformation of her Applied Science students had been 'amazing'. At the end of the first year, their working ethos was described in the following terms: 'There's a whole very grown-up atmosphere in there, very grown up sort of feel about the whole room' (Rutherford, CL).

The sometimes uneasy balance between independence and encouragement and support which has run through this section was caught by one teacher:

[...] if I can find courses that will encourage those 10 Ds to become 10 Cs, then my God, I will do, and I think vocational science has the potential to do that, I really do, because it's far more involving the young person and 66% portfolio, which schools should be able to, I was going to say abuse then, but that's the wrong word, schools should, if we are professional, ensure that the young people hit that 66 %, well if not the 66, at least 50 of it. (Crick, T)

Students were asked about this issue in the student questionnaire, and they judged the coursework element of the Applied Science reasonably positively. Some 42% saw it as about right, with approximately equal numbers looking for more and for less coursework respectively. Variations in schools' approaches to handling coursework will have been reflected in students' perceptions, and there is always uncertainty about the transparency of the process to them. In any event students split approximately evenly between those who felt that every lesson involved coursework, those who felt that they undertook such work every week and others who believed they only undertook it every few weeks. The same is true of opportunities to improve each element of the portfolio: a small number, about one-sixth, felt that they did not have this opportunity, nearly half felt they had one opportunity and a further third suggested that they had several opportunities. Our perception is that the most organized schools (which were generally the most successful in terms of examination results) gave clear and carefully managed opportunities to rework the material. Again this reflects a degree of ambivalence about the position of student independence.

The placement of these opportunities to undertake and revise the work was also diverse, with some schools offering, in the judgement of their students (SQ), very extensive support outside traditional times.

Table 6: students' opportunities for revising work

Opportunities provided (in school)	% of students
In lesson time	82
As homework	70
At lunchtimes	44
After school	36
At weekends	14
In holidays	14

n=258

Although these shifts in practice may have been part of whole school policies, they nevertheless display an increase in flexibility, reflecting practices identified during interview by teachers in several fieldwork schools.

For a few teachers the whole character of the teacher-student relationship was altered: we have seen some evidence of this above. Other teachers commented on the opportunities which the extensive lab work allowed for interaction with students (Curie, CL), while another saw it as consequence of the assessment regime:

I knew them, and it was that sense of somebody who knows them well, who cares, I suppose in a way that you do when you're looking at their work all the time and giving them feedback… (Rutherford, CL).

A Y10 male student at this school, referring to another member of staff, commented:

She's the best teacher ever, to be honest. She puts a lot of effort in making sure everyone gets everything done, but you don't feel under pressure, it feels like you do it in your own time. She uses lots of post-it notes in your work, she puts lots of little labels telling you what you should do to get more marks, a better grade.

These aspects of practice were of course not without costs. Setting aside for a moment the nature of the teaching and learning relationship, it is certainly the case that Applied Science was thought to have more managerial, administrative and marking requirements than other courses, and this had caused significant difficulties. When asked about the problems they had had in teaching the course over three-quarters of the respondents to the national questionnaire (NQ2) said that the complexity of managing teaching and learning had been an issue for their schools, though 50% said it was now resolved. For over a quarter (26%) it remained a major challenge. The complexity of the assessment processes was judged to have been a major issue which had now been resolved by just over a third of respondents (34%), but remained a major issue for half (50%). The amount of marking and administration was described as 'horrendous' in one fieldwork school following OCR (Hodgkin, T) and 'a nightmare' (Joule, CL) in another school following AQA. In Crick School, following Edexcel:

it was like, oh, a nightmare, and had [the Head of Department] and I not been such good colleagues and friends we would have probably come to blows because we were both so frustrated. (Crick, T)

At Feynman School the Course Leader merely gestured to a row of filing cabinets when asked about administration issues.

Involvement with workplaces

I'm sure it's this thing that could be fantastic, but getting it into a school curriculum, I mean taking them out for trips as often as you'd like to is just impossible. Getting people in is easier said than done, especially when you have to get seven pieces of coursework done each year – it's very difficult. […] So I'm sure it's a good thought, and somebody has come up with a very good idea, but it hasn't quite worked, and whether it hasn't quite worked in this school yet, or whether it hasn't quite worked nationally, I don't know. (Davy, T)

The notion of workplace involvement is significant in any course or subject designated 'vocational'. While the challenges of managing workplace connections might be thought of as part of organizing the teaching of the course, in fact they tended to be treated as an extra, though a significant one. This was also one of the areas picked up as underdeveloped within the Ofsted reports (Ofsted 2003; Ofsted 2004: para 85). In our fieldwork schools we did not have a strong sense that the process was one of a difficulty in getting to grips with the issue, as had been the case with the organization and assessment of the course, but of a longer term difficulty which showed little evidence of being resolved. The school cited above had redesigned its course with the help of a worker in the local Pathfinders initiative, and the Course Leader went on to comment, one year into the course:

If you are going to start to do this course, you need to get your schemes of work sorted out really two years in advance because you have got to establish your vocational links, and they were not established when I was here in January, and it's June now, and we are only really starting … the vocational links take a long time. (Davy, CL)

Attractive as such vision might be, it bears no resemblance to the realities of schools' practices as we observed them. Even in those cases where relatively well-developed workplace links had been created, such as Rutherford, the process was less systematic and pre-planned.

It is of course not difficult, nor particularly unusual both within and outside Applied Science lessons, to set ordinary classroom activities in a quasi-workplace setting. A representative activity in chemistry would be dressing up an acid-base titration as a measurement of the concentration of vinegar, in a fish and chip shop or factory. Schools were encouraged to undertake this type of contextualization, and teachers were generally prepared to attempt it (with reservations at times about the dangers of patronizing students). In doing so they drew on the wide range of resources which were identified above, and an established tradition of how science might be taught. In this tradition the world of work figures as a context in which to present science and as a focus for scientific skills. One Head of Science reflected this approach when describing Applied Science as aiming to 'put science into the real world and mak[ing] it relevant to the children' (Darwin). In another school the Head of Department concluded:

I think the purpose is to deliver the science curriculum in context to the work place or real situations, to focus and promote key skills. It provides them, in terms of the nature and delivery of the lessons, provides them with the opportunity to work together, it's essential they follow instructions, and promotes independent learning through finding out information for themselves. (Einstein, CL)

In any event, works visits, visits by staff to school or the use of authentic industrial resources or problems appeared broadly but thinly spread in Applied Science lessons. The majority of respondents to the 2006 questionnaire (NQ2) said that they occasionally worked with outside bodies (69%), but less than a tenth (7%) said they frequently did so. Over a fifth (22%) said they never or almost never did. For fieldwork schools, 'occasional' working with outside bodies would commonly consist of a visit from the local fire service. Nationally, schools reported the following pattern of involvement, with more or less all reporting it moderately or very successful.

Table 7: forms of involvement with local workplaces

Activity	% schools undertaking it
student visits to workplaces	64
visitors to school	53
staff visits to workplaces	35
curricular ideas transferred from workplaces	24
materials transferred from workplaces	19

n=149

The limited development in this area had a range of causes, which are perhaps not difficult to predict. Some were practical. One interviewed teacher complained of the bureaucracy associated with any works visit, and the risks associated with it: '[…] to take children out of the school gate now is frightening because, because we are now living in this society that will sue whoever for whatever' (Crick, T). Other hurdles included regulations preventing visits from students under the age of 18, or sites' inability to cater for the whole cohort:

In terms of our young people actually seeing a good lab, for example, it is so difficult [a colleague] went to [an industrial bakery] which is one of the big employers […] a scientific organisation, and there is absolutely no way will any child under the age of 18 get in there. (Crick, T)

The Course Leader in Boyle School concluded: 'It's really, really, difficult. I think the idea behind it is good, but the people who thought it up haven't thought of the logistics'. The SMT member interviewed at this school presumed the disruption to the rest of the timetable had not been taken into account in devising Applied Science, 'QCA or AQA or Edexcel work under a bell-jar, not thinking of how a course has to fit into a whole curriculum'. By 'curriculum' here the interviewee was of course referring to the mechanics of running schools, not the intellectual content of the curriculum. Though it was rarely discussed explicitly by teachers, the energy and time required both to develop such links, to maintain them and to convert abstract ideas into workable classroom and other activities was clearly very large. It was not easily fitted into the other wider pressures which teachers were working under. Only very rarely were schools' work experience programmes systematically used (e.g., in Einstein School).

Some teachers took the view that science-related industries were unenthusiastic:

One big issue that we as a school face,[…] I think every school in the country, probably faces if they're running Applied Science (is) the science industries' lack of commitment to it. I mean, just turn it around a second, I'm responsible for Leisure and Tourism in this school […] the relationship between this school and employers in Leisure and Tourism is as positive as you can get it: they're in the classroom; they set briefs and the students work to them; there's a whole range of activities; they'll come in; they'll do visits … the science industry tries in some ways, not to distance itself, but not to get involved. (Maxwell, SMT)

While it was not common for teachers to be quite so forceful, the difficulties in motivating employers were regularly referred to. The SMT member just quoted developed the point in a way which has a wider significance for the positioning of the course in schools:

The science industries around [here] are quite happy to work with schools, but they want to work with the absolute high flyers […] for whom the Applied Science course isn't the appropriate one. They're less willing to get involved working with the average student and there have been issues certainly for [the Head of Science] of getting into places, and when he talks about the level of the students, it's been: 'Oh, we're not quite sure about that.'

