Breaking the Mould?

Teaching Science for Public Understanding

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PREFACE

The research which is reported in this publication was commissioned by the Nuffield Foundation and undertaken on the Foundation's behalf by Professor Jonathan Osborne, Professor Richard Duschl and Dr Robert Fairbrother of the Department of Education and Professional Studies, King's College, London.

There were two purposes to commissioning the work. First was the intention to evaluate the teaching and learning of the new AS course in Science for Public Understanding, developed originally by the Nuffield Curriculum Centre in partnership with the University of York. Second was the desire to gain some general insights about teaching and learning 'new' kinds of courses which focus on teaching about science by extrapolating from the example of Science for Public Understanding.

The timing of the research – September 2001 to July 2002 – was important for harnessing the developmental aspects of the research to best effect. Crucially, the general findings help set the context for 21st Century Science, a major curriculum development project undertaken by the same partnership between the Nuffield Curriculum Centre and the University of York, which is embarking on the task of revising the core GCSE science curriculum.

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SUMMARY

This study has sought to evaluate the new AS *Science for Public Understanding* course (SPU) offered by the Alliance for Qualifications and Assessment and developed by the Nuffield Curriculum Centre and the University of York. This course aims (AQA, 1999) to encourage students to:

a. sustain and develop their enjoyment of science;
b. take an informed interest in media reports about issues and events;
c. develop, and be able to express, an informed personal point of view on issues concerning science and technology, taking into account, as appropriate, technical, economic and social considerations;
d. make use of their understanding of science and technology in everyday contexts, and in making decisions about personal lifestyle, such as those involving the use of energy for transport and in the home, and those about diet and health;
e. develop an understanding of scientific knowledge as the product of sustained work by groups of scientists over a period of time, and an awareness of the influence of social factors on the scientific enterprise;
f. develop an appreciation of the power of scientific explanations in helping to understand and control aspects of the natural world, whilst being aware of the nature of the limitations of scientific knowledge, particularly when applied to situations outside the laboratory;
g. develop clear and coherent arguments about the quality of empirical data, its interpretation and its implication for decision and action;
h. develop awareness that many technological developments build on scientific understanding and that major scientific advances can result from technological developments, and appreciate that technologies vary in their appropriateness in relation to culture, economic system and level of development.

These aims are achieved through teaching a set of topics which address the two major components of the course – a set of ‘ideas-about-science’ and a set of science explanations – which define what students are expected to learn.

The SPU course was offered for the first time in the year 2000, after two years of trials, and 600 to 800 students have taken the examination respectively in 2001 and 2002.

The data for this evaluation have been gathered through two teacher questionnaires; a set of 29 visits to lessons in nine schools – selected for the variety of institutions in which the course is taught and the range of experience of the teachers; a set of nineteen interviews with teachers; nineteen interviews with students; a student questionnaire; and an analysis of candidates’ examination responses in 2001.

The analytical framework that guided both the design of the research and the subsequent analysis of the data was the tripartite concept of the ‘intended’ curriculum, the

‘implemented’ curriculum and the ‘attained’ curriculum. The first of these is simply the intentions of the course as specified by the examination board, the textbook and other supporting materials. The second, a major focus of this work, is how these intentions are translated into a set of learning activities. A principal aim of this work was to explore the strengths and weaknesses of teachers’ implementation of the curriculum. The last of these, the attained curriculum, is what are the learning outcomes of this experience – both cognitive and affective – for the students who take the course.

The work was also strongly informed by the design of the curriculum around three themes: ideas about science, science topics, and scientific explanations. A fundamental design of the SPU course, as reported in Millar and Hunt (2001), was the expectation that the three topics would be integrated during delivery of the course. A focus of interest, then, was how each of the three themes was, or was not, present and how they were integrated in the implemented and attained curriculum.

However, essentially, this report has attempted to answer two questions:
a. How have the teachers implemented this new science curriculum and what difficulties have they encountered?
b. How have the students responded to this new science curriculum and what have they learnt?

The intention of the study has been to identify the strengths and weaknesses of the course to provide a set of recommendations for two purposes: first, to improve the existing taught course, and second, to advise developers of other such SPU-type courses on appropriate actions and strategies.

Section 3 provides a summary of the intended curriculum. Section 4 illustrates how the curriculum has been implemented, and Section 5 attempts to answer the second question – what has been learnt. Sections 6 and 7 deal with other matters emerging during the course of the evaluation.

CONCLUSIONS

Our first conclusion is that, at least in its intentions, the SPU taught course is distinctive and different from the standard courses that form the core of mainstream, secondary school science education, both in this country and internationally.

Second, the data we have obtained suggest that the course has been most successful in achieving its first aim – "to sustain and develop students' enjoyment of, and interest in, science". The overwhelming majority of students said that the course is both enjoyable and interesting. Moreover, the SPU course has managed to attract students who would not otherwise have studied science post-16. Likewise, nearly all the teachers surveyed or interviewed said that they have found the SPU course enjoyable to teach and commented positively. Four examples of such unsolicited comments are shown beneath:

But at key stage five it is really good. It is a really good course and I am surprised more students aren't doing it. I am surprised … I mean the difference between this and general studies is amazing. I hate general studies. *(Male head of science, comprehensive school)*

It is a very nice course to teach. I don't know whether we have been lucky with the groups we have had but I have thoroughly enjoyed teaching it. It is refreshing. It is refreshing to teach this sort of course. And it would be nice to think that in a few years time there will be a course like this at GCSE but we will see. It is a good course.
(Male biology teacher, comprehensive school)

Um I would love to persuade the students that it's really the science they should be doing. I would love to persuade all my GCSE resits students that they shouldn't be resitting GCSE science, that they should actually be doing something which is less sterile. But they want a traditional qualification. *(Female head of science, FE college)*

We like teaching it, so I hope we can attract enough students to keep it going. You almost wonder whether in a way it ought to be compulsory for all sixth formers to do actually.
(Female head of science, comprehensive school)

In addition, it is noteworthy that nearly 60% of all the students were female – a notable achievement for a course where 50% of the content is physical science.

These are significant achievements in the current context where many other science courses, particularly at GCSE, are failing to engage students (House of Commons Report, 2002). Another particular strength of the course has been the focus on the ethical, technical and economic dilemmas raised by the application of science in today's society. Students found the opportunities provided by the course to consider the social dimensions of science both novel and engaging. The course has also been supported by a textbook that most teachers and students judge to be of good to excellent quality. In addition, the course has an innovative and original approach to coursework requiring two pieces of writing – one a study of a topical scientific issue and the other a critical review of a popular scientific text. And, in contrast to GCSE coursework, students have a degree of choice in both.

Hence, our summary judgement is that this course does offer an educational experience about science that is significantly different from traditional science courses and is engaging and interesting for its students. In that sense, this course has broken the mould and framework which has structured science education for the past 40 years and is to be welcomed.

Nevertheless, it is clear that there are a number of issues raised both for this course, and any other courses of this nature that seek to teach about science and consider its social implications. Practical work is virtually absent, and the course is often not taught in a laboratory. The significance of this omission is twofold. The change of location, combined with the broader nature of the material to be taught and considered, makes new demands on teachers' pedagogic techniques; an example is the skill to run and organise effective discussions that engage all students in thinking critically about socio-scientific issues. Students need to be explicitly taught, not only how to evaluate media reports about science critically, but also how to construct effective arguments which are reliant on evidence rather than personal or group opinion. There has been no handbook to provide guidance of how this might be done or to offer other suggestions for lessons, thematic integration and/or teaching approaches. Lacking such support, teachers have become reliant on the textbook and internet sources to provide a structure and coherence to the course.

In addition, our findings suggest that teachers have found it difficult to break free of the modes of interaction with students which are acquired by teaching standard science courses. Too many lessons were observed where explaining the science predominated, to the detriment of exploring other aspects of science, in particular the ideas-about-science component and the underlying major science explanations. Our findings would suggest that teachers seem to lack an organising framework which puts these two components to the fore. Rather, the science content is still too fragmented, and many opportunities were missed to develop a better understanding of the nature of science, its practices and its processes. Given the lack of detailed guidance for individual lessons on how to coordinate these themes, this finding is perhaps unsurprising.

The other problem associated with the lack of practical work is that opportunities to interpret and evaluate empirical data were diminished. Of itself, this need not be a problem as there are many other sources of secondary data that can be used for such tasks, particularly on the internet. However, given that the topic of 'Data and Explanations' is a significant component of the 'ideas-about-science' element, it suggests that, in effectively breaking the Gordian knot that ties so many teacher to the laboratory, the course may not have provided a set of complementary exercises and strategies to address this important element of any science course and aim **(g)** of this course (see page 6).

Our major finding, therefore, is that whilst the course is successful in attaining its first aim ‘to sustain, and develop the enjoyment of, and interest in, science’ and has made significant strides to achieving aim **(b)** of encouraging students to ‘take an informed interest in media reports about issues and events involving science and technology’, the lack of teachers’ pedagogic skills *required for this kind of course* and strategic curriculum support is limiting the achievement of the other five aims. Changing the cultures that form and mould teachers is, unfortunately, a much harder task than simply changing the curriculum. Indeed, it requires considerable support, effort and time. The SPU course has begun that process and planted the seeds of a different way to teach and engage students with notable success. Enabling it to take root will require continued support and endeavour.

Our view is that innovative courses such as this must be supported at the very least by a teachers’ handbook, but preferably by training materials and courses that provide samples of exemplary practice. For such courses require teachers to adapt and change their existing practice. As such this is a change which is not amenable to short term solutions and will require ongoing support and professional development. Consequently, a number of recommendations have been made about how teachers can be supported in teaching this or other such courses. We have also made recommendations of a more minor nature about the course structure and the examinations. We are not, for instance, convinced that there is sufficient cohesion between the aims of the course, the examination and the coursework.

As for other courses of this nature, in particular, the proposed ‘Science for the 21st Century’ we have made several recommendations that draw on the findings of this study. For designers of such courses we would wish to emphasise three points. These we see as: the need to support teachers who will have to adapt to a novel set of curriculum requirements; the need to ensure that the examination reflects the course aims; and a context which breaks the link between teaching science and the laboratory. The first of these, in particular, will require three components – a teacher handbook, in-service materials and training packs, and a good quality textbook.

Finally, the current position of the course is problematic as an AS. It competes with general studies and critical thinking in many institutions, and students and teachers told us that the name does not provide a good description of what it offers. Moreover, AS courses are under threat as they have too little recognition by the universities and have imposed an extra burden on many schools. The course should possibly seek to build on its own success by using promotional material that draws on the positive comments that both teachers and students have made.

PRINCIPAL RECOMMENDATIONS

The recommendations are split into two major groupings – a set for the existing AS Science for Public Understanding, and a set for other courses of this nature. They are grouped under separate headings and, under each heading, appear in order of their relative significance – the most important coming first.

Recommendations for the AS course

The following recommendations are for the existing Science for Public Understanding course.

Developing teachers' capabilities to deliver the course

1. The change in approach and strategies demanded by this course require the support of a teachers' handbook that would contribute significantly to improving the teaching of the course. Given the small numbers, it may be uneconomic to produce one. In which case, the website should point teachers to specific lesson plans and resources which fulfil the same function [para 4.29, 5.9, 6.3].

2. Teachers need more direction on how to develop students' skills of reading, writing and constructing effective arguments [para 4.48, 5.20]. Argumentation skills are an important skill required by the course and a major course aim [aim **(g)** on page 6]. Teachers need guidance on how to develop, construct, and communicate effective arguments and their evaluation. [para 4.61, 4.63]

3. Teachers need support in order to teach effectively a course that requires different instructional strategies to meet its objectives. Innovative courses of this nature demand that teachers teach out of the traditional box which constitutes science education, introducing, for instance, the exploration of ethical issues about appropriate courses of action. Such topics often require the use of unfamiliar strategies such as the use of open-ended or small group discussion. Whilst some teachers do succeed without support, the majority of teachers would benefit from professional training that explores a range of ways in which such work should be approached. In addition, such training should provide the opportunity to see a skilled practitioner at work. [para 4.14, 4.45, 6.5]

4. Teachers require enhancement of their background knowledge to meet the course objectives. Professional training should aim to develop teachers' background knowledge of the fundamentals of ethics, contemporary views about risk, and the nature of science. [para 4.14, 6.6].

5. More explicit guidance on the identification of salient features in media reports of science for their critical evaluation [para 4.29] is required. In addition, advice is needed on exercises that might assist teachers to develop their students' understanding of the salient features requiring identification [para 4.54, 4.61].

6. Lists of recommended video resources are required as they are an important element of the course. Such a list of recommended videos and their sources on the website would assist teachers new to the course [para 4.37].

Improving the course and course structure

7. Coursework and course aims need better integration. Whilst the coursework element is innovative and well understood by teachers and students, the relationship between its requirements and the course aims needs to be strengthened [para 5.26].

8. There is some evidence to suggest that the intellectual demands of the taught course might need strengthening [para 5.8]. The demands of the examination are appropriate, and the distribution of grades suggests that the examination is well matched to the capabilities of the cohort. Rather, the weakness, where it does exist, lies in the teaching which is not making sufficient intellectual demands on the students. This could be remedied by providing additional material on the website and including one or two more demanding questions in the examination.

9. The title of the course does not convey its essence, and its distinctive nature to potential students. It should, therefore, be reconsidered [para 6.7].

10. The course numbers make its continuation questionable. The clear success of this science course in interesting students in science merits further promotion and publicity within the science teaching community, schools, and FE colleges. [para 6.9].

Examinations

11. There is a need to examine what may be an inconsistency between the taught course and the examination. The chief examiner and the examination board need to consider whether the questions asked in the examination match the specifications and intent of the course. In particular, there is insufficient evidence that the examinations are examining a holistic understanding of the major explanatory themes rather than isolated elements of scientific knowledge [para 5.13]. In addition, evidence of teachers' practice in the classroom would suggest that there is insufficient emphasis on the ideas-about-science – a lack of emphasis that is also reflected in the examinations [para 4.11, 4.18, 5.13, Table 13].

12. One or two more demanding questions may be required in the examination to signal to teachers that this is an intellectually demanding course [para 5.8].

Recommendations for other proposed courses of this nature

The following recommendations are offered for other courses with similar aims. Whilst several are inevitably similar to the previous set, there are distinctions in their nature and substance.

Course content and design

13. The high quality of the SPU textbook has been a vital factor in the success of the course. Given the more discursive nature of such courses, a good quality textbook is considered essential [para 4.35, 4.48].

14. The inclusion of aspects of contemporary science in any science course requires that students have access to the internet as a source of up-to-date information [para 4.28]. Students and teachers need a central reliable guide to which websites are of good quality and pedagogically valuable. In addition, they need structured exercises that develop their skills in using this resource and evaluating critically the information they find there [para 4.28, 4.53].

15. Courses of this nature do not require access to a science laboratory every lesson. Moreover, the laboratory is an environment which dictates to some extent student expectations of science lessons and teacher pedagogy. Given also the need for internet access, any science course of this nature should require that at least half of its lessons are taught in a normal classroom and not a laboratory [para 4.7, 4.53].

16. Practical work and empirical enquiry are an essential component of science. In addition, teacher demonstrations perform an important illustrative role of the nature of phenomena and the scientific world-view. For courses for younger and less mature pupils, we would recommend that practical work, albeit of a different nature, should still be incorporated in such courses [para 4.41]. Its role should be to enable the rapid collection of sets of empirical data for analysis, interpretation and evaluation.

17. For their own sake, courses such as these must be sufficiently demanding and rigorous. Firstly, any course must be able to defend itself against accusations of simplification and 'dumbing down'. Secondly, able students in particular require a course which is intellectually challenging if they are to engage with it [para 5.8].

18. A degree of choice in any taught course about its content restores to teachers an element of professional judgement about what is appropriate for them and their students. Such choice also facilitates 'ownership' of any new curriculum and therefore should, if at all possible, be incorporated. For similar reasons, the element of choice offered to students for the topic of their coursework is also valuable and should be retained [para 7.5].

19. Any science course that addresses the major explanatory themes which contemporary science offers our culture should include some treatment of plate tectonics and the evidence for this world view [para 3.3].

Examinations and assessment

20. For any course of this nature, the development of appropriate forms of assessment is as important as the development of the curriculum materials. The assessment items are the means by which most teachers determine the intended curriculum and it is essential that the curriculum and its assessment are well-matched and complementary [para 4.11, 4.19, 5.13, 5.14].

Teacher support and professional development

21. The change in approach and strategies demanded by such an approach to teaching science makes a teachers' handbook an essential item. Such a handbook should have a large number of lesson plans with explicit aims, objectives and strategies [para 6.13, 4.44, 5.9, 6.3].

22. Courses of this nature demand more of students' skills to read, write and construct arguments. Explicit guidance on how to teach these skills will enhance the quality of student experience and learning [para 4.48, 4.61, 4.63, 5.20].

23. Science courses of this nature require at least a basic understanding of some of the fundamental ideas of ethics, risk and the nature of science. Many science teachers lack such knowledge which has not formed part of their own education. In addition, some of the domains of contemporary science in such courses are unfamiliar, not having been part of their own education. Professional training for any new course should attempt to improve teachers' knowledge of these aspects. [para 3.10, 4.14, 5.32, 6.6]

24. Science courses of this nature require teachers to use and manage open-ended and small group discussions of a fundamentally different nature from that traditionally found in the science classroom. Most teachers will require professional training and support to adapt their practice. Video training materials are very important to illustrate new kinds of practice [para 4.14, 4.45].

25. Teachers need explicit guidance on the identification of salient features in media reports of science for their critical evaluation [para 4.29]. In addition, guidance on exercises that might develop an understanding of these features in their student are required [para 4.29, 4.54, 4.61].

26. Video material is an essential element for courses of this nature, bringing the issues confronting society into the classroom in a stimulating and engaging manner. A list of recommended videos and their sources will, therefore, be required and would be best provided on a website where it could be regularly updated. In addition, consideration should be given to whether such material could be made available by CD-ROM or DVD [para 4.37].

1. BACKGROUND

1.1. The new AS course 'Science for Public Understanding' marks a radical departure for secondary school science education. The basic nature of the school science curriculum has, since its inception both for pre- and post-16, remained predominantly a pre-professional preparation for the study of science for a traditional set of scientific careers such as medicine, engineering or research. Such a science education has generally failed to communicate the grand ideas of science – the 'explanatory themes' that have both personal and cultural significance – and to develop a deeper understanding of science itself or what has been described as 'ideas-about-science' (Millar & Osborne, 1998). In addition, such curricula have been substantatively criticised for failing to address the needs of the majority (American Association for the Advancement of Science, 1989; American Association for the Advancement of Science, 1993; Millar & Osborne, 1998) and have led to the demand that contemporary curricula offer a science education which is a better preparation for citizenship. Whilst attempts to change the curriculum to meet these demands can be seen in the recent changes to the Science National Curriculum (Department for Education and Employment, 1999), particularly in the new component 'Ideas and Evidence' and in the National Science Standards (National Academy of Science, 1995), such changes as there are would best be described as piecemeal and tinkering at the edges rather than substantive. Only two curricula – the Dutch ANW post-16 course (De Vos & Reiding, 1999) and the new AS offered by AQA (1999) – the subject of this report – offer a new vision of what science education might be. Inevitably, the implementation of such a course poses a significant number of challenges to teachers; many of these are explored in this report.

1.2. The concept of a course which aims to teach science for public understanding was initially articulated by Robin Millar of the University of York in an article in the *School Science Review* (Millar, 1996) and more broadly articulated in the document *Beyond 2000: Science education for the future*. Millar's ideas led to an approach from Phil Pryor of the then Northern Examinations and Assessment Board to assist in the development of such a course. The writing of the specification was then undertaken by Robin Millar and Andrew Hunt of the Nuffield Curriculum Centre, in consultation with a small group of teachers who had taught the previous Science, Technology and Society (STS) AS-level which SPU replaced. The development of a textbook and other forms of support for teachers adopting the course was supported by a small grant from the Nuffield Foundation. Trials of the course began in 1998 and the course was offered nationally for the first time in 2000. A useful summary of the nature of the course and teachers' experiences can be found in Millar and Hunt (2002).

1.3. The arguments in *Beyond 2000* have attracted considerable interest both within science education and without, such as the House of Lords report (2000), the Roberts report (2002), and most recently the report of the House of Commons Committee for Science and Technology (2002). More significantly, it has been the subject of a body of exploratory work undertaken by QCA to examine how the science curriculum needs to be changed to meet the needs of the 21st Century. This work has led to QCA commissioning the Oxford, Cambridge and RSA Examinations Board (OCR) to develop a syllabus for a course entitled ‘Science for the 21st Century’ in 2001. Approval has now been given for the development and piloting of such a course from 2002 with the first GCSE examination to be taken in 2005. The development of curriculum materials for this course is being undertaken at the Nuffield Curriculum Centre and the University of York, and funded by the Nuffield Foundation, the Wellcome Trust and the Salters Institute.

1.4. Underlying much of the interest in such courses is a general recognition that school science education is failing to engage large numbers of young people between the ages of 14 to 16 (Roberts, 2002; Osborne & Collins, 2000; House of Commons Science & Technology Committee, 2002). Given that this period of adolescence is a crucial determinant of attitudes to subjects, and that attitudes once formed are enduring and difficult to change, two principal concerns emerge. The first is that insufficient young people are choosing to study science post-16; the second is that large numbers of young people may be alienated from a subject which is the basis of contemporary society and permeates its cultural landscape. For better or worse, many of the political, moral and ethical issues of contemporary life, from global warming to the use of the MMR vaccine, are of a scientific nature. Without some understanding of the underlying science and the nature of scientific knowledge and its determination, there is a growing concern that the ability of many of our young people to engage in a meaningful debate and make a considered and evaluated response to these issues will be undermined. The new AS course ‘Science for Public Understanding’ is an attempt to respond to the second of these concerns, in particular. The course offers an education about the major explanatory themes of science, a set of essential ideas about science, risk, and the ethical and moral dilemmas posed by scientific advances.

2. AIMS OF THE STUDY

2.1. Given these concerns, a question of interest in this report is whether a new course such as SPU can provide a better *education* in and about science for the majority of 14-16 year olds. Such a course would aim to offer a much more holistic and less piecemeal presentation of the major conceptual themes in the sciences, to develop a better understanding of the processes and practices of science, and to consider the moral and ethical implications of the applications of science and technology. To answer some of these questions, the Nuffield Foundation considered it important, therefore, to investigate and evaluate how teachers' attempts to implement such a course, the new *AS Science for Public Understanding* (SPU), were succeeding or failing. In particular, two principal questions emerged about this innovative course. These were:

a. How have the teachers implemented this new science curriculum and what difficulties have they encountered?

b. How have the students responded to this new curriculum and what have they learnt?

The principal aim of this report has, however, been twofold. On the one hand, we have sought to examine the strengths and weaknesses of the existing course and how it might be improved. More importantly, perhaps, we have also sought to identify what are the implications of these findings for any similar course which may be offered to a younger cohort of 14-16 year old students.

2.2. To answer these questions, this study has sought to offer some insights into the strategies, difficulties and successes that teachers have encountered in teaching such a science course and how their students have responded. For instance, are there particular difficulties encountered because the SPU course makes excessive demands on science teachers' knowledge of either the content of science or its nature? Does teaching a science-based course with virtually no recommended practical work pose a new challenge to the range and nature of the pedagogic strategies that teachers have to use? What kinds of learning demands does the course make of its students and what are their responses to the SPU course? These and other questions, therefore, have been the focus of this work and of this report.

2.3. The approach taken to answering these questions was to gather a set of data through a number of instruments and methods – (a) two teacher questionnaires – the first of which had a response rate that we estimate to be 70% and the second one of 60%; (b) a student questionnaire which was sent to 400 students in February – a total of 223 responses were received which represents 28% of the total cohort of 800 students that entered the examination in 2002; (c) a set of 29 visits to 9 case study schools; (d) 19 interviews with teachers from 13 schools; (e) 19 interviews with students from 4 schools; (f) an analysis of a 10% sample of the examination papers from candidates for the examination in 2001. Full details of the methodology can be found in Appendix 1.

2.4. The approach to this work has been to see the curriculum as consisting of three essential components (Robitaille, 1993):

a. The designed or intended curriculum. By that we mean the set of documents which specifies the intentions and rationale of the course developers. These are spelt out to a greater or lesser degree via the course specification (AQA, 1999), the textbook (Hunt and Millar, 2000), and the materials and resources available from the website. Another major component, used particularly by teachers for determining the intended curriculum, is the examination papers. The questions on past and specimen examination papers offer an embodied conception of the curriculum which concretely and specifically answers the teachers' overriding question of what are the specific aims and intentions of any course.

b. The taught or implemented curriculum. This is the set of activities, learning experiences and pedagogic strategies which teachers use to enact the intended curriculum. This component is heavily reliant on individual teachers' conceptions of what the curriculum intends, and their professional judgement about how this might best be achieved. Previous research has shown that the implemented curriculum is not identical to the intended curriculum. The match between intentions and implementation is, therefore, clearly a focus of interest in this work. In short, how do teachers translate the 'intended' curriculum to the 'implemented' curriculum (Bauersfeld, 1979).

c. The learned or attained curriculum. The attained curriculum consists of the outcomes of learning – the concepts, processes and attitudes towards school subjects that students have acquired as a consequence of their experience of any given course. What students learn will be influenced by what was intended for their learning, and the quality and types of opportunities they are afforded. The attained curriculum is determined very much by the individual student – the effort that they expend, their classroom behaviour, the homework they do and so on. Whilst such factors are influenced by the institutional and classroom level structures and experiences, the student does have some control over their level of response and engagement.

2.5. Therefore, in this report, we begin by giving a brief summary of the intended curriculum in section 3. A fuller version can be found in Appendix 2 or, for those who are interested, in the specification, textbook and examination papers. Section 3 also provides some essential demographic data about the teachers, students and the way in which the course is organised structurally in the variety of post-16 institutions in which it is taught – essentially important contextual information. Section 4 presents our findings on the implemented curriculum; it draws on the case studies to report the principal broad features of the lessons observed, explores the use, or non-use, of specific teaching strategies and, in addition, the implications for other courses. We then explore how the coursework element of the course is implemented. Section 5 presents our findings on the attained curriculum. Section 6 considers a small miscellany of issues – such as teacher support, continuing professional development requirements, and marketing the course – which are not assimilable within the main structure of the report. In the text, issues that need attention, or findings of significance, are highlighted in bold. It is these aspects that have been used as the basis for formulating the major recommendations of the report, given on pages 11–14.

3. THE INTENDED CURRICULUM

Course structure and details

3.1. The course consists of two essential components – a set of ideas-about-science and a set of science explanations which are developed through a set of a set of teaching topics. The intention of the course is that the ideas-about-science and the science explanations should be taught and learned within the context of the science teaching topics.

3.2. The science explanations are seen as the major explanatory components underlying much of science. In the course, these are divided between the physical sciences and life sciences:

Physical Sciences
The particle model of chemical reactions
The model of the atom
Radioactivity
The radiation model of action at a distance
The field model of action at a distance
The scale, origin and future of the Universe
Energy: its transfer, conservation and dissipation

Life Sciences
Cells as the basic unit of living things
The germ model of disease
The gene model of inheritance
The theory of evolution by natural selection
The interdependence of living species

3.3. Such a list is undoubtedly open to contention. There are what we consider notable omissions. There is, for instance, a lack of any component of Earth Sciences and the story of the evolution of the Earth – in particular, the evidence for plate tectonic theory – an idea which has transformed our understanding of the ground on which we stand.
Given that this idea has led to a paradigm shift within the Earth sciences, this idea-about-science should normally be a part of any set of major explanatory themes.

3.4. The ideas-about-science component consists of five sub-components which broadly cover or explore issues in the nature of science about (1) data and explanations; (2) social influences on science and technology; (3) causal links; (4) risk and risk assessment; and (5) decisions about science and technology. A fuller version of the components of the course can be found in Appendix 2 or in the full specification published by the Assessment and Qualifications Alliance (AQA, 1999).

3.5. Students' understanding of these two components is developed through the study of a set of topics (Table 1) which are the means of illustrating both the underlying science explanations and the ideas-about-science. So, for instance, for the ideas-about-science component, the topic on health risks might be expected to focus on the analysis and evaluation of risk and cause and correlation, whilst for the science explanations it would develop an understanding of the germ theory of disease and cells as the basic units of living things. However, such information has to be inferred by teachers, as the lack of a teacher's handbook means that such links and interrelationships are not explicitly articulated – this may account for any failure to emphasise these aspects.

3.6. Student understanding of the issues in life sciences and the issues in physical sciences are assessed by a modular examination at the end of the year accounting for 70% of the final mark. The other 30% is assessed through the coursework component which consists of two parts, the study of a topical scientific issue and a critical scientific reading. Traditionally, coursework in science courses has examined students' skill and ability to conduct practical or empirical work in the laboratory. The coursework is, therefore, innovative in that, like the course itself, it requires no practical work. Instead, one assignment is reliant on students' ability to sift and analyse evidence and data associated with a contemporary scientific issue, whilst the second assignment encourages students to engage in writing about science of general interest. In that this second component of the coursework seeks to engage students with writing about science and to examine it critically, it bears some similarity to the study of English literature which seeks both to imbue an ability to review works of literature critically and to develop a love of good writing. Moreover, given that no UK school science course has attempted this form of coursework before, it is a mark of the gap that lies between the SPU course and traditional science courses.

Table 1: The teaching topics in the two modules

Module	**Teaching topic**
Issues in the Life Sciences	Infectious diseases Health risks Medical ethics Alternative medicine Genetic diseases Genetic engineering The move away from a human-centred view of the natural order (evolution)
Issues in the Physical Sciences	Using fuels Electricity supplies Air quality Fuels for the global environment Sources and effects of radiation The move away from the Earth-centred view of the Universe

3.7. The course specification is provided by the Assessment and Qualifications Alliance (1999) and is supported by a textbook published by Heinemann (Hunt and Millar, 2000). In addition, additional support is provided by a website (http://www.scpub.org/) which provides an overview, notes on teaching the course, news of training courses and resources for teaching the course. In effect the website provides significant support for the teaching of the course.

3.8. The approach taken by this course, with an emphasis on contemporary and even contentious science, is sufficient to demarcate it as a different course. However, it is a course that also in its structure makes a serious attempt to teach *about* science and to make use of an innovative and original approach to coursework. **Our conclusion is that at least in its intentions, this is a course that is distinctive and different from that which forms the core of mainstream school science education both in this country and internationally.**

Teachers, students and course organisation

Teacher characteristics

3.9. A major factor determining the intended curriculum is the nature of the teachers, students and course organisation. This section therefore provides background details of these factors gathered during the course of the study. Of the 78 teachers replying to the first questionnaire 49 % were female and 51% male. Their age profile is shown in fig 1.

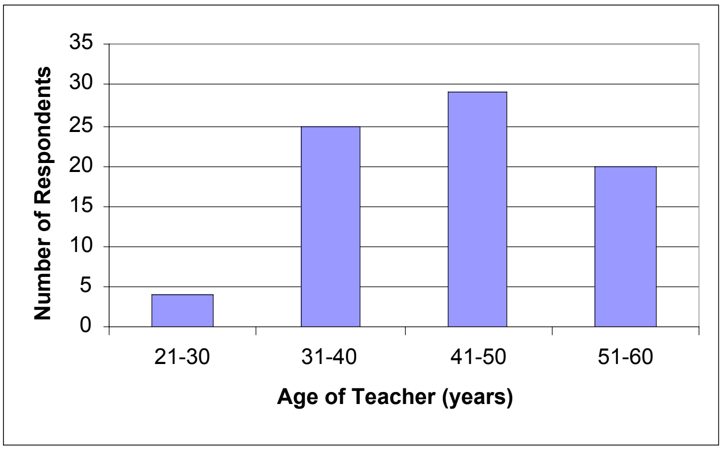

Fig 1: Age profile of teachers teaching either one or both modules of the SPU course

The 78 teachers had approximately 1210 years of teaching experience between them, which gives an average of 15.5 years of teaching experience per respondent. The clear implication is that the majority of these teachers are, by any standards, very experienced. 67 of the 78 teachers had a degree in physics, chemistry or biology. Other degrees were not asked for, but during the evaluation we encountered one teacher of the course who had a sociology degree and another who had an English degree. Fifteen of all the teachers had PhDs. The last statistic, in particular, would suggest that these teachers are an exceptional group who are more highly qualified than most. Their experience of teaching the SPU course was, in contrast, limited – 33% having taught it for only one year, 42% for two years, 12% for three years, and 10% for 4 years. Given that the course has only been in existence since its inception for four years, the latter group of teachers must have been involved in the initial pilots. The data in Table 2 show that the overwhelming majority of the teachers had undertaken no formal study of either the philosophy, history, or sociology of science. Likewise very few had experienced any formal study of philosophy.