It is important to note that a small minority of fieldwork schools was successful in making links with industry. In one case at least the process was linked to the school's science college status. The Course Leader spent a lot of time liaising with the industries, including a pharmaceutical company linked to the specialist status, and planning visits in advance. These would be highlighted in the School's magazine and elsewhere. This was time-consuming for the Course Leader:

And I think the biggest thing that I've spent time on is building relationships with more industry, or links, because that's important. We don't have loads of them, but we do have very good ones. That does quite a bit of time nurturing, building confidence between you and them. (Rutherford, CL)

By the third year, visits had been extended to include U2 content (a visit to an organic farm). In contrast to many schools, the emphasis on inviting visitors had been reduced, as students found some presentations at too high a level. One Yr 10 student commented: 'Personally, I find some of the visitors a bit boring, but it's when we go on trips that we really learn.'

Ramsay School was selected for study principally because of the many links it was known to have made with a variety of local industries. While its location may have helped, on-going success was due to the way in which the school maintained its links: it made sure to thank the firms, ensured that they had positive publicity in local newspapers, worked with parents and targeted industries likely to employ school leavers. Workplaces and other bodies that were involved included London Underground, the local Fire Brigade, St. John's Ambulance, the local ice rink, a local brewery, an amusement park, Compassion in World Farming, local farms and the National Blood Centre. The amount of energy and organization this required hardly needs to be further emphasized.

In each case the development and maintenance of these links relied to a considerable extent on the energy and enthusiasm of one particular teacher. This is hardly unexpected for anyone with knowledge of schools, but it remains significant for a course which is ostensibly centered on a relationship with workplaces. Moreover, even in these successful cases, it is not clear in what way the activities which were occurring were vocational, in the strong sense of relating to any likely future science-related employment for the students. They can appear more convincingly to be a simple enrichment of the science curriculum.

Overall, almost 60% of the Heads of Science who responded to the 2006 questionnaire thought that maintaining a vocational emphasis was still a major issue for the course. A further 24% felt that, while this had once been a problem, the issue had been resolved in their school. Our judgement, from the fieldwork schools, is that this resolution in most cases involved very moderate workplace involvement, and that 24% is an optimistic figure. The scale of such workplace involvement did not however appear to be critical to schools' judgement of the success of the course.

8. Evaluations of GCSE Applied Science

Teachers

I love it. I think it really, really works. It's got a lot of work to it. It's a huge workload for the teacher, but if the school can manage to keep the classes small, the feedback is, you know, the benefits are so obvious. (Rutherford, CL)

I really like it. I think it's much better for the students. I personally get a lot more out of it professionally because I think it's something new to do … although with that there's extra pressure because there's more work, there's a heck of a lot of marking and it's not marking that you can avoid doing, it's marking you've got to do. (Hodgkin, T)

I feel positive about it. I think it's been definitely a worthwhile course to introduce. I would encourage other schools to do it that aren't doing it and we'll carry on, you know, we intend taking it further. (Crick, CL)

The quotations above give some indication of the response which Applied Science is capable of generating amongst certain teachers. To create a single account of teachers' views of the course is inevitably to oversimplify: yet we will offer an overview. First it is important to observe that the course was still developmental in many schools, though already subject to change as a result of the 2006 reforms at KS4. This is hardly surprising given its demands and the unco-ordinated support that schools had received in introducing it. Beyond this, however, a number of teachers remarked on the distinctiveness of the ongoing challenges and opportunities which the course offered. A questionnaire respondent noted:

It is a course that needs very dedicated staff and is one that improves with time, e.g. our coursework gets evaluated each year and replaced with new and more inventive ones each time.

Even in cases where it was judged a considerable success, amongst the teachers interviewed, there was a general consensus that the course had not yet become properly established. In one of the schools where Applied Science had run since it first became available, and was seen as a success in terms of raising grades, appealing to students and generating teacher enthusiasm, departmental schemes of work were judged to be substantially unfinished. Teachers felt 'pretty stretched' by the ongoing task of embedding the course and building on its success (Hodgkin, T). Judgements were not static, however, and there was evidence of considerable open-mindedness among teachers. One Course Leader said:

My initial impression […] was: 'I don't like this course'. I didn't think that there was enough academic science within it and I thought, 'Gosh fourteen assignments, that's a lot of work.' But looking back on it now,… I enjoy the course, I like the fact that the teaching and learning styles are different for children now, because they are having to do a lot more of their own work, going away and getting their own information and I think that's giving some excellent skills that children doing a conventional GCSE won't necessarily develop or pick up. So I enjoy teaching the course now. (Davy, CL)

Evidence of such shifts could also be found in the 2006 questionnaire (NQ2).

At first hesitant that it was 'dumbing' down but now I have taught the course I can see how much it has benefited the pupils – they have much better skills (both scientific and organisational).

The issue of scientific content was a significant one for many teachers. Some saw the reduction in 'content' as beneficial to 'non-academic' students, allowing them to concentrate on skill development, or, alternatively, allowing students more time to get to grips with limited content, rather than failing to understand any of it (Pauling, CL). Other teachers thought there was sufficient opportunity in the course to add in 'theory':

There were reservations about the theory, but I've even converted [a colleague] on that now, and you can put theory in, you can if you want to. (Hodgkin, CL)

There were examples of teachers for whom the issue remained important, though they were often identified indirectly. One teacher described a colleague as 'hating' Applied Science: it was not 'proper science' (Newton, CL). The interviewee said he would recommend schools to try the course with low ability pupils who were not engaging with science, and for whom scientific theory was completely irrelevant. But, 'proper science' needed to be taught to higher attaining students: Applied Science was not the way to produce future scientists.

Overall, however we think that it is fair to say that the majority of teachers in both fieldwork and questionnaire responses regarded the course as successful. This statement needs of course to be qualified by identifying the key criteria that they used for these judgements, which were: improvements in grades in the group around the C/D borderline, increased interest and motivation in science and an improvement in students' behaviour. This combination of criteria, and particularly the last, is itself indicative of how the course was positioned by the schools involved:

…we had kids who were really underachieving before and were quite a challenge in terms of their demands and behaviour issues, but were really taking off. So we were getting this feedback really quickly. (Darwin, SMT)

Having had two sets of examination results, Rutherford School, visited in the third round of data gathering, was quite confident of its ability to predict grades. This allowed a teacher to say of her students just finishing Y10, that the majority were on target for A* to B grades, whereas many had initially been predicted Ds to Fs. Another teacher in the same school described the importance of good grades to previous cohorts:

Students can almost hold their heads up high because they can go to their peers who are studying higher tier for double award and say, 'Well, I came out with a B in my GCSE'.

These comments are reflected in the school's recorded examination results (see Table 12).

Respondents to the questionnaire were specifically asked if students were performing better, as expected, or worse than their target GCSE grades. Over half thought students were performing better (60%) and over a quarter that they were doing as expected (30%). Only 10% felt that students had not performed as well as expected, a figure roughly corresponding to that in the fieldwork, for schools where the challenges of setting up the course had not been met successfully. In the open response section at the end of the questionnaire, one respondent claimed that the course had worked 'wonders' for students who were in bottom sets in Y9 and yet who ended up with grades C and D in their GCSE. Other comments included:

100% obtained CC against predicted 50% on Double Award.

None predicted Cs at modular science. 40% achieved Cs.

50% of target group obtained CC or above. (All SAT level 5 or lower).

Target = 30% grade C or above. Achieved = 60% grade C or above.

This finding is broadly in line with that from a study carried out by MORI for QCA in 2006. Compared to teachers of other GCSEs in vocational courses both Health and Social Care and Applied Science teachers were more likely to regard students' applied GCSE results as better than expected (MORI 2006: 27). In the following section we will examine the situation more systematically, using the National Pupil Database.

Where teachers were not happy with the results achieved they tended to blame a failure to get to grips with the demands of the course, rather than the course itself. A teacher at perhaps the least successful (in academic terms) of the fieldwork schools, which ultimately abandoned Applied Science after one cycle, commented:

The reason why we haven't got some portfolios that are better than grade C is because we didn't get them right at the start. I think the good ones could have been much better for the same amount of effort on the part of the child. (Bunsen, CL)

In the national questionnaire (NQ2), schools were asked to rate a list of major challenges which appeared likely, on the basis of findings from the fieldwork, to have arisen in developing the course. They were also asked to identify the degree to which they had been addressed. We have reported parts of these data within the commentary above, but we bring the findings together in Table 8.

Table 8: issues for the Applied Science course in schools

Issue	Major issue still (%)	Was an issue: now dealt with (%)	Never an issue (%)
maintaining a vocational emphasis	60	24	12
complexity/bureaucracy in assessment	50	33	8
supporting students in working independently	45	31	15
progression routes for successful students	34	22	31
complexity of managing teaching and learning	26	50	15
creating/maintaining science staff commitment	23	21	46
failure of students to achieve expected grades	20	18	42
retaining SMT support	13	7	67

n=149 (not all respondents responded to all questions)

The major challenges which the course creates are evidently heterogeneous: a mix of the problems of interpreting and realizing the vocational aspect of the work, with the more practical and perhaps addressable issue of complexity in the assessment regime. The question of progression, which we see as significant to the long-term future of the qualification and will discuss below, evidently appeared less significant to teachers.

When asked to form an overall judgement of the success of the course in meeting the school's aims for it, over a third of respondents (37%) described it as very successful, while almost half (49%) of the respondents stated that it had been moderately successful in meeting its aims.

Students

In our national questionnaire (NQ2, n=149) teachers were asked how the attitude of Applied Science students to science compared with that of Double Award Science students. Some 70% thought attitudes were better, with 23% judging them unchanged: just under 7% thought attitudes were worse. Several teachers who felt the course was successful identified particularly the confidence and success which the course had generated amongst pupils, including many who had not experienced this previously:

The fact that the class I've got are completely different now to when they were at the start of the year, not because they've grown and matured, because I know a lot of them are still pains in the neck in other classes, and it's so rewarding to actually see the benefits. That they've done well and they know they've done well. For them to feel that good, it's absolutely fantastic. (Rutherford, T)

Students were also asked directly in the Student Questionnaire, about their experiences of Applied Science. In each case Y11 students were asked to compare their experiences with those at KS3, in order to provide some comparator.[24]

[24] We were unaware of any group of students with experience of both Science and Applied Science.

Table 9: students' views on Applied Science compared with Y9 science

	More or a lot more than in Yr 9	The same as in Yr 9	Less or a lot less than in Yr 9
I enjoy Science now…	48	27	25
How difficult is Science now?	58	22	20
How hard do you try?	68	22	10
How much practical work do you do?	58	14	28
How interesting is the course?	54	22	24
How much time do you spend finding things out for yourself?	49	35	16
How relevant to everyday life is Science in Yr 11?	53	35	15

n=248

These data suggest that, for the majority of students, their experience of Applied Science is more positive than that of science in Y9. This might be considered an achievement, given the general trend in students' views of school science during secondary education (Osborne and Collins 2000; Murray and Reiss 2003; Jenkins 2006). Students also appear to agree with teachers that the course is more relevant to everyday life, involves more independent work and is more practical, than was the case in the science courses they had previously experienced.

However these positive experiences and judgements are only to a limited extent paralleled by intentions to continue with science. For some 28% the course made them more likely to pursue further study of science (but 17% suggesting it made them less likely to do so), while 21% were more likely to seek a job involving science (with 17%, less). We were unfortunately not able to gather detailed information about the subsequent destinations of students in any school, but such information as we have available from those students who participated in focus groups suggest that only a small minority saw themselves as entering strongly science-related work. While this is hardly a surprise, given what we know of the targeting of the course, it raises again, in a different guise, the question of how GCSE Applied Science can realistically be described as a 'vocational subject'.

9.Student Attainment in Applied Science

In seeking to understand patterns of attainment among students following Applied Science we have relied so far on data from our own fieldwork and questionnaires. However we have also used national statistics to examine this issue: the present section reports the outcomes of this work. Table 10 shows the performance of students examined in the 2005 assessment round, and compares it with the results for Double Award.

Table 10: 2005 GCSE examination results for Double Award Science and Applied Science

Subject	Gender	N	Mean Score[25]
Science	Male	225 142	4.5
	Female	230 236	4.7
	Male & Female	455 378	4.6
Applied Science	Male	8 195	3.5
	Female	9 989	3.9
	Male & Female	18 184	3.7

[a] source: Joint Council for Qualifications website: http://www.jcq.org.uk/press_releases/results/index.cfm

The data suggest that, in 2005, Applied Science students performed on average nearly one grade lower than Science students. It also suggests that the differential between female and male students is greater in Applied Science than Science, in favour of the former. However the previous sections should have indicated that a simple comparison between the performance of students following Science and those following Applied Science will not suffice to form a judgement of the impact of the course on students' attainment. Schools have carefully positioned Applied Science, and selection of students was central to that positioning. There is ample evidence from teacher interviews and questionnaire data that Applied Science students are likely to have performed less well at KS3 than other students.

In order to take account of student performance at KS3 it is necessary to turn to data held in the National Pupil Database. (See Appendix 4.) Using these data it is possible to determine the relative performance at KS3 of Science and Applied Science students. A summary of these data is shown in Table 11, with Science schools limited to those offering **both** courses.[26]

Table 11: the performance of Science and Applied Science students at KS3 (2005)

Course followed	Number of students	Number of schools	Mean Science level at KS3[27]
Science	52 617	451	5.3
Applied Science	16 033	477	4.6

The patterns of previous attainment identified in our fieldwork and questionnaire data are confirmed. Applied Science students had performed at approximately 0.7 of a KS3 grade lower, on average, than those who followed traditional Double Award Science.

[25] This mean score is based on a conversion of the grading system employed in the GCSE examination into a numerical score with GG=1 through to AA*=8.
[26] Note that in the remainder of this section the comparative sample of 'Science' students are those students who followed Double Award Science in schools which offered both courses. The rationale for this choice and a more detailed analysis and discussion of the data can be found in Bell et al. in press.
[27] Mean scores have been calculated treating National Curriculum levels as a numerical score.

In order to judge the relationship between student performance at KS3 and that at KS4 we have broken down the student population according to their prior KS3 level, so as to control for the latter. This enables us to compare the performance of students who had obtained any given KS3 level, across Science and Applied Science. The approach can be interpreted as a simple version of what is nowadays called a 'value-added' analysis. The outcomes of such an analysis are shown in Figs 1a and 1b. They include the mean GCSE scores in both Science and Applied Science for students performing at each of the KS3 levels 2 to 7, for 2004 and 2005 respectively.[28]

The pattern for the two annual cohorts is broadly similar, though there is a slight shift over the two years. Data for both groups show that, among students obtaining level 2 to 4 at KS3, those following the Applied Science course obtained significantly higher grades at GCSE level than those following Science (the differences are statistically significant, with p<.001 throughout). For students performing at level 5 the performances are comparable, and for students performing above level 5 the situation is reversed. The aggregate pattern here is strong and stable, suggesting that this is a real effect. (It should be remembered that the students concerned are from the same schools, though, in fact, the same pattern is obtained when the whole national population is used in such an analysis, suggesting that the findings are fairly robust.) We have reported this analysis of the NPD data for 2005 in greater detail, and including the use of multi-level modelling, elsewhere (Bell et al in press).

Figures 1a and 1b: Comparison of mean performance at GCSE for Applied Science and Science students, by KS3 level attained

Figure 1a: 2004

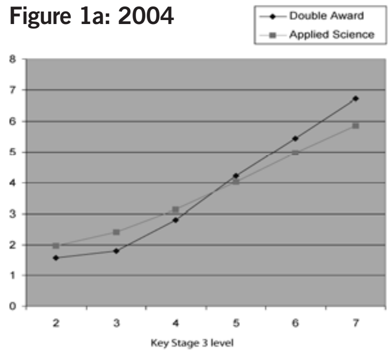
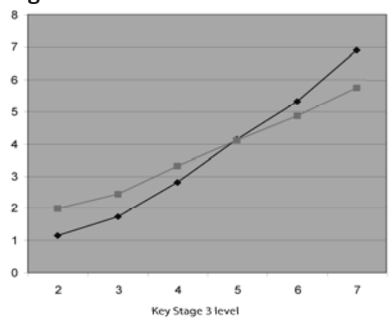


Figure 1b: 2005



As the previous section indicated, some of our fieldwork schools and questionnaire respondents report gains for Applied Science students at the higher KS3 levels also, and in some cases are offering the course to students with higher KS3 attainment than previously. We have no reason to doubt these claims, and it clear that the circumstances in schools vary considerably. It has proved difficult to obtain systematic pupil attainment data from schools in the sample,[29] but in a few cases we are able to obtain them, and to compare these national results with those for individual schools. Table 12 shows the mean scores at KS3 and KS4 for the 2005 (in one case 2004) Applied Science cohort in a subset of the fieldwork schools. The comparison shows considerable differences across the schools, even when students' prior KS3 attainment is taken into account.

[28] We have added trend lines for both graphs in each case, though these are in fact ordinal data, employing KS3 levels. Though the trend lines are useful when comparing the data with those obtained for individual schools, some of which is reported below, they must be treated with caution.