Table 2: Highest level of study of aspects of the nature of science by teachers

Highest level of study							
	None	A	BA/BSc	MA	PhD	Other	No response
Phil of Science	60	1	5	5	1	1	5
Hist of Science	58	1	5	5	0	1	8
Soc of Science	62	0	3	5	0	1	7
Philosophy	59	1	6	3	0	1	8

3.10. Teachers were asked about their knowledge of the course and their confidence with the different components. 51% indicated that their knowledge was either high or very high and only 14% felt it to be low or very low. Given that 75% had been teaching the course for two years or less, these figures are a little surprising. Likewise their self-assessment of their knowledge of the science explanations – that is the major explanatory themes of science underlying the topics – was positive, with 76% rating their knowledge of those in the life sciences as high or very high whilst the corresponding figure for the physical sciences was 65%. Perhaps even more surprising, given their lack of any formal education about the nature of science (Table 2) was the fact that 88% rated their knowledge of the issues and themes covered by the ‘ideas-about-science’ component as high. These figures for knowledge were matched equally by their confidence to teach these components (Table 3). As will be seen later, these levels of confidence were not borne out by the data collected from the school visits or the teacher interviews. Rather data gathered from these sources suggest that teachers had not really understood the different nature of the course and lacked confidence in the innovative components of this course and their effective treatment. **Hence, our general view is that teachers’ confidence in their own knowledge and understanding is misplaced.**

Table 3: Teachers responses to questions asking them to indicate their level of confidence to teach different components of the course.

Confidence to teach aspects of the course			
	All or most %	Some %	Little or very little %
Life sciences	81	13	6
Physical sciences	70	24	5
Coursework	78	18	4
Technical, social, economic and ethical aspects	82	15	3
Ideas about science	85	15	0

The student cohort

3.11. Teachers' responses to the question asking for the number of students taught show that, in 2001/2, 55% of the cohort were female and, in 2000/1, 58% of the cohort were female. The returns from the student questionnaire were similar – 61% female and 39% male. Currently, the only other post-16 science course that attracts more girls than boys is biology A-level, where 63% of the A-level candidates were female in 2001. What this statistic shows is that the course is attracting girls to continue with the study of science post-16, even though a significant element of the course is devoted to aspects of the physical sciences which, presented in their traditional form, have been unappealing to girls. Other than biology, no other optional science course has ever been known to attract more girls than boys. This must be recognised as a significant achievement which offers at least some prospect of answering one of science education's holy grails – how to engage more girls with the study of physical science.

3.12. Table 4 shows the other subjects that the students were taking as well as this AS course.

Table 4: Subjects taken by students other than SPU at A/AS level (n=223)

Subjects at A/AS other than SPU			
Science %	Non-science %	Mixture %	No reply %
12	33	44	10

These data show that the course is managing to attract a third of students who are doing no other science, with 44% doing a mixture of science and non-science subjects. The course is therefore achieving some success in attracting the kind of student for whom it is intended.

3.13. 32% of the students taking the course had made the decision unaided. For a further 45%, the course had been taken after advice. The source of such advice is most likely to be staff at the institution rather than peers, as the course is not sufficiently well-established to have built a reputation for itself. Nevertheless, students were met during this study who said that they had recommended it to year 11 students. 37% of students were allowed to take the course with no prior science qualification. The others were required to have either a GCSE in double science (43%) or a single science (13%) with a minimum of grade C. A further 5% were asked for other unspecified qualifications. Asked in a free response question why they were taking the course, 45% stated for interest and 35% to broaden their range of subjects. Other reasons given were as a backstop (5%), on advice (4%), and because they had no choice (7%). The latter figure is most likely explained by institutions insisting on additional breadth to students' range of studies.

Course organisation and structure

3.14. The delivery of the course varied in that, of those teachers who responded, 31% were teaching all components of the course, 41% were teaching only the life sciences component, and 28% only the physical sciences component. The number of hours allocated to teaching the course varies substantially from less than 2 hours a week to more than 5 hours a week (fig 2). The average figure would appear to be 3 hours per week.

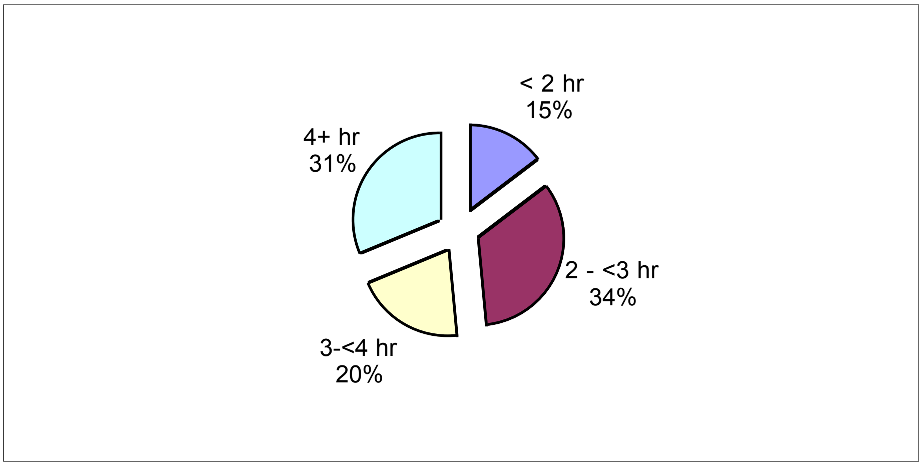

Fig 2: Number of hours per week allocated to teaching the SPU course

3.15. However, the manner in which the course is delivered would appear to vary. Whilst no data were collected on how the course is organised during the course of this study, schools were found that taught the course across two years with two hours a week allocated to its teaching; and FE colleges that taught it in year 13 on varying amounts of time – the minimum being two hours. This would account for what appears to be a relatively low contact time, given that the course organisers recommend a minimum of four hours per week to complete the course. However, the majority of schools would appear to teach it as an AS course in year 12. It is reasonable to assume, therefore, that the normal number of hours allocated to the teaching of the course approaches 4 hours per week.

3.16. The schools themselves were a mix of comprehensive, sixth-form colleges, FE colleges, and independent schools (fig 3). 94% of the teachers worked in co-educational schools and the other 6% in all-girls schools. None worked in boys-only schools.

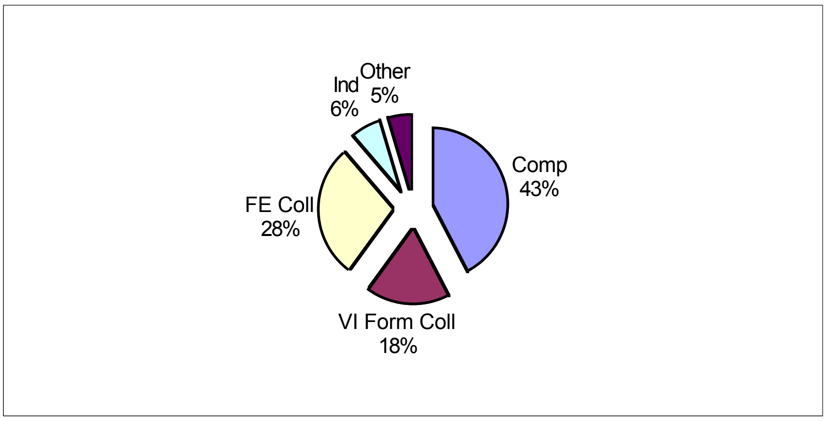

Fig 3: Percentage distribution of types of educational institution in which teachers were working

Only 13% worked in institutions with a post-16 cohort of 150 or less. Rather, 59% worked in institutions where there were over 250 students post-16. Given that 250+ students is a fairly large student cohort, this finding would suggest that the course is offered in institutions which have a large body of students from which to recruit a economic group size. Of the 78 teachers, 12 were not teaching the course this year. Thus, 66 teachers taught 645 students in all giving a mean group size of 9.7 students. Combined with the finding that the overwhelming majority (66%) of teachers who responded to question 11 asking how many groups they were teaching indicated that they were teaching only one group, these data would imply that the course is being taught, even in large post-16 institutions, in quite small, single groups. This is a state of affairs which most institutions would regard as less than desirable, and a finding that calls into question the continuing viability of the course unless recruitment improves.

4. THE IMPLEMENTED CURRICULUM: PRACTICE, PROMISE, AND MISSED OPPORTUNITIES?

Principal features

4.1. For the purpose of exploring how this new course was implemented in the classroom, the original intention was to visit three lessons in 10 schools. In the end, 29 lessons of 10 teachers drawn from 9 schools were visited between December 2001 and May 2002. Whilst the original intention had been to make some of the series of three visits over a short period and others across a longer period of time, pragmatic imperatives such as teacher and researcher availability and other factors meant that the visits were made opportunistically rather than determined by any specific research criteria. All of these visits were made by prior arrangement with the teacher concerned. Teachers were informed of the nature and purpose of the research, that the visit was not an assessment of their capabilities, and that all information gathered would be confidential. For every visit, extensive field notes were made. These notes were then transcribed and analysed for their principal features using the qualitative data analysis package NVivo. The process of coding generated 64 codes, 20 of which were used 15 times or more. Therefore, the following account of the nature of the lessons draws principally on these codes in constructing an account of the nature of SPU lessons.

4.2. The first and most noticeable feature of these lessons was the dominance of classroom discourse by the teachers. Time and time again, it was the teachers who were observed to initiate the discourse in the classroom, controlling its form, and possibly its function, by using predominantly discourse strategies in which the teacher initiated discussion by asking a question (often closed), seeking a response and then providing an evaluative response that indicates to the student and the class whether their answer is correct or not. Several examples of this dialogue, commonly termed initiation-response-evaluation (IRE) are provided beneath.

Example 1

Dialogue here is becoming very IRE dominated. A student suggest 'granite' as a source of contamination and Ralph[1] [the teacher] asks what is being given off. Student responds 'radon'. Ralph then continues with a string of questions:

- *Is the exposure to radiation bad for you?*
- *Why is it bad for you?*
- *Does radiation cause cancer?*

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[1] To preserve anonymity all names are pseudonyms.

Example 2
It is difficult to define the quality of this lesson exactly. John is an academic with a strong interest in one particular area of science. On my second visit, he tells me that he does not have a PGCE, which is self-evident as he has little clue on how to run a discussion. The quality of student contribution has not been good and limited by his desire to convey a large body of information.

Example 3
I am left with the impression that Alan is interested, but that he is more of the maestro teacher and finds it hard to let go in the lessons and let students do the talking. This discussion limped along and was only sustained by the significant contribution of one bright pupil. The result is that, at least in this lesson, the students spend too much time listening and not enough time doing or thinking. It will be interesting to see the next lesson and whether a similar pattern is maintained.

[At this point, I note that I am losing my concentration in the welter of words emerging from Alan]

4.3. Whilst this observation is in one sense unexceptional, as it is the teachers' responsibility to initiate and control the learning activities in the classroom, it was surprising that so much of the dialogue took this form. The analysis of the case studies shows 76 instances where such types of discourse were noted. It is surprising because one of the primary aims of the SPU course is for students to 'develop, and be able to express, an informed personal point of view on issues concerning science and technology'. It is hard to see, therefore, how this aim can be achieved when insufficient space is provided for students to develop such capabilities by opening up the nature of the discourse in the classroom to make it more of a genuine dialogue. It is well-known (Scott, 1998) that discourse of an IRE nature is authoritative, primarily closed, focussed on the transmission of information, and has a fixed and intended outcome. In contrast, discourse of a more open nature seeks to involve multiple voices, all of which are seen as equally capable of contributing to the development of new understandings. Fundamentally, its intent is to generate new knowledge – insights whose outcome may not be anticipated and to permit all participants to engage in reflecting on the issue at hand.

4.4. In interview, many of the teachers recognised that their use of whole class discussion was somewhat excessive:

Teacher: We try to keep it as wide ranging as possible really. But I still probably stand at the front and talk too much. That is just me. I am good at that.
(Male, mature teacher, head of science, FE college)

Teacher: Whole class discussions I find better. Um because you have got more individuals to input, you know, input their views and opinions, um so we do quite a bit of that.
(Male teacher of biology, comprehensive school).

Teacher: Whole class discussion I use quite a lot although I think probably I have been using it too much this year. *(Female head of science, FE college).*

Teacher: Yeh I am not used to teaching discussion lessons and I always end up interrupting them too much. *(Female science teacher, comprehensive school)*

There was also a disparity in the data from the questionnaires on the use of whole class discussion [see Table 5 and 6] with 33% of teachers saying they use discussion every lesson compared with 80% of students. Thus, the picture that emerges is one where whole class discussion is a predominant feature of nearly all lessons, and where the use of small group discussion is much more variable and dependent on the teacher and the topic under consideration. Yet, as one teacher acknowledged, whole class discussion is a difficult technique to sustain with a class:

Oh well … it is difficult. I mean first of all starting a discussion or keeping it going I find very difficult. Um especially if they all agree, what do you do if they all agree? You know, the discussion stops immediately so it is actually, you know, trying to act as devil's advocate. … I just find it very difficult the whole idea of getting them to discuss an issue they may not have a particularly strong opinion on.

(Head of biology, girls' grammar school)

4.5. Possibly the best explanation for these findings is that science teachers and their actions are structured by the nature of the agency they serve – science education, a practice which Ravetz (2002) has characterised as the last authoritarian socio-intellectual discipline. For much of the teaching of science requires the teaching of consensually, well-established knowledge which is uncontroversial and not open to challenge or questioning. Consequently, science teachers tend to adopt a style which attempts to persuade their students of the validity of the scientific world-view and construct for themselves the entities that populate the scientific universe. The result is a dialogue which tends to be closed and authoritative. The normal daily practice of the science teacher does not provide many opportunities for the kind of interpretive and open discussion that the English teacher or History teacher might encourage. In these disciplines, the essence of a good lesson is to encourage children to recognise that there are plural interpretations of any given piece of writing or event, and that a core requirement is the consideration and evaluation of the evidence and arguments for each position. Similar findings about the nature of discussion were also evident in the work of Ralph Levinson and Sheila Turner (2001), whose work explored the introduction of socio-scientific issues into science lessons. They found that 'critical thinking, participation in debate and discussion of controversial topics are far less of a feature of science lessons than they are in humanities', and that many teachers were concerned or made anxious by activities that required the introduction of ethics into the classroom.

4.6. In addition, science teachers are provided with specialist laboratories for their teaching which permit them and their pupils to demonstrate, explore and investigate phenomena. Such practical work requires explicit, authoritative instructions from the teacher; this again constrains the nature and extent of discussion in the science classroom.

The result is that science teachers have few opportunities to engage in more open dialogue about the nature of science or its technological implications, and fail to develop the skills required.

4.7. A point of note, however, emerging from this study is that about half of the SPU lessons observed did not take place in a laboratory. The main reason for this was that either the teacher wanted access to the internet for the course and had successfully negotiated the regular use of a room with internet access, or that there was a lack of laboratory space and it was recognized that the course did not require such facilities. For the teacher though, changing the context of the lessons to an ordinary room, or one with internet facilities, helps to force a change in their style of teaching and, additionally, gives an important signal to students that this is a different kind of science course which is not reliant on laboratories. **For those seeking to develop new courses of this kind, encouraging teachers to teach the course outside of a laboratory may be an important factor in promoting the change in pedagogy necessary for such a course.**

Dominance of science content

4.8. The course is not overly scientific in its intentions as the specifications state that it can be undertaken with a good knowledge of GCSE science. Moreover, an analysis of the 2001 examination papers (pages 62–6) suggests that less than 50% of the marks were allocated to a knowledge of science. Nevertheless, many examples where the content of the lesson focused on developing a knowledge of scientific ideas were observed – examples of which are shown beneath.

Example 4
George [the teacher] asks a student if he managed to look up how long it would take for him to be killed by background radiation. The student responds ‘No’ as it took too long and he gave up.

George then talks about dose and dose measurement and introduces the notion of artificial exposure and asks where it comes from? There are some half-hearted attempts to answer this. He then says that they are going to look at nuclear power and nuclear energy in general. He states that he has to begin by covering the background and asks ‘Can any remember what alpha, beta and gamma radiation are?’ and proceeds to give an explanation around some IRE dialogue. Some of the pupils are taking notes [hence this lesson has a very sciency feel to it]. He states that there are other forms of radiation. The board is being used here to record and display information.

He says that this is described as ‘ionising radiation’ and asks ‘What do we mean by ionising radiation?’ First student when pressed says ‘don’t know’ and then another gives a fair explanation.

He then gives an explanation of how fission happens. George has a relaxed and amiable style but what I am seeing is still very much science teacher mode. The room itself is a ordinary room, the tables are set out in a rectangle with a hollow in the middle, and there are science posters on the wall. [At this point, I begin to wonder what would help to get him out of this mode?]