[29] This is of course unsurprising, since assessment data are sensitive and cannot be accessed without significant amounts of effort

Table 12: performance data for individual schools

School	Applied Science		Science	
	Mean score at KS3*	Mean score at KS4**	Mean score at KS3*	Mean score at KS4**
Hooke	5.3	5.3	5.5	5.0
Bunsen***	5.0	2.9	N/A	N/A
Boyle	4.4	4.5	5.2	4.6
Feynman	4.0	3.7	5.1	4.6
Faraday	5.1	4.0	5.4	4.1

* based on treating KS3 levels as numeric scores
** based on grade GG=1 etc. through to AA*=8
*** 2004 results

A contrast can be drawn between Hooke whose staff judged their course to be successful and Bunsen which appeared less effective, and ultimately dropped the course. The data suggest that, from an apparently similar start point in terms of KS3 performance, the two schools produced very different outcomes at KS4 for their Applied Science cohort. It is also notable that Hooke succeeded in obtaining a higher aggregate performance with their Applied Science students, from a lower start point, than with their own Science groups. Differences can no doubt be found across all schools and all courses, but these data nevertheless demonstrate the overall impact of schools' practices in a number of cases. The apparent success of the course at Hooke and Boyle is also visible if these schools' outcomes are compared with the national trend lines in Fig. 1b, though, as indicated in footnote 28, these trend lines need to be treated with caution.

The data above suggest that schools' instincts about the students who might benefit, at least in terms of examination results, from following Applied Science are broadly vindicated, as is their hesitation about employing the course with higher attaining students. However conclusions such as this are dangerous, given the variation across schools. For example it is possible that there is some underlying systematic difference between schools entering higher attaining students for Applied Science and other schools. A multi-level model analysis of the data also demonstrates that the value-added effect is indeed rather greater for girls than boys (as suggested by the national KS4 data), and that attainment in Applied Science courses is better predicted by KS3 performance in English, and less well predicted by that in science, than is the case with Double Award Science (Bell et al. in press). All of this suggests that the way in which this course is used in schools, and perhaps the intrinsic characteristics of its approach and content, are having identifiable but sometimes locally characterized effects. Whether local or not these impacts are nonetheless significant for students' attainment, and likely attitudes. Further analysis is needed if these issues and the underlying processes in schools are to be adequately understood.

10. Conclusion

We began this report by observing that GCSE Applied Science was created at the intersection of two important regions of educational policy: the promotion and reform of science education, on the one hand, and the reform of 14-19 education, on the other. Each is a challenging policy location in its own right, and, despite the grand claim in the 14-19 Education and Skills White Paper that science would be put 'at the heart of education' (DfES 2005: 3.16), they speak to each other only intermittently.

In consequence, science education policy can seem to develop independently of the wider 14-19 agenda (and of course vice versa). References to science in generic 14-19 policy documents commonly take the form of either rhetorical statements such as that just cited, or the enthusiastic promotion of innovations which are deeply uncertain in their likely impact. The support given to the 21st Century Science initiative (Millar 2006), particularly its reinvention as a route to improving post-16 science take up within the 2006 KS4 science reforms, is a recent example of the latter (HM Treasury et al. 2004: 6.26; DfES 2005: 4.15). The proposed specialist diploma in science, the decision in relation to which is still not published at the time of writing, is potentially another. The introduction of GCSE Applied Science also falls into this category. Its rationale, or what it was intended to achieve, is unclear, and we have not been able to cast light on these points, beyond what is already visible in the rhetorical flourishes identified earlier. Yet the probable outcome, at least in terms of the positioning of the new course in schools, should have been apparent to anyone familiar with schools, the history of GNVQ Science and the broader situation of vocational education/training within post-14 provision.

In the 1990s GNVQ Science was a callow interloper confronting one of the highest status subjects in the curriculum: a subject, moreover, with a well-established vocational dimension of its own. GNVQ quickly became a second class version of established post-16 science courses. It served institutional and individual purposes which may or may not have been in the best interests of the students involved, but were at any rate a long way from the rhetoric of 'parity of esteem' which was still current when GNVQ was introduced (Edwards et al. 1997). How could it be otherwise? Yet there were also positive signs of the capacity of GNVQ science to motivate and re-engage students, where it was organized and taught with care and commitment (Young et al. 1995; Solomon 1996; Major 1997; Ofsted 1998).

Politicians have a notorious inability to learn from anything other than very recent experience, or to apply it beyond the horizon of the next election (Higham and Yeomans 2007). Indeed Alison Wolf used 'vocational GCSEs' as an exemplar of the limitations of government learning, in her widely-cited book *Does education matter?* (Wolf 2002: 95-7). Yet something had been learnt from the experience of GNVQ when the GCSEs in vocational subjects were introduced. It was however knowledge of a largely 'political' kind, mainly to do with how the new qualifications would be perceived rather than with their substance. Critically, the qualification suite of which Applied Science was part was integrated with the established 16+ assessment regime. The specifications were established as GCSEs, used the GCSE grading system and offered the full range of grades.

This decision has conditioned how schools have deployed all of the new GCSEs, but it has perhaps been particularly critical for Applied Science. It has provided a stronger negotiating position, as it were, within the highly politicized space of the curriculum and the (still very unequal) competition with established GCSE science courses. We have seen that teachers stressed to parents and students the full range of GCSE grades available. They acknowledged when interviewed that this was a key criterion by which these client groups judged the course.

Yet, while Applied Science was represented when being introduced as distinctive, the likely reality of the course received little attention. Such issues as the target population, the qualification's relationship to other science qualifications, the teaching methods and resources that it would require or how it would be supported were left to their own devices. Above all else, little thought appears to have been given to the meaning of its distinctive educational purpose, beyond the formulae of 'relevance', 'work-related outcomes' and so on. Indeed, as we have seen, conflicting messages were offered about target population and the likely progression of that population.

A framework which is sometimes used in seeking to understand curriculum reform is that of the TIMSS-derived 'intended', 'implemented' and 'achieved' curriculum (Robitaille et al. 1993: 25-30). While this approach has a certain rationalistic appeal, it seems to have limited relevance to the experience of GCSE Applied Science, in part because it is not easy to understand what the 'intended curriculum' was. It is a truism that the meaning of an educational policy is properly realized only in the context of its detailed implementation, when it engages the traditions, priorities, resistances and accommodations of the sites where it is converted into a set of practices. The process can be conceptualized in several ways. It can be understood in terms of the co-construction of policy, a process which remains bilateral even when actors are apparently highly differentiated in terms of power (Hill and Hupe 2002: 137). It can be seen in terms of the interpretation of policy as text (Ball 2006), with the balance of readerly and writerly aspects articulating with the power relations involved, so as to enable or resist alternative readings. It is even possible to offer an analysis in Foucauldian terms, through the creative and formative aspects of the microstructures of power (Foucault 1979), sustained in this case through the omnipresent assessment regime. Although it is not appropriate in this context to pursue these theoretical approaches at length, a review of the preceding account would, we suggest, show that each could be used to cast light on aspects of the realization of GCSE Applied Science.

A range of circumstances influenced the reception of Applied Science. An important positive influence on attitudes to the course among teachers derived from the problematic situation of science in the curriculum. There is a strong appetite among science teachers for courses which offer a different account of science (Donnelly 2004; Donnelly 2006), particularly one which sets out to relate it to aspects of students' lives and thus gives it an enhanced meaning for them. Such a reform is anticipated to motivate students in a subject which, because of its core status impacts significantly on examination results and other accountability measures in schools. Applied Science was also able to appeal to the enthusiasm among science teachers for undertaking more laboratory work. There was a range of other positive aspects of the course for many teachers: it was seen as requiring less 'content' (as scientific knowledge is commonly called these days) and the ongoing assessment through coursework rather than formal examination was seen by many as an advantage, for at least some students. Overall, Applied Science possessed a range of political and pedagogic assets. However, to mobilize them effectively required careful positioning, particularly in relation to choice of student. As we hope to have shown in this report, that positioning is critical to understanding its development. It was underpinned by the key judgement for most teachers, that the course did not prepare students for traditional A-level study in the sciences.

In terms of take-up, a significant number of schools took the view that the course had something to offer. By the third assessment cycle, in 2006, probably about 20% of secondary schools had adopted it, not counting those still in the first year. Our findings suggest that they had also come to a relatively uniform view about the type of student to whom it might appeal and the purposes which it might serve. Attendance and behavioural characteristics, including a likely willingness to work conscientiously at portfolios, and a positioning at or just below the C/D borderline in terms of likely GCSE science grade, were the key criteria for entry, in most schools. The key horizon for the course in almost all schools was that of potential A-level candidates in the traditional sciences: such students were almost never accepted for Applied Science. We will say something about A-level Applied Science in a moment.

We have used the word 'course' at intervals in this report: but Applied Science was emphatically not available to teachers as a 'course'. It was a specification, and a distinctly novel one at that, at least for science teachers without experience of GNVQ. This represents an important element in the account which we have offered. Science curriculum reform projects have shown a wide range of attitudes towards the professional authority of teachers (Donnelly and Jenkins 2001). Applied Science offered a different model to those which have historically been available in activities such as the Nuffield projects and the Secondary Science Curriculum Review (though one heavily derivative of GNVQ). Teachers, and students, are provided with an assessment framework of a highly specified kind.[30] This framework, together with an interpretative regime much of which would be identifiable only through 'case law', focused on the required outcomes of the course at a day to day level. Awarding bodies, of course, judged and had responsibility for the course only at the level of assessment outcomes: there was in effect no other 'quality control' mechanism for its teaching and assessment. The bureaucratized control of those able to undertake assessment which had been prominent within GNVQ was omitted. Furthermore there was no trialling or other introductory period.