Example 5

Sally [the teacher] stops at this point and asks 'Are there any points in the video where you felt confused by the science?' [My impression is yes but nobody says so.] Again, she asks 'Did you understand what it was saying?' Student mentions the word pollution. She asks, 'What particular name did it give to pollution?' She says: 'You don't see streams of brown gas coming out of the exhaust of your car. What is the end product of the process? How did that smog form? What else had to be there? What have they done to cars? What does a catalytic converter do?' [The students are giving very limited responses and this is taking on the form of a very standard IRE dialogue].

Sally explains how catalytic converters work briefly and the inclusion of carbon canisters. She then asks why are catalytic converters a problem?

Examples 6

The teacher asks a question about the waste products and there is a sense of frustration 'You should remember this from year 8', he says. I note that the dialogue is very IRE at this point.

He puts up the equation

$CH_4 + O_2 \longrightarrow H_2O + CO_2$

And says 'What's wrong? If you know what is wrong, make it right whilst the others catch up.' [The notion of catching up is another reinforcement of the traditional nature of this lesson.] There is some discussion about balancing the equation. He then draws the molecular picture on the left-hand side and asks if they can draw the molecular picture of the products. Then after a couple of minutes, the picture is produced with the use of IRE dialogue and he says to them that he is pretty impressed with what they remember of their chemistry.

He then gives the example of being a student living in rented accommodation and why you have to watch it if there is not enough oxygen going into the flame. He explains about the production of carbon monoxide. He calls this 'oxygen starvation' and gives a note 'the less oxygen produced then you get CO even then not all the fuel is burnt up.'

4.9. Part of the reason for the dominance of science based content lies in the fact, illustrated by these examples, that the students have simply forgotten the concepts introduced by GCSE. Of necessity, the teachers are then forced to engage in an activity which helps the students to remember the salient concepts. Another reason is that GCSE science is being applied in new contexts. The workings of a catalytic converter, a radiation badge, a nuclear bomb and nuclear fusion, were all examples of scientific artefacts that teachers were forced to explain before there could be any consideration of the issues raised by the application of the technology. One teacher, when asked if his lesson was typical with so much science content, replied that only about 1 in 4 lessons required this kind of treatment. However, it was one of the most noticeable features of all the lessons observed for the case studies. Therefore, it is difficult to escape the feeling that part of the reason for the dominance of science content is that this activity – explaining science – is familiar territory for most teachers, one with which they feel at ease and fluently deploy whenever there is an occasion which demands its use. In short, these teachers are moulded by the culture of the discipline and activity in which they have engaged, often for many years. Breaking that mould is neither straightforward nor simple.

4.10. Another problem with the teaching of the science component per se is that its emphasis was very topic focussed – that is the lesson was about air pollution, alternative energy resources, genetic manipulation or whatever. One of the aims of the course is to develop a conceptual understanding of a set of major science explanations [see para 3.2], yet these were never explicitly referred to in any of the lessons visited. It is hard to see, therefore, how students can develop an understanding of such conceptual schemas if that overarching explanatory framework is never brought explicitly to their attention. Part of the problem lies in the absence of any teacher's handbook and the lack of any explicit in-service training courses for those about to embark on teaching the course. The fact that the teachers never referred to these ideas, either in their lessons or in the interviews, suggests that they are not an organising framework that they have assimilated or, if they have, prioritised – illustrated by the extract below from an interview with one teacher.

Teacher: Well what worries me is the idea of me not having sat down and grasped all the different parts of the syllabus. This has been niggling at me but having spoken to you about it, it has sort of brought it up to a more of an issue, um.

Int: Well, I think the underlying question is how much you use or refer to the specification?

Teacher: Not much as my specification as far as I am concerned is that textbook.

4.11. There are no examples in the examination, for instance, that ask questions of the form 'Why is the idea of cells as the basis of living things an important and useful idea? Give two examples of its use to explain important life processes.' Such questions might communicate to teachers and students that it is important that they have grasped the underlying set of science explanations. **We recommend, therefore, that it would be sensible for the examiners to explore and reconsider whether the style of question they are using does assess students' understanding of the science explanations.**

4.12. Another problem with developing an understanding of the science explanations for teachers is that the learning experience is highly atomised and structured around discrete experiences of an hour. Invariably, such experiences can only focus on one discrete topic rather than the underlying theme. **What this finding suggests is that the course materials need to emphasise these overarching themes, and that course materials need to develop summary activities where students have an opportunity to see how the underlying science explanation offers coherence across a broad set of phenomena.**

Ethical, economic and technical aspects of science

4.13. Nevertheless, these lessons were different in many ways from traditional science lessons. Firstly, the teachers all recognised the need to discuss the ethical, economic and social implications of the scientific topic being discovered. Various strategies were observed as a means of attempting to initiate discussion, such as the use of role play and small group discussion. However, the predominant strategy was to initiate whole class discussion by asking questions which were designed to elicit a response from pupils. The success of this depended on the degree of openness of the question and the confidence of the students [see Example 7 beneath]. It was observed in the later visits, for instance, that the groups had established a dynamic where they were both more familiar with the other group members and with the teacher; this led to more contributions from a wider range of students[2]. Also, it is undoubtedly a fact that the small group sizes for this course are helpful [see Example 8 beneath] and any attempt to initiate such discussion with larger classes and students who are less mature is very likely to be less successful. The most successful use of this strategy was when the teacher deliberately took a provocative stance that could be characterised as extreme. Thus, in Example 9 beneath, the question asked by the teacher about parents' rights successfully provokes a response from the student. In another lesson on energy generation, the teacher challenged the students by stating that it was strange that the use of 'nuclear power is decreasing, but isn't this quite efficient?' Later, in a discussion of safety issues, he simply asked 'But how safe is safe?' Another good example was a lesson which raised the ethical implications of genetic manipulation where the teacher provoked a discussion with the statement that 'Short people are not as successful as tall people, so why not insert some genes that would give your baby an advantage? What's the difference between this and a vaccine?' In all of these cases it was notable that such a strategy was followed by a large number of student contributions and an often vigorous or even heated discussion. However, its occurrence was not common and used only by the more confident teachers.

Example 7
Tina [the teacher] then asks what is the problem of a rising sea level, particularly in countries like Bangladesh. A suggestion is made by a pupil that it will damage the water table in low-lying land and Tina reinforces this explaining that it will make the land uninhabitable. I am struck that again, as in many other classes, there is one bright pupil who is engaged with this material, asking questions and making a more significant contribution than others.

Example 8
A student makes the point that this issue is complex. The person who gets hit by a car, also gets taken to hospital by ambulance. [At this point, the discussion is going quite well with students making significant number of contributions. I wonder whether this is due to the small group size or the time that they have been on the course and their familiarity with one another. I think it is the latter after watching the whole lesson.]

[2] One school was encountered where the teachers had both had a negative experience of teaching this course. This was exceptional, and our view is that the root cause of the problem lay in an unfortunate group dynamic that was difficult for the teachers to surmount.

Example 9

The students gradually take up the discussion [about the hospital which had taken out a court order to insist on operating on Siamese twin against the parents' wishes] though notably it is the ones near me – the two articulate girls – who contribute most. Eileen (the teacher) is going around attempting to provoke the discussion: 'Do you think the parents have rights?' A student says 'Can't do it without the parents' permission'. ' Eileen responds, 'That's why they have got a court order.' The discussion is now becoming more animated and moving practically to a whole class discussion [My opinion now is that this is forming a good discussion because the statements are provocative and the students have responded.] The students raise another case which is similar in that two Siamese twins were separated and one died.

4.14. Traditional school science normally keeps a fairly rigid boundary between the content of science and the issues raised by its applications (Osborne & Collins, 2000). This course has managed to dissolve these barriers such that consideration of the implications of science are a regular feature of these lessons. Two more examples of this are shown in Examples 10 and 11. Discussion of socio-scientific issues was the element which engaged more of the students as their own knowledge enabled them to make contributions to the discussion. Normal science courses deal in consensual well-established knowledge which is not up for negotiation or challenge – particularly by adolescents who lack a knowledge of the field and its epistemic justification. Transcending the boundaries of the content of the normal science course transforms this state of affairs, and opens windows of opportunity for students to contribute.

Example 10

Eileen [the teacher] says that she is going to do some work on cost-benefit analysis and she gets out some notes. The lesson moves into discussion of off-task issues. She then writes 'Cost-Benefit Analysis' as a title on the board and interestingly, starts by asking what every word means from the students. She then gives the example of phenylketonuria, and says that every new-born baby is tested for this at birth even though it is very rare. She asks why they bother. She explains what the disease is – an allergy to certain foods which lead to severe brain damage – and that the cost of treating it is £126,000 per child. She does not know or does not explain how many children get it in all. This she compares with the cost of testing every child – £20,000. She then asks 'Why don't we do this for cystic fibrosis?', putting this question up on the board, but it is not clear what students are supposed to write.

Example 11

Geoff [the teacher] talks about bodies who knew about radiation getting together such as the International Commission on Radiation Protection (ICRP), the National Radiological Protection Board and says that he is going to talk about these and their work. Students don't need to remember these [a contrast from most science lessons]. He explains that these bodies work in the industry, set the rules and advise government which makes policy [His style is didactic but there is a liveliness about his approach which makes it a change.] Policy, he explains, comes down to three principles:

1. Justification [no practice unless it is beneficial, there must be a PNB (positive net benefit)].

[The students are writing notes at this point despite his earlier comment that they didn't need to remember this. Is this conditioning?] Geoff asks a question about what 'net' means which suggests a sensitivity to language, and uses an analogy of how the students get paid by Sainsburys.

2. ALARA and then says that he is not going to tell them what it means but promptly does – As Low As Reasonably Achievable.

3. The third principle is based on dose limits.

4.15. Interestingly, such courses transform or undermine the authority of the teacher who recognises that they are not an expert in the domains now under consideration. A particular instance of this occurred in one lesson when the researcher was approached by the teacher:

Louise [the teacher] comes over to me at this point in time and admits that something that she has found quite hard is the ethical aspect of the work. Two of the students are doing ethics in RE and have been effectively teaching the group; they have brought in a book 'Ethics and Religion'. (Female teacher, comprehensive school)

This teacher then went on to discuss utilitarianism and John Stuart Mill, suggesting that her knowledge was somewhat better than she thought. Another teacher expressed the view that one of his concerns was:

Having lessons where you are not telling them the truth kind of thing. You know you are being open to not knowing, a bit like that last one, where I happily admitted. So as long as you are prepared to do that I think it is okay.

(Male teacher, head of science, comprehensive school)

The data from the teachers' questionnaire indicates, in contrast, that 50% of teachers find dealing with the ethical component either very easy or easy. Nevertheless, given that the teachers described here were exemplary teachers in many respects, it is hard to believe that other teachers do not likewise find these components challenging to teach, **and that guidance or professional training on how to deal with the ethical components raised by socio-scientific issues in a satisfactory manner would improve the quality of the teaching. Specifically, this requires training on how to manage classroom discussion, and the opportunity to observe skilled practitioners at work either on video or in situ.**

Ideas-About-Science: the missing component?

4.16. Perhaps the most innovative aspect of this course is that it is the first UK science course which has placed aspects of the nature of science, its social practices and processes, and ideas about risk at its core. Other courses such as Science in Society (Lewis, 1981) and Science in a Social Context (SISCON) (Solomon, 1983) have included elements. In addition, there have been a range of materials developed for teaching the nature of science, such as the SATIS materials (Association for Science Education, 1986), but no other course has made the teaching of 'ideas-about-science' so central. Given the relative lack of experience of teaching such ideas, and the body of research that suggests that science teachers lack any depth of knowledge about the nature of their own discipline (Kouladis & Ogborn, 1989; Lederman, 1992), a major question of interest is how well this aspect is being taught.

4.17. Whereas the treatment of the ethical dimension of science was a notable feature of most of the lessons visited, evidence drawn from the visits to schools would suggest that this component was marginalized, with many missed opportunities to explicitly address ideas *about* science. Extracts drawn from field notes illustrate some of these instances.

At this point Tina asks an interesting epistemic question which is notable by its rarity not only in this class but in a lot of classes which is 'What is the evidence for that?' The response from the pupils is silence either because they do not know or, in part I think, because I think it is an unusual question. …. My own feeling at this point is that there is a missed opportunity to teach about the need for an explanatory mechanism to underpin any correlation. It occurs to me that I don't think I am seeing much explicit teaching of the 'ideas-about-science' and wonder why?

(Field note: Lesson in girls' grammar school)

The teacher then draws their attention to some articles in Scientific American and New Scientist which he bought last week. The one in New Scientist is arguing that we have to revise our concept of what a black hole is, and he uses this to make a point that with science 'all the time we are having to revise our theories'. [This is a fairly unusual metacomment about science, but it is not explored by looking at other examples or what are the limits to such a statement] … [It has been a long afternoon: a lesson dominated by science explanations, albeit done with some panache but with a conventional science feel to it and with a notable lack of variety. The students were engaged by the contemporary nature of the material but other than asides about science and certainty and issues of risk, any exploration of the nature of science has been largely missing].

(Field note: Lesson in FE college)

The teacher then says that this is leading to a real problem about air quality asking 'What does ozone cause?' So if you have asthma you might have a problem. She then tells them about a small survey that she did herself that when the levels of NO went up, so did

the number of people reporting ill in the school. [Notably however, she does not capitalise on this to discuss cause and correlation – another missed opportunity?]
(Field note: Lesson in FE college)

[However, there is no exploration of the ideas about science here and there has been none in the lesson so far of note.] *(Field note: Lesson in FE college)*

4.18. This state of affairs was not always so – one lesson was observed where the teacher had downloaded materials from the Leeds University website for teaching the nature of science (see http://www.nuffieldfoundation.org/curriculum/aboutscience). This exercise required the student to work in small groups, look at instances of research and decide, in each case, what was the purpose of the research. In the second part of this exercise, the teacher gave them four specific purposes for their research 'Describing what happens', 'Testing ideas, 'Developing methods' and 'Focussing on problems'. Students then had to use these categories to match each example with one of these purposes. Whilst this lesson was a welcome change and led to some good discussion, the exercise had a sense of being somewhat artificial and decontextualized from any specific features of science. Evidence from other research undertaken at King's College suggests, likewise, that attempts to teach the nature of science, where the process is divorced from the content, lead to artificial exercises whose point is not clear to students. The implication is that issues about the nature of science need to be explicitly taught in the context of specific examples of content. However, that requires teachers to recognise such opportunities and to include them as a specific learning goal of the lesson. But the evidence would suggest that such aspects are not in the forefront of their planning:

Teacher: Um the ideas about science is probably harder to tackle. I personally enjoy just getting students to discuss the controversial issues. And the students do as well generally in the school. Um I … the ideas that scientists or scientific theory how they developed is a little bit drier, I feel. Students would much rather chat about whether it is right or wrong or that they agree with it. *(Male head of science, comprehensive school)*

Int: Well GCSE doesn't deal with things like correlation versus cause and hypotheses and models so much does it? I think that is really what I mean.

Teacher: Yeh , um oh the idea of, of the theory of how you study science?

Int: Yes the bit in the specification about ideas about science.

Teacher:Yeh, I mean I haven't dealt with that. Clearly we are going to do that about cause and that. And I guess we have to have specific examples but I haven't taught them that specifically, and perhaps I should, and perhaps I am missing out on that, probably am aren't I? … Probably because I haven't sat down and thought about it that much. Because when I looked at the syllabus I thought it was, I couldn't I just couldn't, I don't think it's set out well, and it doesn't tell me how to teach it properly. … And when I looked at the exam um questions, they don't seem, when I looked at the exam papers in *order to think what sort of thing should I be aiming for, it didn't highlight that I should be facing those statements so I haven't done.*

(Female biology teacher, comprehensive school)

Teacher: Yes to a certain extent I mean its um linking them in with the factual element I find quite difficult and I try and almost… it follows on that they, you know I don't teach them specifically, it's just that it follows on from an idea. But I do find it quite difficult to incorporate them all and to a certain extent you are hoping they are covered by what you are teaching by the content. *(Head of biology, girls' grammar school)*

Int: What about the ideas about science?