On the face of it a course developed in this way offers a good deal of flexibility to teachers (and, through the portfolio, to students) in respect of both curriculum content and teaching methods. However the realization of that flexibility was altogether more ambivalent. In these respects Applied Science provides a significant contrast with another, more prominent, reform introduced at about the same time: 21st Century Science. Here teachers were provided with an array of support mechanisms, a course with a well-articulated purpose, and an intention to move their practice in centrally-defined directions (Millar 2006). The two approaches provide an interesting contrast.[31]

For teachers of Applied Science the flexibility which existed within the interstices of the assessment framework was real: many of the activities which the course required allowed a wide range of interpretations, and much else could be incorporated around the assessment structure. It would however be wrong to say that teachers necessarily experienced this as greater freedom, or as professional authority. In part this was because the assessment regime, albeit abstract and open, remained all-pervading, especially since in most schools SMT anticipated improvements in examination results for a key student group. In fact the space left around and within the required portfolio elements could be experienced by teachers as a threatening void, particularly for a generation of teachers familiar only with the minutiae of National Curriculum science, the KS3 Scheme of Work, and the other apparatuses of diminished professionalism.

Schools' engagement with the course, and the support they received, were ad hoc and largely dependent on the energy and even chance encounters of staff. Few schools were quickly able to turn the 'flexibility' to immediate good effect, though possible candidates within our fieldwork schools include Rutherford, Crick and Hooke. Most schools, however, launched the course with minimal planning and limited understanding of the assessment or teaching regime they were seeking to create. This was not a promising start. However some, and we think the majority, as judged by our fieldwork and questionnaire responses, were able to address and redeem this situation to a significant degree. These schools created a course which, in their judgement, offered a distinctive and worthwhile version of the science curriculum, as well as demonstrating some improvement in examination results for many students. As Figs 1a and 1b above suggest, nationally this improvement may have had a fairly distinct cut-off, though some schools clearly outperformed the national pattern.

There were casualties in this process: teachers and schools not able to adjust to the newfound, albeit highly structured, freedom. When we referred to 'risk' in our title we had in mind these schools, and most importantly, the students who followed the course they created. Some schools decided to cut their losses. An analysis of those which disappeared from the National Pupil Database data for Applied Science between 2004 and 2005, suggests that some 20% (approximately

[30] Specified, that is, in terms of broad outcomes. The interpretive rules governing how these outcomes were valorized were much less clear, as some schools learned to their cost.

[31] One author co-ordinated the national evaluation of 21st Century Science and his report can be found here: http://www.21stcenturyscience.org/news/evaluation-report,897,NS.html (accessed 14 March 2007).

50) decided not to continue the course beyond the first cycle. Nevertheless, in the majority of schools the course was made to work, and, as the comments in the preceding section indicate, for many teachers involved it has been seen as a significant success, created from inauspicious beginnings and with very little effective support.

The rhetoric and criteria of Applied Science provided both a constraining framework and a resource for teachers. We will comment here on four key aspects of how it was realized: the notions of independent learning and of science as a vocational subject; the 'positioning of the course; and the possibilities for progression.

Teachers in our fieldwork schools made a good deal of reference to independent learning, and this idea had been a significant strand in the representation of the new GCSEs by DfES, QCA and the then LSDA. The portfolio element of the specification lent itself to this, and schools developed more or less elaborate mechanisms within which students worked to develop and improve their assignments. Feedback to students often identified with some precision what was needed to obtain further marks, and opportunities were provided in a wide range of circumstances, including after school and during holidays, to undertake the necessary work. Teachers in several schools commented positively about the enthusiasm for this which many pupils showed. The articulation of this activity with the assessment framework was very tight, so that most teaching activity was construed either as potentially assessable, or preparatory to an assignment, when it was not itself explicitly part of an assignment. The extent to which this highly instrumentalized and structured activity represents independent learning in any proper sense of the term remains an open question. In the context of GNVQ similar practices have been seen by some as no more than a mechanized semblance of independence (Hodkinson 1991; Bates et al. 1998). It is certainly the case that, in the context of a GCSE Applied Science, there is very limited freedom for students to address the concepts and practices they are studying in their own terms (Bates 1997). However we should note that many teachers took a more positive view than this: for them the practices which grew up within GCSE Applied Science appeared to meet the criterion for what could be realistically achieved by their students.

The meaning of 'vocational' in an educational context has been the subject of much still unresolved debate: its importance within political agendas for 14-19 reform has served only to complicate matters. In the context of science, matters have a distinctive character, for two main reasons. These are: first, because traditional science education can be construed as already heavily vocational; second, because, outside professional science and science-related occupations, identifying science as an industrial or occupational 'sector' is highly problematic. In the early 1990s, when this issue was addressed in connection with GNVQ Science, the argument quickly became inflected, engaging the broader debate about how science education could be reformed to make it more worthwhile and attractive for more students (Hunt and Russell 1994: chapter 7). We have suggested that a broadly parallel trajectory has been followed with GCSE Applied Science, amongst teachers at least. In our view the specification has been incorporated into schools as a mode of science curriculum reform of a general kind, with limited 'vocational' significance, echoing activity which has occurred for at least a century, and arguably longer (Layton 1973). We should make clear that we believe it to be none the worse for that, but we must enter a major qualification.

The course has been, as we have seen, 'positioned' in several respects: that positioning includes targeting a particular group of students and excluding another group (ironically, the latter grouping incorporates almost all potential scientists in the narrow, professional sense of that term). While the situation resembles the experience of GNVQ in the 1990s, a major difference is that it applies within the compulsory curriculum, and indeed within a core subject. We do not make this point directly as a criticism, though we are sure that others would see it as an example of unwarranted exclusion of students, which might embody as yet undisclosed class, gender and other dimensions. We are not at this time in a position to comment further, but such a clear stratification (for it is largely, though not entirely, a 'vertical' stratification by perceived attainment, not a 'horizontal' differentiation by supposed aptitude or 'learning style') is of major significance. It needs to be understood and communicated directly to students and parents. In our study we felt that we often observed something closer to a 'management' of these groups. Ofsted, in one of its early reports, observed that students (and, by implication, parents) needed to be clearer about the consequences of the choices which were being offered (Ofsted 2004: para.90). The potential gender and other implications could be explored further, through the National Pupil Database, and the Pupil Level Annual Schools Census (PLASC).

This brings us to our final theme, which relates to progression, and the wider post-14 reform agenda. Several of the schools in our study planned to introduce A-level Applied Science[32], but decisions about this were found to have a greater strategic significance for SMT than had the introduction of GCSE Applied Science. Science staff in several schools during the data collection were involved with the decision, effectively making cases to, and awaiting decisions from, senior management. Questions of funding and staffing were of course prominent. However these questions were conditioned by others, focused on the impact on existing A level science courses, likely progression routes into HE and elsewhere, and the general policy of thus stratifying the student body at GCSE level. Only in one or two cases (Rutherford and Boyle) were decisions already taken.[33] Unfortunately the timing and focus of our study have prevented us from pursuing this issue empirically, into schools' take-up of A-level Applied Science.

[32] This specification, which had derived from Advanced GNVQ via the AVCE, was first examined at AS level in 2006 and A2 level in 2007. It shares many of the distinctive rhetorical and assessment emphases of GCSE Applied Science, though entry and attainment are to date low. In 2006 at AS-level 659 students were entered for the double award and 1289 for the single. http://www.jcq.org.uk/attachments/published/284/News%20release.pdf (accessed 10 April 2007)

[33] Some of the tensions can be identified already from our own fieldwork. Staff at Boyle School initially allowed students to enter traditional science A level courses with a grade C from Applied Science GCSE. From September 2005 onwards it was decided that, to take traditional science AS Levels, pupils needed to have gained at least a grade C for Unit 2 (the formal examination) in Applied Science, and to have raised their overall grade to B or A via coursework. Other pupils were tracked towards the Applied Science A Level. The 'political' implications of these kinds of judgements for the status of different courses, and the progression opportunities of students, should be apparent

This issue extends more widely than Double Award Applied Science. The 21st Century Science project, on which the present GCSE science reforms draw heavily, had experienced considerable success with its own applied strand. 21st Century Science Applied, although a single award qualification, had some similarities to double award Applied, not least in its apparent positioning as part of a stratified system of science provision within schools, but also in its educational rationale and content. Partly in consequence of the success of the 21st Century single award Applied course, the 2006 KS4 science reforms have introduced a widely available Additional Applied single GCSE. This appears to be proving popular with schools, though, yet again, early indications are that it occupies the lower tier of a strongly stratified provision. Again, students following these courses could more readily progress to an A-level Applied Science course than to traditional specialist science A-levels.

There is then evidence of the growth of an 'Applied' strand within the post-14 science curriculum, as part of a potentially integrated 14-19 science phase. Such a development would connect science more strongly with the mainstream agenda of post-14 reform. At the time of writing there is also the possibility of a specialized science diploma, of uncertain relationship with these existing qualifications. Many questions of structure, pedagogy and support are raised by these developments: they have frequently surfaced in this report. Overall, it seems to us that this 'applied' approach to the science curriculum does hold promise for broadening the appeal, content and pedagogy of science education. However the wider questions raised by these qualifications should be apparent. They include: the nature of the student population for which the qualifications are intended; the occupational destinations which are envisaged for these students; and, critically, the distinctive educational purposes which are intended for any 'applied' route. The answers to these questions will be critical to determining the educational meaning, positioning, and ultimately the legitimacy, of this broader vision of Applied Science in schools.

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APPENDIX 1:

The Announcement of 'Vocational GCSEs'

The press release in July 2000 through which 'vocational GCSEs' (later 'GCSEs in vocational subjects') were announced.

"Education and Employment Secretary David Blunkett today confirmed that new vocational GCSEs will be introduced in 2002 to replace Foundation, Intermediate and Part One GNVQs as the new vocational alternative for 14 to 16 year-olds.

Vocational GCSEs will be available in subjects including manufacturing, information technology, health care and engineering and will enable young people to move on to apprenticeships and into jobs. They will also help in the drive to tackle truancy among disaffected young people.

This will put in place a further rung in the coherent ladder of vocational learning, rooted in school and moving through Foundation and Advanced Modern Apprenticeships into Foundation Degrees and work-based qualifications…

A recent survey carried out for the Skills Task Force found that 40% of all skills shortages are in craft and technician-type jobs, requiring high-level skills gained through substantial job-specific, work-based training. In manufacturing, with the needs of new technologies and different work practices, although overall demand for technicians and craft workers is falling, the need for these workers to have more and higher level skills is increasing. Vocational GCSEs will be a crucial rung in the vocational ladder we are introducing to tackle these skills shortages."

http://www.dfes.gov.uk/pns/DisplayPN.cgi?pn_id=2000_0313 (accessed 7 November 2006)

APPENDIX 2:

A Summary of the 2001 Criteria for Applied Science Specifications

(Full text available at http://www.qca.org.uk/9950.html. 10 April 2007)

The aims of the course are defined as being to encourage students to develop:

- *an understanding of science and how it is used to the benefit of society*
- *an awareness of how institutions and companies use science in a wide range of essential functions*
- *the ability to apply knowledge and skills to solving scientific problems in a variety of vocational contexts*
- *the experimental and laboratory techniques used by scientists in a range of vocational contexts, taking appropriate consideration of health and safety issues*
- *the skills to use scientific instruments and equipment in a competent fashion and with confidence*
- *an interest in science through studying science in a vocational context."*

The three units required consist of the following elements:

Unit 1: Developing scientific skills (assessed by portfolio: 33% weighting)
Unit 2: Science for the needs of society (assessed by examination: 33% weighting)
Unit 3: Science at work (assessed by portfolio: 33% weighting)

Unit 1: Developing scientific skills.

The first element of this is focused on "working safely in science": students are commonly required to produce a report on safety issues. The remainder of the unit is severely practical and involves students carrying out practical tasks, involving the following skills:

- following standard procedures
- handling scientific equipment and materials
- recording and analysing scientific data in the areas of:
- investigating living organisms
- chemical analysis
- investigating materials.

These tasks are of a fairly routine kind, but may be thought to reflect (modified for the level of a school student) the work that a technician employed in an industrial laboratory might be expected to undertake. They are further broken down into:

Microscopy
Micro-organisms
Qualitative analysis
Quantitative analysis
Electrical properties
Other physical properties

These elements are yet further broken down into a required set of specific activities, e.g. under electrical properties students need to: investigate how:

- the nature, length and thickness of materials influence electrical resistance
- current varies with voltage in a range of devices.

The student's performance is assessed solely through a portfolio of reports of the activities that s/he has undertaken.

Unit 2: Science for the needs of society.

This unit is essentially concerned with scientific knowledge, under the headings of
- living organisms
- obtaining useful chemicals
- materials for making things
- the importance of energy.

and is assessed by a formal written examination which can be taken at a number of points in the course. The questions in the examination are set in a workplace context.

Unit 3: Science at work is broken down into

- science in the workplace
- making useful products
- instruments and machines
- monitoring living organisms.

Under the theme of science in the workplace students must
- identify local, national and international businesses and service providers that use science
- put their employees into one of three classes: major; significant; and small users of science
- find out where the organisations are located and why
- identify the types of scientific activity that are carried out and the job titles and qualifications of the
- people who perform them
- find out what skills scientists need in addition to their qualifications
- find out what careers are available in science and science-related areas.

Under each of the other headings students are required to undertake a range of specific tasks. For example the element called 'making useful products' is broken down as follows. Students will:
- describe the factors that affect how quickly a reaction occurs
- explain the terms: actual yield; theoretical yield; and percentage yield
- explain that some processes are based on reversible reactions and that the conditions affect the yield of the products.

  …
- prepare pure, dry products using three different types of chemical reaction
- explain the underlying chemistry involved in each type of reaction
- explain the industrial importance of each reaction.

For each preparation they will:
- know the type of reaction used
- measure the actual yield
- present the product in a suitable sample tube, with its name, date of preparation and relevant
- hazard warnings
- write balanced chemical equations to describe reactions, when provided with the formulae of reactants and products
- calculate the mass of product that could be obtained from a specified amount of reactant (theoretical yield)
- calculate the percentage yield of a reaction from the theoretical yield and actual mass of product obtained
- calculate the costs of making a given amount of product.

The other two elements, instruments and machines and monitoring living organisms are similarly broken down. Again, this unit is assessed solely through students' portfolios of work.

APPENDIX 3:
Two Case Studies, Faraday School and Rutherford School

Faraday School

Faraday School is a large comprehensive with a 13-18 age range and 1400 students on role. It is situated in a moderate sized town with a range of light industry. The school serves a mixed catchment area. In 2005, 51% of its students had achieved 5A*-C grades at GCSE, an increase from 40% the previous year. Data collection in the school took place mainly in 2004, and consisted of interviews with two Applied Science staff, the Head of Science and an SMT member. In Summer 2005 a follow-up interview with the new Head of Science was conducted: the previous Applied Science staff interviewed had all moved on or retired.

It was apparent that the introduction of Applied Science in the school had occurred at the initiative of SMT, and reflected two main policies: first an attempt to address the perceived underperformance of the Science Department at KS4, and its impact on the school's league table position; second, to contribute to the aim of reconfiguring its KS4 provision to offer distinctively different routes through the curriculum, at least one of which would have a strong vocational 'flavour'. The school was also in the process of becoming a specialist Business and Enterprise College.

It appeared that SMT had put some pressure on the Science Department to offer, if not this course, then some vocationally-orientated provision. A team of staff had been created by invitation, but it was not apparent that this had been with the support of the Science Department. The Head of Department commented: 'I think we might have been allowed to decide for ourselves'. The department had been exploring possibilities of a more vocational course, though it is not clear how energetically. The SMT interview included a rare comment about the involvement of governors in the process of decision-making. Concern had been expressed about a dilution of the science curriculum, and perhaps about the 'closing down of opportunities' for some students. The governors' concerns had been addressed, but the comments reflected a sense of hesitancy in the school's take-up of the course.

The course was taught to two middle attainment classes of about 24 students each. Staffing was based on volunteers who had attended courses and decided that Applied Science had something to offer: it is not clear what would have happened had volunteers not been forthcoming. Since two members of the Applied Science team were NQTs, it may be that the 'volunteering' was not quite as free as the word suggests. Two pairs of teachers taught the two classes in each cohort, specializing in physical and biological science respectively. No member of staff had overall responsibility for the course and there was no allocation of points. When asked about how decisions were taken, and who had responsibility for taking decisions, answers tended to be somewhat vague, with a quasi-collegial flavour. The Head of Department was not involved in teaching the course.

Perceptions that the Science Department was underperforming were reinforced by comments from the SMT member who was interviewed: students were seen as being turned off science, and it was hoped that the course would help remedy this for the middle attainment range. Although from an SMT perspective the course was seen as part of a wider initiative to offer a range of vocational courses, there was little acknowledgement of this within the science staff interviewed. The choice of students for the course reflected the aim of increasing C grades: the focus was firmly on students in the C/D borderline, with a clear hope that the proportion obtaining grade C would increase. Parents of the children selected had received a letter telling them about the course, and explaining that it was felt that it would benefit their child. It appeared that few parents had expressed any reservations, though in one or two cases there had been a shift back to Science. Staff felt that there had been some perception that the course was for less able students, but said that this had disappeared. The students themselves suggested that it was a course for those who were better at coursework than examinations, and were broadly positive in their comments.

All staff involved had attended courses provided by awarding bodies, though these had focused mainly on assessment. Staff commented that the Applied Science course had appeared very confusing at first. The four teachers involved had been given one day off-timetable for planning. The team had put the course together themselves, and had used a commercial scheme. They had found this helpful but needing substantial modification. One team member suggested that Applied Science would be very difficult to implement without some support of this kind, suggesting a substantial reliance on the material. Worksheets from the scheme were employed in both the lessons seen. The focus in the lessons seen was on practical activity: the titles of the two worksheets were 'Finding out about solutions and emulsions' and 'Determining thermal conductance'. These activities included some emphasis on everyday situations where science is relevant, though they were not in any clear sense 'vocational'.