Teacher: Yes I think I have more difficulty with that side, teaching that … that … yes definitely. *(Life sciences lecturer, FE college)*

4.19. An analysis of the examinations for 2001 suggests that part of the reason for the lack of emphasis on ideas-about-science is that it only forms around 10% of the examinations [see Table 13 on page 63]. Thus, although it is specified as a major aspect of the course in the intended curriculum, it is under-emphasized in the examinations and teachers are simply responding in a rational manner in the emphasis that they give to the differing aspects of the course. This is, after all, a novel area both for science teachers and examiners. There is not, therefore, a body of expertise that exists about how it should be taught or how it should be examined. **Clearly the message for both this course and any future course is that the examination board and the chief examiner need to give more thought to how ideas-about-science can be imaginatively examined and, likewise, the course team need to give more thought to how it can be taught through relevant examples where issues of both content and the process of science can be considered.**

Teacher strategies and learning activities

4.20. Another factor that significantly influences the implemented curriculum is the type of pedagogic strategies utilised by the teacher. Some, such as whole class discussion, permit the teacher to maintain rigid control over student actions and provide a very strong authoritative framing for the subject. Others, such as independent study or small group discussion, relinquish much more control to the student, and allow students greater possibility of generating and contributing to the development of new meanings and understanding. In this section, we report on the use of a range of strategies and their effectiveness. In addition, we consider the implications for the implementation, not only of the SPU course but also for other courses of this nature.

Table 5: Teachers' responses to question asking for the frequency of use of teaching strategies.

Teachers' responses	1 Every lesson %	2 %	3 Half %	4 %	5 Never %
Teacher talk	33	35	23	8	0
Teacher-led discussion	38	29	25	8	0
Small group discussion	10	10	33	44	2
Role play	0	0	6	56	38
Student own study	6	31	27	35	0
Discussing student issues	10	25	33	27	4
Practical work	0	2	6	54	38
Using past questions	2	8	23	67	0
Working from worksheets	8	25	29	35	2
Note taking from board	8	2	23	48	19
Using the internet	4	19	19	40	19
Using videos	2	19	19	58	2
Individual tutorials	0	4	6	52	33

Table 6: Students' responses to question asking about the frequency of use of teaching strategies

Teachers' responses	1 Every lesson %	2 %	3 Half %	4 %	5 Never %
Teacher talk	80	14	6	0	0
Teacher-led discussion	32	34	26	8	0
Small group discussion	11	22	35	26	4
Role play	1	2	8	35	53
Student own study	16	29	35	19	0
Discussing student issues	23	32	26	16	3
Practical work	2	8	15	43	30
Using past questions	3	13	26	43	14
Working from worksheets	21	29	30	16	3
Note taking from board	23	27	17	21	12
Using the internet	12	19	21	23	24
Using videos	3	20	36	30	10
Individual tutorials	2	2	9	41	45

4.21. Tables 5 and 6 (above) show the data obtained from the teachers' questionnaire and the students' questionnaire respectively about the use of strategies by teachers. These two tables show the teachers' view of the frequency of use of different teaching methods compared with the students' view. The answers are given on a 5-point scale ranging from Every lesson (1) to Never (5).

4.22. The four heavily shaded areas in these tables show where the teachers' view is very different from the students' view. The largest anomaly is for teachers' use of whole class discussion which has been previously discussed. A similar large difference of view also appears with note-taking from the board – only 10% according to the teachers but 50% according to the students. Working with worksheets is, similarly, seen to take place less often according to the teachers (33%) than according to the students (50%). The lighter shaded area (discussion between students working in small groups) indicates a difference in the same direction (20% compared with 33%) which, whilst not so large, is still of note. The general picture emerging is that the teachers think the basic nature of their lessons is more student-centred than do the students.

4.23. The discussion of issues raised by students shows, likewise, a disparate gap. However this time teachers see this as taking place less often (35%) than do the students (55%). Taken together, these data suggest that that the use of discussion, albeit dominated by the teacher, is a major feature of SPU lessons. Discussion and self-study are mentioned by at least 60% of both teachers and students as occurring in half or more than half of the lessons. A more detailed consideration of each strategy now follows.

Small group discussion

4.24. A feature of the use of whole class-discussion is that it was often sustained by one or more able or vocal students who would ask many questions. The danger with such students is that they dominate the discussion, and are used by teachers to maintain the momentum of the dialogue and the illusion that this is a valuable learning activity since intelligent questions are being asked. The reality is that the majority of students allow their fellow student to undertake this role as it saves them from the demands of having to think of a thoughtful question or intelligent answer. A standard pedagogic strategy to ensure that all students are engaged in thinking is to use small group discussions. Students are essentially given a brief which requires either the information to answer to a question to be found, two opposing ideas to be discussed, and/or an argument constructed for one position or another. Such a strategy both provides a relatively non-threatening context for students who lack the confidence to articulate their thinking publicly in front of the whole class, and forces critical engagement with the topic to hand. One of the surprises of the data collected for this study was the relative rarity of observing this technique (6 times in 29 lessons), given the importance of discussion in the course. Two good illustrations of its use are shown in Examples 12 and 13. Even then, it was notable that such activities were twice curtailed after three minutes by the teacher moving to a general class discussion. Such activities also need to have a clear aim, timeline and outcome, otherwise students will engage in off-task activity – this was observed twice.

Example 12

Jim [the teacher] now asks them to 'write this statement down': 'Electricity has been mankind's most important discovery'. He explains that what he wants them to do is to work in pairs coming up with a list of 'fors' and 'againsts' the statement.

(Male biology teacher, comprehensive school)

Example 13

Paul begins by saying that in their groups, please write down as many reasons as you can as to why scientists do research. Notably there is no specification of what the groups are, and the students seem to cluster themselves in four groups. The students begin this task and Paul goes from group to group discussing what kinds of reason they do research for. He talks to the group near me asking whether Dyson did research.

(Male head of science, comprehensive school)

4.25. The data in Tables 5 and 6 would suggest that this technique is used in at least half of the lessons, so the incidence in the case study visits may be exceptional. Such an approach is a standard technique for initiating reflective discussion by all students, and its lack of use suggests that it is not a technique with which all science teachers were either familiar or confident. In interview, for instance, a range of views were expressed about the use of this technique:

Teacher: Discussion between students working in small groups. No, we don't use that at all, I mean, with only eleven students there … and in fact two of those who don't attend very often. Both have personal problems. (Male experienced teacher, FE College)

Int: Do you ever break into say three groups of two or … two groups of three?

Teacher: I haven't done personally no. We have talked about issues as a class, as a whole class and partly that is down to where I teach. I am teaching it in quite a small room. And so it would be physically not that kind of easy to push people apart to work on something without them really hearing what the other group would be working on. So it is partly a logistical thing. (Head of science, sixth-form college)

Teacher: Discussion between students working in small groups. I do do quite a lot of that, and one of the main reasons that I think that is really useful is for the shyer students, because you get actually better discussions going in a small group, because some of the less articulate students are really much more willing to talk in a small group, particularly if it is a self-selected group where they are with their friends. And it also means that people can't opt out; it means that everybody has to be engaged.

(Head of science, FE college).

4.26. The last quotation shows a clear understanding of the value of this pedagogic technique. Nevertheless, the data from the interviews suggest that there was a reluctance to use small group discussions because the teachers think that the class size makes it a small group anyway; because it permitted them to work in friendship groups leading to off-task discussion, or because they preferred whole class discussion:

Teacher: Um Discussion is small groups, umm it's a fairly small group anyway. Yeh I have done that but tend not to.

Int: Because?

Teacher: It's … I don't know really. It's just that … the type of topics don't necessarily lend themselves to small group discussions. I mean I have done it once or twice. Whole class discussions I find better.

(Male experienced biology teacher, girls' grammar school)

The internet

4.27. Another feature of these lessons was the use of the internet. Analysis of the case studies shows that either use of, or reference to, web-based resources was a feature of 17 of the 29 lessons. Students were either observed using the internet for research purposes, or materials were offered to students that had been found using the web, or references were made to suitable websites. In five of the nine institutions, teachers were either teaching the course in a room with internet access or had specially booked a room for these purposes. Of itself, this is not surprising. The contemporary nature of much of the content of the course means that the easiest research tool for up-to-date data or information on scientific issues is to be found on the web. Students were observed, for example, analysing real-time data from air pollution monitors around the country, looking up materials for their coursework, or looking at websites that gave information about alternative energy resources. The general air associated with the use of the internet and such tasks was one of industriousness and engagement suggesting that, as well as being a valuable research tool, it is also engaging for students and a factor in sustaining their interest in the course. In short, the internet has become a tool that can offer significant support for learning.

4.28. Nevertheless, it was clear on more than one occasion that the internet was used somewhat aimlessly; one of the problems teachers face is making good use of this resource which provides, in some cases, almost boundless information. On several occasions, students were quizzed whilst working on the internet on how they decided which resources were more trustworthy or better than others. The answers – that reputable sources were most trustworthy, that it was a question of putting in the appropriate keywords, or just reading the summary – were at best somewhat vague. The impression gained was that, along with the evaluation of newspaper articles [see the next paragraph], students were not being taught the salient features to identify in evaluating information. Not surprisingly, students who began with the SPU website, where the process of sifting and evaluating data sources had been undertaken by the course developers, were observed to make more effective use of this resource, getting quicker access to more salient information. For those seeking to develop any such similar course for GCSE, the message is fairly clear that exercises with the internet are an important feature – particularly given the dynamic and changing nature of the issues at the forefront of contemporary science. However, such exercises need to be highly structured, with a pre-selected set of limited websites providing reliable information of good quality, or access to real-time data that can be used for data interpretation and analysis exercises.

Newspaper articles and media reports of science

4.29. One of the features of these lessons is that newspaper articles were frequently used by teachers as focus for reading or discussion. Given that one of the aspirations of the course is to develop the ability to critically evaluate media reports of science, the fact that such reports are a notable aspect of these lessons is to be commended. However, only once was any explicit attempt to teach students how to evaluate these articles ever observed. Students were asked to work in small groups and handed one media report each. They were then asked to decide what features made it a credible article. Students came up with a number of features, such as whether the work was based on names of respected scientists, whether it was confirmed by other scientists, and whether it contained some degree of balance. In addition, there was some discussion of the weight that should be attached to the implications which should be drawn from the use the conditional tense in the articles. This was an effective pedagogic exercise, which produced much extended discussion. However, it was apparent that the teacher concerned had only a fairly superficial model of what the critical features were that should be considered in evaluating media articles about science. Students were not challenged when arguing that what mattered was the use of 'figures' to support the article's argument, and there was no attempt to define or argue what should be the relevant features to look for and why. Yet there is now a body of research and scholarship which has identified what are the specific features that matter in evaluating media reports of science (Pellechia, 1997; Zimmerman, Bizanz, & Bisanz, 1999). Whilst it is unreasonable to expect this teacher to know of this work, it is not unreasonable to expect any such course to provide guidance to teachers about these features, and how to structure any exercise which might explore their identification and use. Instead, what was observed here was a teacher inventing such strategies with little guidance, in what was really a good first attempt at such an exercise. **The message of this observation is that clear, explicit, guidance is needed for teachers on what are the important features to identify in evaluating media articles about science, and strategies for developing students' understanding of them.**

Role play

4.30. The data in Tables 5 and 6 suggest that role play is used infrequently or never at all. Perhaps, therefore, it is somewhat surprising that in the 30 case study visits this technique was observed three times. Teachers articulated a variety of reasons for its non-use such as:

Teacher: Role play I have not done any of it. Um the reason I think like many teachers is that I am sort of frightened of it. I don't … it is an unknown I don't do role playing with anyone really much. *(Experienced head of biology, girls' grammar school*

Teacher: I have never tried role play with this group, and I can't remember trying it more than once or twice in thirty years of teaching. It has just never really grabbed me. In other circumstances it has, but I have never found it fitting into science lessons much.
(Mature head of science, FE college)

Teacher: Right so role play. I don't use role play. I wouldn't say I had never used role play. I find if you do the big scale role play, the public enquiries and so on I find it takes an awful lot of time to set it up. I am not sure that they get enough learning out of it.
(Female head of science, FE college)

4.31. Where role play was observed, it was done with varying degrees of success. One version, observed twice, was to ask students to take on the roles of specific countries engaged in the supply and use of oil. An extract to illustrate the nature of this activity is shown in Example 14 beneath.

Example 14
There is then a further dimension introduced to the role play which is that the students are asked to consider how they are going to contribute to reducing the production of carbon dioxide – in essence engage in the Kyoto type bargaining between countries. Geoff [the teacher] suggests that those who export fossil fuels might like to meet at the back of the classroom. He tells them 'to think which countries are their allies and who will these be. Consider what the implications are for your country and what scientific arguments do you have?' … After an opportunity Geoff puts the motion to limit the export of oil. The 'countries' then make the following points:

- *Europe: we are burning lots of fossil fuels and it is causing acid rain and other ecological problems.*
- *Bangladesh: global warming is leading to rising sea levels and we are a low country which will be flooded if there are no limits on the export of oil.*
- *Saudi Arabia: we need to export oil for our income.*
- *Somebody: (possibly Japan) makes the point that they need to import as they don't have much in the way of fossil fuel.*
- *At this point, Japan, Brazil and Denmark are all called on.*

Geoff asks 'Russia and Nigeria what are you going to do if your oil exports are limited?' He then asks 'Who haven't we heard from?' making a significant effort to go round every student and get them to participate.

4.32. This approach did meet with some success, with students even bringing or making flags of the countries they were representing. Initiating the activity required a measure of persuasion and cajoling, but gradually students were observed adopting the role required of them. In contrast, another role play taken from the SATIS 16–19 materials on the trial of Galileo was a dreary affair with students doing little more than reading out the information from the cards. The exercise lacked passion and little was done to help students understand the historical context, empathise with the characters they were supposed to represent, or understand why it was so difficult for people of the time to change their cosmological beliefs. Again, it is clear that if teachers are to use such strategies they need to be supported and shown how to make effective use of them. At the very least, this means that the teachers need almost recipe-like formulations of what instructions to give the students, how to encourage the adoption of roles, and how to structure the activity with suggested timings. **Such observations point again to the need for a teachers' handbook.**

Worksheets and textbook

4.33. The case studies suggest that both worksheets and textbooks appeared to be used on a fairly frequent basis, and the data in Tables 5 and 6 support this observation. However, the data in Table 6 suggest that the actual frequency of their use is somewhat contested, as students indicate that their use is more frequent than their teachers suggest. Worksheets were drawn from a range of resources, being either teacher's own self-produced material, material from the SPU website, the Leeds site of materials on teaching the nature of science, third party material produced by the Wellcome Trust or the Progress Education Trust, SATIS worksheets, or media articles supplemented with questions. Somewhat surprising was the discovery that a few of the teachers were unaware of the existence of a website supporting the course. Of those who were aware, a few had been disappointed by what they had found at the beginning of the year and had not returned since. This was unfortunate as, during the course of the year, the body of resources available on this website had increased substantially.

4.34. Likewise the textbook was valued as a resource and was observed being used by teachers for the good quality of the information provided, either in written or graphic form. Some teachers found the discussion points in the margins to be of particular value. In addition, in those institutions which gave homework, the textbook was a natural resource for appropriate questions. Table 7 shows which aspects of the textbook were particularly valued by teachers.

Table 7: Teachers' views of the textbook and its value

	1 Very useful	2	3 Useful	4	5 Not useful	Omitted
	%	%	%	%	%	%
Historical aspects	31	35	29	2	0	2
Science explanations	19	19	42	15	4	2
Data	38	38	19	6	0	0
Questions	40	19	35	6	0	0
Discussion	27	35	19	17	2	0
Coursework	54	27	15	4	0	0

4.35. The only criticism of the textbook made by teachers was that the level of reading skill required was demanding for some of the students. The following comment made by a very experienced teacher of science summarises these views.

I think the textbook is very good and we are pretty dependent on the textbook to some extent. … I have been through it again there are some very good things in it, but I could also perceive that it could be structured a bit better. It has quite a lot of sort of dense stuff that some of these kids particularly if they are AS students … the AS students I had found it quite really hard going because they just haven't got used to reading at that level.

Whereas the A2 students, the year 13 students found it more straightforward, they had a bit more resource to go to. *(Female biology teacher, comprehensive school)*

A problem with the textbook was that although it was recommended in several institutions, students could not be compelled to buy it. Alternatively, even if they had purchased or been supplied a copy, there was no certainty that they would remember to bring it to the lesson. The simplest way of circumventing this problem, observed several times, was to photocopy the requisite parts of the textbook. Many positive comments were expressed about the textbook which was seen as a valuable resource both for teachers and students. For teachers, it provided a valued structure to the course and a reliable source of high quality teaching material that could form the basis of discussion or student work. For the students, its value lay in the clear guidance it provided on coursework and as a revision guide. On a 5-point scale where the extremes were ‘1-very useful’ or ‘5-no value’ 30% rated the textbook as very useful and another 42% picked the second category. 66% of the students also indicated that the textbook was used in every or nearly every lessons; the highest rated components of the textbook was for the explanations of the science and its support for coursework. **The conclusion to be drawn from these data is that the textbook is a high quality resource that supports the teaching of this course. However, more fundamentally, in the absence of the teachers’ handbook, the textbook has become a vital resource, since there is no other source that draws together so much material on contemporary science in one book. Any new course will require a similar supporting text.**

Videos and their use

4.36. Videos were observed being used as a teaching resource in six of the lessons visited. The data from the questionnaires shown in Tables 5 and 6 would suggest that they are used in 40–50 % of the lessons. These were generally recent videos that had been recorded from a variety of resources or ones that, despite their age, were still highly relevant to the issues of the day. Example 16 provides an illustration of the kind of material shown. All were of a high quality, either demonstrating aspects of science that it would be impossible to do easily, such as the effect of ozone on rubber, or looking at the generation of energy by a variety of means around the world, and exploring the issues that emerged. All had a contemporary feel and were engaging, interesting and genuinely educational. Teachers suggested that there was no shortage of such material and mentioned using videos from the series *Extinction files, Walking with beasts, The human body series, Gene stories, Horizon* and other sources.

Example 15

The video is about climate change. It shows that in the summer of 1988 there is prolonged drought in USA. There was a cooling of the land masses in 1960s and it argues that the oceans are critical in the Earth’s system. As we don’t fully understand the past, it is difficult to predict the future. Students seem to be engaged by this video and watching with interest. Video argues that there are lots of things that are inter-related. Unless we act now the consequences will be dramatic. It looks at desertification in Israel.

There is a nice metaphor that we have yet to fall into pothole, get ourselves out and then dust ourselves off. So is there a way out, it asks? Video introduces nuclear power and states that last year it saved 120 million tonnes of CO_2 being dumped into atmosphere.

The students are still watching. Argues that one solution is replanting forest but to take up the CO_2 from one 1000 MW would require 280,000 acres. There should be a matching of the life of power plant to the planting of trees, but we are destroying world forests at the rate of 50,000 million acres per year. There is modelling by scientists of two graphs of the rain in Sahara versus rain in Northern Europe which shows the pattern of rainfall changing and shifting to Northern Europe.

4.37. What this course clearly does is enable the boundaries of science to be expanded so that such material, rather than lying at the periphery of the course and in danger of marginalisation, becomes central and essential to the course. All of the teachers were positive about the use of video, the enthusiasm in the tenor of some of their comments was notable. Not only did they think this material valuable for their students, but it was also inspirational for the teachers themselves, as illustrated by the following quotations.

Like the really good ones have really good like science things red blood cells all floating around well and all the DNA structure shown well and the replication shown clearly. And combined that with interesting examples which is what Robert Winston does superbly, like with the boy who had the hair on his face, or the black um family who had the Albino children and I think they were really, really great. The Huntington's Disease ones which tied in really well and showed the operation of this woman having the foetal cells put into her brain which was an excellent video. And then like we did a piece of writing and we discussed it and they can be the basis for like a couple of really good lessons.

(Young female teacher of biology, comprehensive school)

But there was a really excellent one about nuclear power in France for example and it was all about the pros and cons and why France has such a different policy from us and it was good. I thought oh God this is excellent, it was just absolutely right for what we were doing and there was a lot of debate and discussion and socio and political sort of questions about it. And the safety and the whole French attitude – a lot of vox pop from a local group and it was brilliant.

(Mature female teacher of biology, comprehensive school)

The one caveat given about the use of video material is that it was important to be selective. There were few videos that could sustain interest for longer than half an hour. In addition, teachers need to decide in advance how the information presented will be used. In the lessons observed for this study, the video was often used as a stimulus for discussion, but this is likely to be more difficult at KS4 with larger classes, and guidance will be needed for teachers on a range of possible strategies for their effective use.

Nevertheless, any new course must, therefore, recommend or even require the use of video material. It is an important resource for illustrating aspects of science and the consideration of the ethical, technical and economic implications of its application. Given the large body of videos in the public domain or presented annually, it would

be inappropriate to produce anything other than a recommended list of potential sources. Another facility that might be useful would be a CD-ROM with short video clips that could form the focus of discussion or other activity.

Practical work and teacher demonstrations

4.38. Practical work is not a feature of this course. 92% of the teachers surveyed indicated that it was hardly or never used; the comparable figure from the students was 72%. There is no teachers' handbook which might suggest typical experiments, and the textbook makes no reference to any experiments that students might have seen. Indeed, when asked whether they used practical work for the course, most of the teachers were either puzzled by the question as it was something they had not even thought about or were simply dismissive. Fundamentally there were two reasons why practical work and teacher demonstrations were such a marginal feature of the course. One of these was simply structural, in that the lessons were taught more often out of a laboratory in a normal classroom where the lack of laboratory facilities made practical work impossible. Secondly, the teachers did not perceive the course as a practically-based course – which it is not. There is, for instance, no practical examination and no assessment of any practically-related skills. Teacher demonstrations were observed on three of the case study visits, where they were being used to illustrate and explain the underlying scientific concepts. Only 59% of the students on the course needed either double science GCSE, single science or a combination of single sciences at GCSE to take the course. Hence, there may occasionally be the need to use such demonstrations. However, in all cases, the demonstrations occupied less than 10 minutes of the lesson and were an additional rather than central feature.

4.39. Nevertheless the absence of practical work was commented on by several students in a question on the questionnaire which allowed open-ended response. In addition, students commented on the absence of practical work in two of the case study visits. In part, the image of science is that empirical work is an important component of scientific activity. Hence to have a course which ostensibly has the word 'science' in its title and yet not to engage in any empirical activity seems strange, if not contradictory for some students. In addition, there is a well-documented literature which shows practical work to be an important element in engaging young people with science (Osborne & Collins, 2001; Solomon, 1980). For this course, the positive response to the course overall suggests that its absence is not an issue.

4.40. For any proposed GCSE course, its inclusion is more debatable and contentious. On the one hand, the excision of any practical work would enable the course to be taught outside of the laboratory helping to distinguish it from other science courses and opening up space for a range of alternative teaching strategies. On the other hand, the lack of practical work may be seen as off-putting to both students and teachers who see this element, and the laboratories in which science as taught, as a distinctive and motivating factor. Undoubtedly there is little point in emulating the kind of practical work required for current GCSEs, since it is held in very poor esteem by teachers [see House of

Commons report on Science Education (2002)], or in assessing practical skills because that is not what the intention of such a course should be. Yet, such a GCSE course will require, at a minimum, some use of teacher demonstration to illustrate a range of scientific phenomena that students' prior science education will not have covered. In addition, practical work adds to the diversity of student experience as, in the words of one teacher when commenting on why he did use practical work occasionally, 'the key to successful teaching and keeping the students engaged in teaching is changing your activities all the time'.

4.41. For these reasons, it would seem that to excise practical work from any future course would be a radical step which might be off-putting for both students and teachers. Rather, what is needed is a re-examination of the role and function of any practical work or demonstration in such a course. Apart from its illustrative nature, there is a clear role for practical work in collecting sets of empirical data whose analysis and interpretation are not predictable or well-known in advance [see House of Commons report, 2002], and for which there are potentially multiple interpretations. Such exercises permit debate and argumentation, and bear more similarity to the activities of the professional scientist. Moreover, the work undertaken for the Nuffield A-level Physics practical exam has shown that there are many simple and brief exercises which will enable data sets of either causal or correlational data to be collected rapidly from a wider range of contexts than those of the exact sciences, which have traditionally dominated practical work in school science. In addition, such work will be educationally valuable in raising many of the 'ideas-about-science' which are still under-emphasized in this course. **Such arguments have led us to the conclusion that practical work, albeit of a different nature, should still be a component of any course offered pre-16.**

Student presentations

4.42. Student presentations were observed in four of the case study lessons visited, and students preparing for one in another visit. One of these required the students to produce the main points that they wanted to make using Powerpoint. The quality of the Powerpoint files was good but unfortunately the quality of the presentations, like the others observed, was not so good. Similar comments were obtained in the interviews from teachers.

Teacher: We did student presentations on risks and they were bloody hopeless. I thought next year I am going to do a few more of these because they needed to practise this skill.

Int: Are you surprised?

Teacher Am I surprised? Well they are second years and I thought they might be a little bit more competent at it then they were.

4.43. However, our view is that this finding is not surprising. Young people of this age are not used to speaking formally in front of their peers, and the experiences can be at worst nerve-wracking and at best unsettling. They do not know how to project or use their voices as a means of emphasis, and their conceptual grasp of the material is often weak so they cannot identify the wood from the trees – that is the salient points from the extraneous. This is not to argue that they are without merit. As the point made by the teacher beneath illustrates, some students, particularly those who make the presentation, do learn a lot from the experience.

Teacher: Student presentations: We have done two or three, probably do maybe four in a year.

Int: And your feeling about those?

Teacher: Umm they are fine but there is a huge range of participation between students. Some students will just read from a piece of paper and others really get into it and you know, … get a lot from it and the others get a lot from it as well so, they are ok.

Int: Ok

Teacher: And some are not so good for others.

4.44. The real problem with such presentations is twofold. First, some mechanism is required whereby other students are pressed into engaging with what, in comparison to that of their teacher, may be a fairly lacklustre presentation. A simple mechanism for this is to insist that each pair of students think of one question for the presenter afterwards, but this was never observed or suggested in interview. When it was suggested to a teacher in a post-lesson discussion the idea was welcomed, suggesting again that teachers need a source of such strategies. Second, it needs to be recognised that such presentations need scaffolding with a suitable set of generic headings which will aid and assist the student to structure their talk so that it addresses the important features of the topic. This was observed once, where the teacher wisely reminded the students that their talks should make clear what they thought, what their opinions were, what were their concerns, and what they saw the principal issues to be.

4.45. Student presentations have a twofold value. First, they force students to engage with a body of scientific knowledge and its applications in a level of depth which is generally more than normal. Communicating knowledge to others always requires a good background knowledge of the issues yourself. Thus, the activity is a learning experience for the presenter. Moreover, the presentation begins that process of developing the skills required for such tasks and speaking in public which, many would argue, is a key skill increasingly required in a diverse range of adult contexts. However, how to make a student presentation an effective learning experience for those students listening is not well understood, at least by science teachers. It is clear that the non-traditional nature of this course requires science teachers to make use of strategies of which they have only limited experience and which, on the whole, are not part of their regular repertoire. **Any new course intended for a larger populace must be supported with materials that explore what kinds of strategies might be used and how to use them effectively. Ideally, video training materials illustrating their use would be an invaluable support showing how the strategy might be enacted and acting as a vital model of what is proposed.**

Note-taking from the board and past questions

4.46. Traditionally such activities have been a normal feature of most science teaching. The transmission model of teaching which is still strongly embedded in science education means that most science teachers spend a significant body of time providing notes. This is often done in the belief that only the process of copying down well-structured notes will enable the student to remember the information. This is expressed in one teacher's response to a question about their use of note-taking:

Teacher: Notes from the board obviously. I will fight tooth and nail to be given the opportunity to do that. Because as a standard teacher you can't teach science without giving them information.

Int: Do you give them as much as you would do in a standard science course?

Teacher: No I give them less. But then I wouldn't want to not give them any you see, because they also went away today with some notes, like they have got three separate principles of radiological protection. Now it is no big deal but they are there and so if they are revising it often helps for them to have something that goes 1, 2, 3.

(Male science teacher, FE college)

4.47. The argument against this process is that most notes produced by the teacher on the board are generally first draft, not well-prepared, and there is little mental processing in the activity. Such an argument is encapsulated in the view that copying is a device by which the notes of the lecturer become the notes of the student without going through the mind of either, and in the comment by one teacher that 'science is recapping scientific facts, and the student won't gain skills from copying off the board particularly.' Note-taking was observed in the case study visits in approximately a third of the lessons, though sometimes the notes were diagrammatic and with a conceptual emphasis. When it was used, it was predominantly to summarise aspects of the scientific explanation rather than the debate of any issues. In the questionnaires, only 33% of teachers indicated that they used such an activity in half or more of their lessons, whereas 60% of students indicated that it was used in half or more of their lessons, suggesting that the true figure is possibly about 50% of all lessons. Even then, that use is not evenly spread as some teachers make more extensive use of note-taking. The general picture is that teachers were much more reluctant to give notes for this course, partly because the textbook was a good source of high quality information and, hence, it was unnecessary. Where it did occur it was for the kind of reasons expressed below.

Note -taking from the board a little bit. Tends to be summarising the major points after you know arguments for, arguments against that sort of thing. Yes I suppose those are main things and sometimes explaining science points to … for instance antibiotic resistance, I must have taught it four times already this year and they still talk about immunity. So there are certain things like that that I hammer and those are just straight science teaching. *(Female head of science, FE college)*

4.48. Any new course will need to recognise that note-taking is a traditional technique which teachers use to varying degrees. The evidence from this course is that a good quality textbook has, at least for some teachers, weakened some teachers' reliance on this as a means of transmitting information. **Likewise, for any new course, such a good quality textbook would be valuable and is recommended.** And like the SPU book, it should principally be just that – a textbook with accompanying questions and activities that can be used for homework – and not a hybrid of a textbook and activity book which often fails to fulfil either function well. Moreover, any GCSE course will place a greater emphasis on discursive activities that require reading and more extended writing than the standard GCSE science course[3]. **Significant thought will need to be given to the kinds of literate exercises which will scaffold and develop the competencies and skills required by the course in a progressive manner.** Here the work of Wray and Lewis (1997), Wellington and Osborne (2001), Norris and Phillips (1994) and Garrat et al. (1999) may be useful.

4.49. Similarly the use of past questions is a traditional science teaching technique. Its rationale was justified by most teachers in the following terms:

Firstly you familiarize them and second they embed what they have learnt. Because there are enough questions out there now to find a couple for most topics. Oh and the bottom line of course is that that is what they are going to get in their modules, and you want them to get as good a grade as possible. So it is practice. *(Head of science FE college)*

The only complaint offered by teachers was that there was a shortage of exam questions because the course has only been offered since 2000. All teachers traditionally look to examination questions for a more precise definition of what the intentions of any course are. For it is much easier to identify the content, skills and processes required of a course from such questions than the often loose or vague language of a syllabus specification. Such material is also used for practice at examination questions, for homework, and to familiarise the students with the level and demands of the course. The data in Table 5 and 6 suggest that past questions are used on average in a little less than half the lessons for this purpose. **The message for any new course is that the production of typical examination questions is an essential requirement to communicate the knowledge, skills and understanding expected of the students, and that the more questions available, the greater the confidence of the teachers will be with what they are doing.**

Individual tutorials and independent study

4.50. Tables 5 and 6 show that individual tutorials with students were not a very strong feature of this course. Where they were observed in the case study lessons, they took the form of a one-to-one discussion with the student about their coursework whilst the rest of the class was undertaking some independent study, either individually or in small groups. Teachers confirmed that this was the case in interview. The small group size for this

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[3] Many of the current GCSE science examination questions can be answered successfully by providing the relevant points or facts in bullet form and do not require candidates to provide full sentences, logical connectives or extended explanations. Not surprisingly they do little to develop students' competency at constructing explanations or expressing a reasoned argument.

course in most institutions meant that there was a much larger opportunity to engage with individual students. The problem for any GCSE course is that the group sizes are likely to be significantly larger, and opportunities for assisting individual students on a one-to-one basis diminished. Whilst this is not desirable, it is not seen as a major problem for reasons that are considered in the section on coursework on the next page.

4.51. Independent study was an observed feature of the SPU course, and examples 16 and 17 show instances of such activity. Students were asked to undertake research tasks, generally on the internet, using a specific brief either produced by the teacher, or drawn from other sources such as the SPU website.

Example 16
He then tells them that by Thursday morning, they will be expected to have produced the leaflet [on different sources of energy] and he says that we will have a discussion about what we have found out. Students go off and are told to come back 5 minutes before the end and tell him what they have found out.

Example 17
She then moves onto what she wants them to do today. She says that she got four things and that she wants them to write a short summary on each of these topics. She wanders around with the topics and lets them select. All the topics are drawn from the SPU website. She gives them some OHTs that they can work on. She tells them that she will use this next lesson as a summary to show what they found out. At this point, a student asks when are you going to go through the coursework. She asks for the OHT to be placed in the tray so that they can be photocopied for the others. She then takes them to the Learning Resource Centre.

4.52. However, interviews with the teachers showed that independent study was not a strategy that was universally used. Teachers who did not use it, or who only used it for coursework, said that there were problems either with access to the internet, or with its reliability in the school. Others felt that their students could not be trusted to get on with the work and lacked the skills to undertake such work and needed to be coached. Another argument made against independent study was that it destroyed the group dynamic and there was insufficient time. One teacher who did use it said that students needed clear pointers to what kind of information to look for otherwise they resorted to a trial and error strategy.