Teachers commented that the course was very different from traditional Double Award Science, with less content but the same standards, and that there were fewer constraints on the teacher. No contacts had been made with local industrial firms or other workplaces and this was judged a problem with the course by one member of the team. One staff member had formerly been employed in a nearby chemical works but had not made any approaches to the firm.

Staff stressed the greater emphasis in the course on pupil independence, but suggested that this was not easy to maintain. They commented that the assessment regime motivated pupils, and that there were opportunities for working with them to improve gradings. There did not however appear to be any uniform policy about how work was to be graded and followed up. Staff, who were interviewed about one year into the course, felt that they had gone through the material too slowly, partly as a result of using, and perhaps relying too strongly on the commercial material. They also felt that the intensity of the assessment regime, and its associated organizational demands had been difficult to sustain. It was difficult to gain any sense of the overall structure of the course, which was said to have little documentation, and to be planned mainly from meeting to meeting by the team. Nevertheless, the judgements by staff during interviews on the course were reasonably positive. However a major doubt expressed by all of those interviewed was the absence of clear progression opportunities. The course itself seemed to suffer from a lack of clear leadership and perhaps a lack of distinctive purpose within the department. In particular there appeared to be no member of staff willing to take up the possibility of researching and championing a post-16 course, something which was of particular significance within this 13-18 school.

Follow up interviews at this school proved problematic because both of the Applied Science teachers interviewed moved on, while the Head of Department retired. However an interview with the new Head of Department in the Autumn of 2005 allowed an overview of the subsequent development of the course to be obtained. The key moment in the process appeared to have been when the outcomes of moderation were received. The portfolios submitted by the school to the awarding body, which had suggested a fairly promising picture for the likely gradings, had been significantly downgraded by the moderator. As a result students had underperformed compared with their predicted Double Award grade: in consequence the school had taken a decision to drop Applied Science when the current cohort had completed. So far as could be judged the previous approach and organization had been retained, with little clear leadership, and no-one nominated to take a leading responsibility for the course, to pay attention to the guidance which was available from examining groups, to make queries and so on. It seems likely that the absence of such a person contributed both to the outcomes of the moderation process, the lack of long-term planning and organization of the course and, ultimately, the decision to withdraw from it. Nevertheless the school was considering offering a single award applied course from among the new specifications available in 2006.

Rutherford School

Rutherford School is a suburban 11-18 Catholic science college. It was first visited in Spring 2004, towards the end of its first year of Applied Science, and then again, over a three-day period in Summer 2006, towards the end of its third year offering Applied Science. It has approximately 1,300 students: in 2004, 69% of students achieved 5 A*-C grades, and in 2006 this rose to 73%. Three-quarters of the 2006 GCSE Applied Science students gained grades A*-C. The school was chosen for further study within the project because of the apparent success of its Applied Science course.

This account is based on first round interviews with a member of SMT, the Applied Science Course Leader, and a teacher of Applied Science, together with observation of two Y10 classes working on U1 (finishing coursework) and a consideration of the school's in-house documentation. In the third round, the Course Leader and the same teacher were re-interviewed, in addition to which a teacher coming to the end of her NQT year was interviewed. Four students discussed the course in a taped focus group meeting. Two Y10 lessons were observed: students were carrying out the practical for the Unit 3 assignment, focusing on making and assessing the effectiveness of one electrical or electronic device, in this case a moisture tester for a houseplant supplier. Again, access was given to in-house materials such as assignment sheets, teachers' notes, and schemes of work.

In the two years between visits, Applied Science grew substantially in terms of its cohort-size. Initially, almost 40 students took the course; the second cohort comprised approximately 60 and the third 80. Applied Science had gone on to replace Foundation Modular. It was matched to students on an individual basis, dependent on staff members' views of students' 'learning style' and career aspirations. Students had shown unease at being placed in the first cohort, but within the year, they were very positive. By the third year:

Now it has a completely different reputation, people actually opt to do Applied Science, to be in an Applied Science class. Their parents want them to be, that's because the exam results were so positive last year and also because the students' comments about Applied Science are incredibly positive. (Course Leader)[34]

The choice of awarding body had been the Head of Department's, who concluded that it was hard to choose a specification 'just by looking' so:

in the end we just went for the Board that we worked with already, actually. Because I know so many of the people it's useful too, and they're also the biggest Board, so often they have the best resources produced for them.

The Course Leader joined the school shortly after the decision to offer Applied Science had been made: responsibility for the course was a clearly-defined part of her job. Towards the end of her second interview, the Course Leader noted:

The organisation of it and the underpinning preparation are absolutely key …You need the one who's responsible for it to be pretty organised because you need to think of how this subject is going to go over two years, but also how it might grow over those two years. And to make sure the marks are right and the specification is being followed, and you are going to get a success, because it doesn't really matter what you put in your CMS, Centre Mark Sheet, if those marks are totally inappropriate, your whole Centre will be affected and that's a massive problem if that does happen.

The textbook edited by the awarding body's Chief Examiner was purchased, but most teaching was based on in-house materials. Assignments were devised prior to the start of teaching and these remained in place over the three years, with only cosmetic changes to the presentation of assignment sheets. The Course Leader explained,

But that's because I researched it well beforehand and I had gone to meetings, I'd chatted to the Exam Board representatives, so I sort of wanted to know before I stepped into a classroom that I was going to start in the right way, so I haven't changed a lot.

Attention was given to devising tasks that would enable the highest attaining students to access the full-range of grades. For the third year, writing frames, tables to be filled in and similar such support were prepared for the academically weakest students. This level of support put a ceiling on the marks available, but was judged appropriate for these students, on the grounds that it enabled them to reach their potential. In terms of marking and standardisation, the Course Leader was from the start able to draw on her own previous experience of moderating other science courses and thus apply the mark scheme consistently. Her role also benefited from having worked for the awarding body: she quickly becoming involved in devising the new (2006) Applied Science specification. By the time of the second interview, the Course Leader was involved in providing INSET within SSAT for other schools interested in Applied Science, as well as moderating Applied Science portfolios.

Whilst choice of specification and its translation into student assignments are clearly critical, Rutherford's success lay, according to the Course Leader, also in choice of teachers: 'I think that's very important that you pick your teacher-type as well as your student-type.' The school's policy on students was, first, to exclude any who knew they wanted to take A-levels in traditional sciences. Beyond this, teachers selected candidates with good attendance, and who would be willing to undertake coursework. The initial aim was to increase the proportion of C grades: in fact some higher grades were also achieved. Another Applied Science teacher explained:

It's really the students you've got. A lot of people I've spoken to about Applied tend to put it in as a blanket solution to low ability students, and it just doesn't work. Because it is coursework-based, you need students who will be there and who will write. And that's basically what it comes down to; they need to be able to communicate in both English and maths. Actually their scientific knowledge becomes the least important because it isn't about that, largely, this course.

The choice of teacher did not relate to their industrial experience or familiarity with vocational education, but to their anticipated relationship with students:

This course is successful mainly because you build strong relationships with your students and it's all about formative assessment and assessment for learning, co-operative learning techniques. And the most successful classes have been where the teacher has been very, very persistent, consistent and built good relationships, even with challenging students. (Course Leader)

From the second year all students kept the same teacher throughout the course. Students had clear views about the characteristics of a good teacher of Applied Science: 'they've got to care about their students; they've got to want them to get the grades that they deserve' (Y10 boy). Something akin to a social contract was described: 'I think Miss [X], she doesn't just see it as a job coming in, teaching kids and then go, I think she sees it as coming in, helping–well, friends really, to get decent grades' (Y10 boy). One Y10 girl, discussing in-house grades, displayed a sharply realistic insight into the process:

And for us to get As, we're not really the keenest people in school. In science we do knuckle down a lot, don't we? Like for us

[34] By 'opted' the Course Leader appears to mean that students were asking if they could be chosen for the course. Throughout, teachers selected the Applied Science cohort.

getting As, it's a big achievement.

The workload on staff was judged to be substantial. Marking was a continuous process:

[Students] know that we're always going to come back to what they have done and we're always going to make it better. Nothing they ever do is the final thing, they have always got a chance to improve on it and they do that. (NQT)

The Course Leader insisted to staff that annotation was used throughout to justify marks. Abbreviations had been agreed to cut down on marking time. Occasional Saturday morning sessions were held, where students missing coursework were required to catch-up: commonly, many more decided to take the opportunity to improve up-to-date assignments. For one teacher, the additional time taken by these aspects of the course was partially balanced as lessons required less preparation, in part because of the quality of the schemes of work, but also because of the teaching and learning style.

And I think also, the planning for each lesson is a lot less than it would be for a normal double award, because I feel the lessons are actually a lot more laid back, sometimes I don't feel as if I do anything, because they get on with things and I'll say 'Who wants me to do something?' and they won't need me in the lesson.

A colleague put it differently:

It does require a totally different kind of approach. Being able to respond to immediate issues I would say is the main thing, because students work at such different paces and because it's coursework-based. You've just got to deal with 20 people on an individual basis, it's not like you walk in and you teach – you walk in and you deal with the problems that you have got on that particular day, so like you can be teaching 20 separate lessons, 22 separate lessons, whatever, basically. And that makes it interesting, but it also makes it slightly stressful.