4.53. For any new course, the view of the authors is that the occasional use of independent study and research is essential. At the very least it will be required for undertaking any coursework, but it is also important as students have to learn to access information and critically evaluate it without the support of a teacher. In addition, it is a strategy that adds variety to lessons. Moreover, much of the information that students may want to gather about contemporary issues is to be found on the internet. This poses two problems, however. One is simply the physical problem of access. Most science laboratories still only have one or two computers which may or may not be connected to the internet. Even then, school networks have poor reliability and often slow connections.

It is difficult, therefore, to see how the internet can provide a regular and reliable resource. Nevertheless, schools do have computer laboratories and these can be booked. **It would therefore make sense for such a course to devise 'internet lessons' where the activities require the use of the internet for a *whole* lesson.** This would make it worthwhile for teachers to book the internet facilities for their class. It should also be remembered that many students will have access to the internet at home. Thus use of the internet should be encouraged by reference to a website where more additional information can be obtained. However, these will need to be websites whose existence can be relied on such as that of the World Health Organisation. Such a resource is currently provided for the existing course, and teachers have found it valuable as it saves teachers the problem of searching out appropriate websites to supplement their lessons. **Establishing a similar site for any new course is, therefore, considered essential.**

4.54. The second problem is that students need to be explicitly taught how to evaluate the resources they find. If they have been pointed to a website by a teacher that, in its own right, endows the source with credibility and authority. Nevertheless, it should be the aim of the course to develop some of the skills necessary to discriminate the trustworthiness of particular sources. The criteria for evaluation of reports about science on the internet are essentially similar to those for media reports about science.
Exercises that scaffold and develop an understanding of these criteria are, therefore, an essential aspect of any future course.

Coursework

4.55. A major element of the implemented curriculum in SPU is the coursework. Discussion of aspects of the coursework such as deadlines, choice of topics and general progress occurred in approximately half of the lessons visited. In addition, a third of the marks are awarded for student coursework. Hence, the time allocated to the study of coursework, be it in school or out of school, is a significant element of students' experience of the course. The coursework consists of two components – a study of a topical scientific issue and a critical account of scientific reading. For the study of the topical issue, the general approach seemed to be to provide the students with a list of suitable suggestions as a stimulus for the kind of work they could do. Teachers reported that the coursework was done to a higher standard when students self-selected a topic, as there was an intrinsic motivation to undertake the work. Final topics were checked for suitability with the teacher, but there seemed to be little problem in identifying suitable topics for study. The scientific reading is based on a book, or several chapters from a book, about science which may well be a popular account of science such as Richard Dawkins' *The selfish gene*. As with the first piece of coursework, teachers reported that they gave students a fair degree of latitude in choosing the book but that the final choice was a process of negotiation with the student to ensure that it met the requirements of the specification. Schools with more time allocated for the course often required students to undertake trial runs of the coursework. In addition, teachers were observed regularly providing formative feedback to the students on an individual basis about their coursework or, alternatively, chivvying them about choosing topics and producing the necessary work. The course textbook has a whole section devoted to coursework which both teachers and students identified as one of the strengths of the textbook in their separate questionnaires.

4.56. Both these coursework components are novel for UK science courses, particularly the latter, and it might be anticipated that there may be a number of problems associated with such innovative approaches to assessment and its implementation in the curriculum. Teachers may, for instance, lack a clear understanding of the aims of the coursework, how they should advise students to approach it, and what standards should be used to judge student work. The board (AQA) requires that all teachers attend at least one moderation meeting where samples of coursework are distributed, marked by the teachers and then the teacher's marks compared with the board's marks. This process permits the teachers to gain some common understanding of the criteria to apply in marking the work. Views about this meeting tended to be mixed. On the one hand, some teachers had found it to be very valuable:

It is not like trying to assess GCSE investigations, what affects the rate of reaction or something. It is quite different from that. And I mean I have heard nothing to the contrary so I assume our coursework marking from last year was fine. We haven't had stuff back, so we have both done it, it is like an instant moderation then. So I have done it and written lots of comments and kept my mark secret and Richard is going to do the same and we will see and last year we were pretty good.
(Female head of science, comprehensive school)

4.57. On the other hand, some teachers did express some concerns about the standards to apply in assessing coursework. These concerns, where they were voiced, were mainly about disparities that had emerged at the moderation meeting between the perspective of the board, and the criteria applied by the teachers.

The one in the end of November, in London. And I think most of the teachers there disagreed with the way the examiners did the marking. Well, all the teachers marked, I think there was one example piece that we were given, marked it low. And the examiner said – no, it should be higher. And there was another piece which we thought wasn't so good. So I can see difficulties, we'll have to see. However, we have got all the guidelines there and fingers crossed it will come together. *(Science teacher, FE college)*

I was very unhappy about the moderation meeting for the coursework that I went to. Because I found that it wasn't helpful in terms of the marking of the work. And I came away from there wondering if what I've been marking would actually meet their … how I marked would meet their criteria. Because I found there was a little bit too much subjectivity coming into how you view a piece of coursework. As opposed to objectivity. But I don't know. I got very confused at that meeting. *(Science teacher, FE college)*

4.58. Nevertheless, the majority of teachers did say that they were moderately confident that their students' work was appropriately assessed. The key to such confidence would appear to be the use of blind double marking – a process which is a requirement of the board where there are two or more teachers of the course in the school. Having shared their understanding of the standards, the teachers would then mark separately and compare marks, resolving any disagreements.

4.59. When it came to the skills required for coursework, two aspects were mentioned repeatedly by the teachers – the ability to evaluate critically different sources of information, and general literacy skills. The relative ease of access to the internet in most institutions means that finding relevant information is relatively straightforward. In addition, students observed doing coursework during some of the visits expressed the view that they valued being able to use the internet, as the information was up to date and easy to find. Nevertheless, the problem, succinctly articulated by one teacher is:

The ability to evaluate evidence – that's what they find most difficult. And they can write about and they can describe a book, and they can even criticise it to a certain extent, but evaluating the validity of the argument or where the sources of information have come from, they find very difficult. *(Head of biology, girls' grammar school)*

But I think they do rely quite heavily on getting lots of stuff from that [the internet]. But the trouble with that is it is very difficult to then sift out from it what you want.
(Female science teacher, FE college)

4.60. When asked whether they thought the course developed such skills, the general response was qualified assertion. Nevertheless, it was clear that this was more of an aspiration than a reality, as the more perceptive exposed a number of doubts about how effective that process was:

Not a huge amount I don't think. I think it is up to the teacher really to encourage them … because it is an AS level they have come from GCSE; some of them are A2 level in other things and they have some idea of doing research anyway. But the ones that have come straight from GCSE where there are things like multiple choice questions and not actually finding out data, so some of them do find that quite difficult. And to be disciplined. I have allocated some lesson times to coursework but not a great deal because I can't really afford to do that but I have gone to the library and showed them if they don't know already how to use the internet and things like that.
(Female teacher, FE college, social science background)

Yes and no, probably not enough, probably not enough. Um certainly when I have done internet searches I have asked them to consider the relevance of the site and how good it is, and whether or not we can rely upon it. Um but that is probably it.
(Female head of science, girls' grammar school)

4.61. Observations from the case studies cast further doubt on the success of the course at teaching these skills, since students seemed to lack clarity about how to evaluate information obtained from the internet. The general view within the field of literacy studies is that such skills need to be explicitly taught (Andrews, 1995; Wray & Lewis,

1997). The lack of any teachers' handbook means that teachers are essentially using their own intuition about how to teach and develop such skills in their students.
What is needed, therefore, is sets of exercises that teachers can use to explore and develop generic criteria for the evaluation of information, and scaffolds in the form of questions that students might ask of a source which would help them to evaluate critically data and information. In addition, students need to practise constructing and evaluating their own arguments – a process which provides insight into what constitutes an effective argument. The existing course does provide some limited support on the website and in the textbook, but this is in the form of general advice rather than being embedded in specific exercises.

4.62. The other issue raised by coursework is the literacy demands that such work makes. Several comments such as that below were made by teachers:

One or two of them have had literacy problems in their actual writing of a lengthy piece of work. They don't, I think, have masses and masses of practice about how to put a piece of work like that together, although they do have experience of coursework in other subjects. I think it is quite hard for some of them to focus on what they are actually trying to write about. *(Female head of science, comprehensive school).*

The course does require and make more use of the printed word than traditional science courses. Even the internet is essentially a written rather than a visual medium for communicating information. In addition, students are required to synthesise and construct arguments which can only be done through a combination of reading and writing. This is not a skill that students are used to exercising in science nor the teachers used to teaching – evidence for which can be seen in the quotes beneath.

They find that surprisingly difficult to put down both sides of the argument. Even though they might know what it is, but they do. Or they don't – they give an opinion and they don't back it up with much evidence. That is the other problem.
(Female biology teacher, comprehensive school)

There are a lot of new concepts. A hell of a lot of new concepts that they have to get in. Things like data analysis and using the media, even things like just basic discussion skills. and if you are presenting an argument you have got to acknowledge both sides of the argument and then explain why you have chosen one of these points to use evidence. All those sort of standard kind of skills which are necessary for the course which they don't have. And so I go very very slowly at the beginning.
(Female head of science, FE college)

They possibly do a lot more reading than they would have done, certainly as far as I see in any GCSE course there is much more of an onus of them to sort of sit down and read quite large bits of text through, obviously they don't tend to do that at GCSE or if they are exposed to that they don't tend to do it very well. … there is opportunity for them to improve their literacy skills, but some of them do find it very difficult to put together a large piece of written work. *(Biology teacher, comprehensive school).*

4.63. These comments reflect two weaknesses of the SPU programme. On the one hand, there has been a lack of recognition by the writers and developers of the intended curriculum of the extent to which the course makes significant demand on students' ability to read, write and evaluate information. Teachers, on the other hand, have, to some extent, realised that developing these skills is an essential requirement of implementing the curriculum, but have lacked the pedagogic skills and understanding of how these skills can be developed. For although there are many arguments that language and literacy are not an adjunct of science but, rather, an essential constitutive element (see for instance, Wellington and Osborne (2001); Osborne (2002)), this is generally not recognised within the culture of science teaching. Rather, it is seen as the responsibility of the humanities teacher. The SPU course has, therefore, brought this issue to the fore. For the existing teachers, more specific guidance is needed and, if possible, CPD courses that address this issue. For any new course at GCSE, the implications are significant. **Students will need support to develop their non-fiction reading and skills of analysis. More importantly, they will need support to develop their ability to write and construct written arguments. Likewise teachers will need support on how the teaching of these components should be implemented.**

5. THE ATTAINED CURRICULUM

The focus of interest in the following sections (5.1–3) is what have been the outcomes of the implemented curriculum.

Student engagement

5.1. One of the major factors affecting the attained curriculum is student engagement. For it is almost a statement of the obvious that only a student who is interested in a topic or discipline will be prepared to expend the effort required to learn and understand new concepts, and to undertake the tasks required by the course. A major way in which the SPU lessons were different from many other science lessons was the level of engagement shown by the students. Whilst the level of engagement was not uniformly high, it was generally positive. For instance, students were uniformly well-behaved, and off-task behaviour was rare. For the overwhelming majority of the time students were self-evidently listening to the teacher. Another indication of student interest and engagement is that some students were observed in nearly all lessons raising intelligent and thoughtful questions. Some of these were questions about science, some about what decisions teachers would make when confronted with ethical dilemmas, and some student-initiated questions about events in the news. Such moves change and challenge the normal mode of discourse in science classrooms where, predominantly, it is the teacher who asks the questions. What was notable was that the point at which students did become highly engaged with the topic was when space was provided for them to express their ideas and opinions. For instance, in example 18 beneath the issue of animal research generated a large number of student contributions.

Example 18
Tina [the teacher] continues the theme of relating the historical to the contemporary context and asks 'What kind of pressures do scientists today work under? Students suggest: pressures from groups against animal testing; media pressures; a pressure to release information early before others. Tina asks 'Don't you think there are financial pressures? How do scientists live?' The discussion here becomes animated.

5.2. Such a response was a feature of discussions of the issues raised by what, in comparison to much of the content of GCSE, were contemporary questions raised by science for society. These data lend support, therefore, to the view that contemporary issues in science are a point of engagement for students with science and a vital aspect of any such course. This is further borne out by the interviews with the students who, when asked how the course was different from other science courses, mentioned that it offered the opportunity to engage in debate and discussion (14 of the 19 students), and 10 mentioned that they valued being able to express their own opinions and that those opinions were taken seriously. Likewise, when asked about the content, the major aspect mentioned was that it dealt with contemporary science (9 students) and that much of the course dealt with issues outside science (9 students). Perhaps most striking was that when asked about their experience of learning during this course, the most common feature commented on was that *it was fun and enjoyable* (19 students). More importantly, the responses to the student questionnaire (Table 8) show that 62% of the students found the course very enjoyable or enjoyable.

Table 8: Student responses to a question asking them to rate their perceptions of course as a whole. (n=298)

	1 %	2 %	3 %	4 %	5 %
Enjoyable	16	46	27	6	2
Interesting	32	42	17	6	1
Easy	14	33	42	8	1
Different	26	39	24	7	0

5.3. Similarly in the last question on the student questionnaire – an open-ended question which asked for any other comments – the most common remark by far was that the course was interesting and enjoyable. **For a science course, this must represent a major achievement and it would be a mistake to undermine this achievement.**

Student views of the learning demands of the course

5.4. The student questionnaire provided some data which shows the student perspective of the course. Table 9 shows student answers to the question asking whether the course was the same or different from GCSE. Only 6% felt that that it was the same as GCSE science. This indicates that the course has successfully achieved one general objective of offering a distinctive science education course.

Table 9: Student perceptions of course compared with GCSE (n=223)

Same %	Different %	Not thought about it %
6	67	27

5.5. When asked an open-ended question about how this course compares with GCSE science courses, students gave a range of responses shown in table 10. Again, these confirm that the course is seen as being different by a large percentage of the students. The only other issue raised by these responses is the rigour of the course. It might be reasonable to expect an AS course to be more exacting than a GCSE science course – particularly as GCSE science course is perceived by many as somewhat of an intellectual wasteland (House of Commons Science & Technology Committee, 2002). Yet only 14% of pupils stated that the SPU course is harder than GCSE [Table 10].

Table 10: Student responses to an open-ended question asking them about their perceptions of course compared with GCSE (n=298)

More interesting	Different	Same	More open	Harder	Easier
%	%	%	%	%	%
16	41	9	10	14	8

5.6. When students were asked how they were coping with different parts of the course, it is clear that the physical science component of the course is more challenging and causes some difficulty (Table 11). This was supported by teachers at interview who also said that this part of the course posed more of a challenge for the students. Even then, over 50% of students stated that they were coping easily, or very easily with the physical sciences (Table 11).

Table 11: Student responses to question asking how they were coping with different parts of the course

	1. Very easily	2	3	4	5. With great difficulty	No reply
	%	%	%	%	%	%
Life sciences	26	44	26	3	1	0
Physical sciences	14	34	35	10	4	4
Ideas-about-science	18	49	27	5	1	0
Scientific explanations	17	39	37	5	1	0

5.7. Coupled with the data obtained from Table 11, where 62% indicate that the course is very easy or easy, there is a more than a suggestion here that the course may not be stretching students sufficiently, and that any revision of the course should consider the introduction of some exercises which require more application and depth of thought. Some support for this came from one of the teachers who has been teaching the course since its inception:

Teacher: I think I personally think it could do with a little bit more rigour in one or two areas. Some of the data analysis for instance, we talk about sample size. I don't want to get into statistics. I don't think it is appropriate. But I think some of it is a little bit too wishy washy. I think we probably need something more rigorous than the ethical side. I think they might actually find it easier to have a more sharply focus on how they argue.

Int: What do you mean by more rigorous – more content, more demanding, more examination questions?.

Teacher: Well … no I think more … one or two slightly more clearly designed principles about what we are aiming at. … I don't think we are rigorous enough about the conflict between the individuals in society is one that comes to mind immediately. I think animal rights is another one which is probably another popular… it is not one that interests me particularly but it is very very popular with students. And you do get an awful lot of very wishy washy thinking.