Some of the pressure of the course was eased as a result of the school's very close home-school links. The Course Leader commented:

Here we have very supportive parents on the whole, and therefore if you've got trouble with a student, they'll want to know about it. And likewise, if you've got something good to say about (the student), they'll want to know about it.

When interviewed in 2004, she had spoken about sending letters home to parents praising students for handing in coursework on time. That students very much appreciated this aspect was apparent in one of the 2004 observed lessons, when they received letters with their teacher's congratulations for completing their first portfolio. This practice had increased, and by the time of the second round of interviews, special cards had been printed for a range of positive letters home.

The second way in which the burden of the course was mitigated was through a sharing of responsibility. By 2006, five teachers were teaching the course, some to both Y10 and Y11. As one said:

I'd say I felt more confident in my ability, having gone through it, and always knowing that the other teachers are also pretty good. We always work together and there's times when you ask questions in the base [Science staff room] and someone's always got an answer for a particular problem – how students tested whether their moisture testers actually worked and how did they communicate that in their assignments, little practical problems.

New colleagues were formally and informally inducted into the course. The Course Leader had worked with the NQT, who had been a graduate teacher at Rutherford, during the summer holiday before she took up a class. Throughout her NQT year this teacher had followed the teaching sequence of another colleague's class, and both members of staff had shared worksheets that they had devised. This, one commented, 'halved the planning really' (NQT).

The school had close links with companies linked to its Science College status, particularly involving a local pharmaceutical company. The company worked closely with the Applied Science course, and had won an award for community links in Summer 2006. It was recognised that building and sustaining these links required time, effort and planning:

It's hard working with industry, it's not easy, I mean I spend holiday times going to meetings at the hospital or [the pharmaceutical company] or whatever. And I think it is important that you realise that it is a two-way process. The time it takes to get a contact is probably much longer than you'd anticipate, but it is worth it. (Course Leader)

By the third year, the Course Leader had organised visits to the local sports centre, fire station, pharmaceutical company, organic farm and was developing links with the hospital for post-16 visits to see MMR scanners, X-ray equipment and its laboratories. In the two year period between interviews it had been decided to emphasize visits rather than visitors, because the students had found it too difficult to cope with presentations unsuited to them. At least one visit to the school had been discontinued because the employees had not been able to adapt to the needs of Key Stage 4 students.

Overall, very few of the fundamental decisions that had been made for the first teaching year (2003-4) had been changed by the third. The single biggest difference between 2004 and 2006 was that Unit 2 was no longer integrated into Unit 1.

The students found it incredibly difficulty to pick out what they needed to know for their assignment, as opposed to what we were teaching them for the exam, even when you were quite specific and saying 'When we're doing this assignment, I'm teaching this science. This is going to be useful in the exam.' When it came to the exam, they would be like, 'Well, we haven't done this' and I'd say, 'Well, you remember in that…' 'Oh yeah.' But they couldn't locate it across. So you tend to teach the exam material in a similar way as *you would any GCSE science. But obviously, linking everything to industry and to real life, as much as you can, as you would anyway.* (Teacher of Applied Science)

The full Applied Science team had agreed this change.

The concern at the time of the 2006 interviews was about the future of the course, as the Course Leader was moving on:

I knew that at the minute I was really the sole person who knows about Applied Science inside and out. The other teachers are really good, but obviously it is my expertise that has created the course.

Much of the success of the course appeared tied to this particular member of staff, who that year had standardized every single piece of portfolio work across the school. She had also devised the assignments, written teachers' support notes and played the principal role in inducting new staff. She hoped that the need to revise the schemes of work and assignments, in line with the 2006 specification's changes, would afford her an opportunity 'to involve more staff just for ownership really and a bit more shared responsibility'. She was seeking to re-define her role for her last couple of months in post, so as to manage this transfer of responsibility. The planned and managed quality of this process reflected the wider characteristics of the creation of Applied Science at Rutherford School. Her success in communicating and realizing the potential of the course was demonstrated in the enthusiasm of colleagues and students:

I love it, I don't ever want to teach double award ever again. I absolutely love the course. (NQT)

It's more interesting now than it was last year [Y9]. When we were doing that I found it really, really boring and now it's made me want to come to science. (Y10 Girl)

APPENDIX 4:
A Note on Data Collection

Data collection in the project consisted of the following main elements:

- fieldwork in schools (including documentary studies, teacher and SMT interviews, lesson observations and some student focus groups);
- observation of training sessions by awarding bodies and others;
- interviews and documentary surveys at QCA;
- two national questionnaires addressed to Heads of Science;
- a student questionnaire;
- analysis of the National Pupil Database for the 2004 and 2005 GCSE cohort.

Interviews and focus groups

Teachers from twenty schools were interviewed, over three rounds of data collection, in a rolling programme , with some continuities to introduce a longitudinal element:

Round 1: (2004) 10 schools
Round 2: (2005) 4 round 1 schools plus 4 new schools, together with telephone interviews of Heads of Applied Science in 4 other schools
Round 3: (2006) a more intensive 3-day site visit to a round 1 school, plus 2 new schools.

Interviewees also included other support providers, such as a Pathfinder consultant and awarding body Chief Examiners. The total number of adults interviewed was 64, and the total number of students interviewed 45. The numbers of training sessions observed were: AQA: 5; OCR: 5; Edexcel: 6.

Questionnaires

In 2005 a preliminary national questionnaire (NQ1) was addressed to all secondary schools, to ascertain which schools were following Applied Science, or intended to do so. The total response was: 248 offering or intending to offer Applied Science, and 333 not doing so. The total number of maintained secondary schools at that time was 3367[35]; the total of schools entering students for Applied Science in 2005 was 476.

In 2006 a more detailed questionnaire was sent to schools following Applied Science (NQ2). The total response was 149: this represents a response rate of just over 60%.

A questionnaire was sent to the Y11 students of a random sample of 50 schools (SQ) A total of 248 responses from students were received, from 11 schools: it is not possible to estimate the response rate by student, but that by school was 22%.

National Pupil Database for the 2004 and 2005 GCSE cohorts

These data were obtained after a request to the DfES Schools Statistical Unit (request numbers: DR050302.03 and DR060320.05). We are grateful for the co-operation of the Unit in enabling us to undertake this part of the work. The dataset consisted of anonymized performance data for the entire 2004 and 2005 GCSE national cohort, including anonymized school data, and selected data about students' Key Stage 3 test results.

[35] Table 1 Schools and Pupils in England: January 2006 (Final).
http://www.dfes.gov.uk/rsgateway/DB/SFR/s000682/index.shtml

The Consultative Group

The project also convened a consultative group made up of teachers from fieldwork and non-fieldwork schools. The group offered comments on generalised findings and questionnaires. The group met four times (February 2004, November 2004, July 2005, and January 2006).

Summary of Fieldwork in Schools

Anoymized school name	Round	Age Range	Applied Science Year	Awarding body	Type of Fieldwork
Boyle	1	11-18	2	AQA	I + O
Bunsen		11-18	2	AQA	
Rutherford		11-18	1	AQA	
Hodgkin		11-18	2	OCR	
Crick		11-16	2	Edexcel	
Darwin		11-18	2	OCR	
Davy		11-16	1	AQA	
Einstein		11-16	1	AQA	
Faraday		13-18	1	AQA	
Feynman		11-18	2	OCR	
Halley	2	11-18	2	Edexcel	I + O
Maxwell		11-16	2	OCR	
Hooke		14-19	3	AQA	
Joule		11-18	1	AQA	
Boyle		11-18	3	AQA	I
Hodgkin		11-18	3	OCR	
Crick		11-16	3	Edexcel	
Feynman		11-18		OCR	
Millikan		11-18	2	Edexcel	T
Newton		11-18	2	AQA	
Curie		13-18	2	AQA	
Pauling		11-18	1	AQA	
Ramsay	3	11-18	2	Edexcel	I + O
Rutherford		11-18	3	AQA	
Thomson		16-19	3	AQA	

Type of Fieldwork Key:
I Interviewing in person,
O: Observation,
T: Telephone Interviewing

The schools were mainly suburban and 'small town' comprehensives drawn from the South East, the Midlands and Yorkshire and Humberside. None was selective or independent. Three schools can be classed as inner city schools and two as rural.

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The Centre for Studies in Science and Mathematices Education, University of Leeds

The Centre for Studies in Science and Mathematics Education was formally established on 1st March 1970. Apart from a course of initial training for graduate teachers of science and mathematics, suitably qualified students may prepare for the following higher degrees: M.A., M.Phil., Ph.D., Ed.D. (Inquiries should be directed to Prof. Phil Scott, Director, Centre for Studies in Science and Mathematics Education, The University, Leeds, LS2 9JT.) There are well-developed research interests in a number of fields including: children's learning of scientific and mathematical concepts; the social history and politics of science and technology education; computer-based learning of science and mathematics; the implementation and evaluation of science and technology curriculum innovations; the national assessment of children's scientific attainments, adult scientific and technological literacy and the public understanding of science. A website for the Centre may be found at: http://edupc1130.leeds.ac.uk/research/cssme/index.php

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