5.8. Part of the lack of rigour can be explained by the approach taken by some of the teachers to preparing material for the course. As the course is an AS with no A2, student achievement does not carry so much significance as standard A-levels, either for the student or the teacher. The result is that this course is not taken so seriously and some of the case studies revealed occasions when lesson planning took place 'on the hoof'. Evidence, in part, to support this view comes from the lack of homework that is given to students compared with other subjects where student responses show that 51% think that the they are given less or a lot less homework. In contrast, 33% of teachers reported that the course took more effort to prepare as opposed to the 13% who said it took less. As it was the first time of teaching the course for many, this finding is not surprising. **Nevertheless, this course, and any other course produced in future, needs to be able to defend itself against accusations that they have simplified and reduced the demands of the course and its difficulty to a point where students' experience, as enjoyable as it is, does little to develop their knowledge or intellectual capabilities.** Another danger is that teachers may be deluded into thinking that their students are coping well with the demands of the course when, in reality, their students have serious weaknesses in either their knowledge, their skills or both. Some suggestion that this may be so comes from an examination results where the pass rate in 2001 was 81.6 and the number obtaining grade A or B was 36.6% – no higher than many other AS levels.

5.9. There is little that can be done to change teachers' attitude to their preparation, but the observation that the preparation for this course may be less than others does point to the need for good quality lesson plans to be easily available for such teachers, either on the web, or in the form of the teachers' handbook. Given the small numbers currently taking the course, the website would be the easiest form of distribution. **For a GCSE course, the context would be different. The quality of teaching, nevertheless, is a crucial determinant of the success of a course and, therefore, teachers need to be supported with readily available resources and teaching strategies of good quality.** And given the significance of examination results, it is unlikely that homework will be taken lightly.

Examination performance

General features

5.10. Invariably, the question of what level of understanding and knowledge is achieved by students – the attained curriculum – is more complex and difficult to answer. The pass rates from the board for the examination are shown in table 12. These would suggest that the examination is no more or less difficult than many other exams at this level.

Table 12: Pass rates for the examination in 2001

Grade	A	B	C	D	E
Cumulative percentage	9.4	252	451	647	816

5.11. To provide more insight into candidates' performance on the examination, two approaches were taken to explore the learning of students – one was to examine a selection of scripts produced by the candidates for the examination in the summer of 2001, and the second was to interview a small sample of students from four centres. For the analysis of the examinations, a 10% sample of students was randomly selected from the full lists and the marks for each question transcribed. Each question was then coded for the component of the course that it was thought to be examining using a set of codes by two of the researchers independently. Initial agreement for the Life Sciences examination (SPU1) was 53% and 65% for the Physical Sciences examination. The codes were then discussed and agreement on the second coding was over 90% for both exams. The principal codes used were numerical skills for questions testing arithmetical and numerical manipulation; data analysis for questions involving data interpretation; ideas-about-science; ethics/economics for questions requiring consideration of issues from such a perspective; scientific ideas for questions testing knowledge of science; and argument and writing skills for questions testing skills of expression. The results of this analysis are shown in Table 13 (on the next page) for both examinations. The table shows the maximum available for the identified component; the percentage of the total mark available allocated to that component; the average mark achieved by the candidates on that component; and then the average mark expressed as a percentage of the maximum mark available for that component. The figures for the totals are shown in the bottom row.

5.12. The first question to ask of these data is whether the balance of marks allocated is appropriate. For the written papers the specification indicates that 40% of the exam should be for knowledge and understanding and 30% for application, analysis and synthesis. If the coursework is testing knowledge and understanding, and, if it is assumed that only the scientific ideas component requires knowledge and understanding, then it would suggest that broadly the balance is correct here. However such arguments are wholly dependent on the nature of the components and what it can be legitimately argued that they are testing. Our view is that these data show that the examination has managed to successfully reduce the testing of knowledge and understanding to a point where this component of the SPU course is significantly less than 50% of the marks. This is

Table 13: Data showing distribution of marks in the examination in 2001 for a 10% sample of candidates.

	Maximum mark available	% of total	Average mark achieved	% of max mark
Numerical skills	7.0	5.8%	4.1	59.1%
Data analysis	12.5	10.4%	8.3	66.4%
Ideas about science	12.5	10.4%	5.6	44.5%
Ethics/economics	23.5	19.6%	12.8	54.3%
Science ideas	47.0	39.2%	19.3	41.0%
Argument	9.5	7.9%	4.6	47.9%
Writing skills	8.0	6.7%	4.1	51.1%
Totals	**120.0**		**58.7**	**48.9%**

commensurate with the aspirations of a course which seeks to develop other knowledge about science and a broader range of skills.

5.13. The data show two additional significant features. The first is that the weakest performance of the students is on their understanding of the scientific ideas themselves. In one sense this result is not surprising, as the course states that the prerequisite for the course is simply a knowledge of GCSE science. However, even in the generalised form in which much of the science is presented in the lessons observed, it is not unreasonable to expect that another year spent thinking about, and using, scientific ideas would lead to some growth in knowledge and understanding; this finding invites questions about whether the manner in which the scientific knowledge is taught or developed is adequate. Alternatively, it could just be a reflection of the fact that, for some people, science is intrinsically difficult, and that students taking this course are doing so irrespective of their ability to grasp the underlying ideas. **Our view is that this component of the examination still has a tendency to focus on examining the specific rather than the general explanatory themes. Redressing this anomaly would not only make the examination more commensurate with the aims of the course, but also may lead to an improved examination performance.**

5.14. The second notable feature of these data is that the ‘ideas-about-science’ component appears to form a relatively marginal aspect of the examination and, in addition, that this aspect and the ability to write an argument appear to be the other two components on which students perform weakly. The under-emphasis on ‘ideas-about-science’ in the examination may well account for why this component appears to be under-emphasized in the teaching of the course. Not unnaturally, the corollary of this finding is that students will be unlikely to perform well in the examination if not much time is devoted to exploring such ideas. These data raise some issues for consideration by the chief examiners of the course. Our view is that there can be no curriculum development without similar attention being paid to the development of appropriate mechanisms of assessment that have at least a benign effect on the curriculum.

For the developers of new courses at GCSE, this means that a significant amount of their efforts must be devoted to producing assessment items that match the aims and objectives of the course.

Specific examination performance

5.15. As part of the enquiry into student learning, three specific exam questions were evaluated. The common feature for the three questions was that they required students to justify or give reasons to support a position. Two of the questions were from the Life Science exam and one question was from the Physical Science exam. Each of the selected questions allocated marks for the quality of written communication (QWC). Table 14 on the next page presents the narrative stem of each question and, as reported in the AQA SPU Teachers' Guide, the scientific issue addressed and the scientific explanation embraced by the topic of each question.

5.16. A randomly selected sample of student responses consisting of 20 scripts with high marks and 20 scripts with low marks were read and scored using an analysis schema for qualities of argumentation. The evaluation scheme employed eight evidence categories or argumentation positions, based on the idea that arguments are made from the use of standard exemplars. The categories were adopted from Walton's (1996) 25 categories for argumentation for presumptive reasoning. The eight presented below were held to be indicative of the kind of evidence statements employed by students in science discourse (Duschl, Ellenbogen, and Erduran, 1999):

- Argument from the use of if–then*
- Argument from the use of examples
- Argument from authority*
- Argument from cause to effect*
- Argument from correlation*
- Argument from the use or reference to sign
- Argument from consequence
- Argument from analogy

5.17. Comparisons were made between high and low performing students on two dimensions; total number of arguments and number of scientific arguments. See Table 14 on the next page. The latter are marked in the above list with an asterisk (*). For Question 1.d in SPU 1, both the number of arguments and the number of scientific arguments were significantly different between high and low scorers. However, the results for Question 2.c in the same examination showed that there was *no* significant difference between high and low scorers on either the number of arguments or the number of scientific arguments.

5.18. For the question, 1.b.iii, in the physical science module (SPU 2) both the number of arguments and number of scientific arguments were significantly different between high and low scorers. Looking at the narrative stems of the questions shows that the two questions that produced significant differences required students to make use of data; in question 1.b in SPU 1 in the form of a graph, and in question 1.b.iii in SPU 2 in the form of a table. In contrast, Question 1 SPU 2.c asked students to 'justify their own opinion'. Our analysis of the student responses revealed that it was possible for students to answer such a question with a high number of 'arguments from' but still get low marks. Beneath are two examples of such responses.

Table 14: Details of examination questions used for analysing student responses

Question number and narrative M = total possible marks; QWC= Marks available for quality written communication	**Scientific issue**	**Scientific explanation**
SPU 1 Q1.d Would you permit schools to have your child vaccinated with MMR? Justify your answer with reasons, drawn from the data presented here or from other sources. M (6) + QWC (2)	Infectious diseases	Cell theory; germ theory of disease
SPU 1 Q2.c The use of animals in research involves ethical as well as technical issues. Give and justify your own opinion on whether animals should be used to develop an AIDS vaccine, even if the animals suffer. M (6) QWC (2)	Medical ethics	None
SPU 2 Q1.b.iii Some people are choosing to generate part of their electricity from photovoltaic cells on the roof of their home even though the cost is currently high (about 20p per kWh as compared to around 6p per kWh for mains electricity). If the costs came down so that they were only 5% more than mains electricity would you want to do this in your home? Justify your position. M (5) QWC=2	Electricity supply	Energy: transfers Conservation Dissipation Decision about Science & Techology

No of Arguments=8 Mark=2
Animals should be used because what would medicine be like today if we had not tested on animals. There would be cures for relatively no diseases meaning that the whole country would be treated to a lot of pain and suffering in our lives. Improvements in non-animal testing means that less animal testing has to be done which is good, but animal testing should still be carried out. There is no other way of finding the drug's whole effect on the body and it is necessary to find side effects to AIDS vaccines. As so many people die of AIDS we need to find a cure as soon as possible and if animal testing does it quicker than I am for it.

N of A=12 N of marks=3
I believe that without much research that has been carried out on animals there would not be help for cancer patients, the MMR vaccine may not have been successful and the even basic operations may not be able to be done. Animals that are used for testing are normally breed for that sole purpose, don't know anything different from the laboratory life and are kept under very tight regulations. The animals are well fed and cared for and live in controlled environments. I do though disagree with testing on animals from the wild or in their natural surrounding or with animals that are put under unnecessary pain. With all research permission must be granted off the home office and there must be a 'means to the end' of testing.

5.19. It is notable that question 2.c., in contrast to the other two, did not explicitly require the consideration of a scientific explanation or the analysis of data, although there was a table of data provided in the question. The results suggest, therefore, that either the procedural knowledge needed to make sense of graphs and tables is not being addressed in lessons or the lower ability students were not able to use this knowledge in the exam. Similarly, the data show that 18 of the 40 students on question 1.b.iii on the physical sciences module received more marks for their quality of writing than for the quality of their response. Beneath are two examples of differing responses.

H – (1 mark + 2 quality of writing) (X)=mark
No, because although it is hugely beneficial to the environment even a small price difference adds up over time to an enormous amount of money. This is a very greedy and selfish point of view, but spending extra money on energy is likely to be a realistic option only for relatively wealthy people, or those who are very environmentally conscious. Although, again a very selfish point of view, reducing the use of energy provided by fossil fuels in my home would only have a very small effect (X) on the environment for a large personal loss.

L – (0 mark + 2 quality of writing) (X)=mark
I would use PV cells on my house as it would help the environment. The cost at the moment is to high but a slightly higher rate would be acceptable. (6/100) x 105 = 6.3. This price would be well worth using PV cells.

5.20. This analysis would suggest that students are not provided with sufficient opportunities to practise and model the use of data, graphs and tables in the construction of arguments, and that students are not being taught how to construct a good and effective arguments in or about science. **Steps need to be taken to ensure that more explicit teaching of the features of argument are incorporated in lessons and likewise, that the marking scheme identifies the particular features of argument for which marks will be awarded. This is particularly true of instances where students are called on to give arguments from personal opinions.**

Students’ and teachers’ perceptions of the attained curriculum

Student perceptions

5.21. Two initial pilot interviews were conducted at an FE College for the purpose of refining and developing a set of interview protocols (Appendix 3). Nineteen student interviews were then conducted at four different schools – two comprehensives and two FE colleges. The interview comprised four parts and, on average, took approximately 30 minutes to conduct. Part 1 of the interview focused on students’ understanding of the goals and aims of the SPU Course; part 2 focused on the coursework; part 3 the school work, and in part 4 students were asked to read an article on the use of cell-phones and then give reasons for agreeing or disagreeing with the position taken in the article. Interviews were conducted in March and April as late as was practically feasible.

5.22. In the first part of the interview, students were given a chart listing all the teaching topics, the ideas-about-science, and the scientific explanations that comprise the course. They were then asked to highlight and mark those items on the table that they recognised as having been studied or discussed in class. Tables 15, 16 and 17 show the results from using this probe. The general impression given by the data in Table 15 is that there has been a fairly comprehensive coverage of the teaching topics with only one topic – ‘Move away from human-centred view of natural order’ which had less than 12 student responses. Initially this finding raised a concern that teachers might be avoiding the teaching of evolution, but a review of the data for science explanations in Table 17 shows that ‘Theory of evolution by natural selection’ was marked by 18 of the 19 students. An explanation may be that the label was not recognised by students, suggesting that it is not used in the classrooms whilst discussing evolution – possibly because there was a lack of explicit reference to the ‘science explanations’. In general, however, these data suggest that the curriculum is implemented with no significant gaps.

5.23. For the Ideas-about-Science, nearly all of the major components were recognised by the majority of students (Table 16). ‘Causal links’ in the Physical Science section was the exception, only being identified by twelve students. In contrast, in the Life Sciences section it was marked by 16. These data may suggest a difference in emphasis in the teaching materials, and any subsequent reviews of the course should consider whether there is sufficient emphasis on causal links.

Table 15: No of responses from students indicating that a topic had been taught or discussed in class.

Science topics	Total
LIFE SCIENCES	
Understanding health and disease	
Infectious diseases	18
Health risks	18
Medical ethics	15
Alternative medicine	14
Understanding genetics	
Genetic diseases	18
Genetic engineering	16
Understanding who we are	
Move away from human-centred view of natural order	8
PHYSICAL SCIENCES	
Understanding our uses of energy resources	
Using fuels	19
Electricity supplies	18
Air quality	18
Fuels and the global environment	18
Understanding the effects of radiation	
Sources and effects of radiation	17
Understanding where we are	
Move away from an Earth-centred view of the Universe	14

Table 16: No of responses from students indicating which aspects of 'ideas-about-science' had been taught or discussed in class.

Ideas-About-Science	Total		Total
LIFE SCIENCES		PHYSICAL SCIENCES	
Data and explanation	14	Data and explanation	16
Social influences on Science & Technology	19	Social influences on Science & Technology	16
Causal links	16	Causal links	12
Risk and risk assessment	14	Risk and risk assessment	12
Decisions about Science & Technology	13	Decisions about Science & Technology	17

5.24. For the Scientific Explanations (Table 17), one life science and four physical science topics were marked by 12 or fewer students. These were the 'interdependence of species', the 'particle model of chemical reactions, the 'model of an atom', the 'radiation model of action at a distance' and the 'field model of action at a distance'. The failure to identify these suggests that these terms are not being used as conceptual organisers during the course and that it is the topics, rather than the underlying scientific explanations, which are emphasised in the course.

Table 17: No of responses from students indicating which scientific explanations had been taught or discussed in class.

Science explanations	Total
LIFE SCIENCES	
Cells as the basic units of living things	12
Germ theory of disease	18
Gene model of inheritance	16
Theory of evolution by natural selection	18
Interdependence of species	6
PHYSICAL SCIENCES	
Particle model of chemical reactions	5
Model of atom	7
Radioactivity	15
Radiation model of action at a distance	11
Field model of action at a distance	7
Scale, origin and future of universe	18
Energy: its transfer, conservation and dissipation	15

Student perceptions of the course aims

5.25. The second part of this interview addressed students' perceptions of the SPU course aims. For each of the nine aims, students were asked to read the item aloud, indicate if they understood the vocabulary, whether they had met or addressed this aim, and then to indicate whether the aim had been met by coursework or school work. Table 18 shows the results obtained from this probe.

5.26. The principal finding here is that the students at least feel that the curriculum has attained its aims. However, students felt that the course aims were met through school work and not coursework. Some students had only just begun the coursework so the difference between the two may not be so marked. Significantly rare items for coursework were 'Use of Science and Technology in decision-making about personal life style', 'Seeing science as the product of group work', 'The limitations of scientific knowledge', 'Making arguments about empirical data', and 'The link between technology and scientific understanding'. It would be wrong to take this data as offering a serious criticism of the coursework which, on balance, does not appear to be too onerous for either teachers or students. Teachers do not seem to have too many problems assessing it – 45% reporting that the assessment criteria were easy or very easy to use; and it is not disliked by pupils[4]. Rather, the implication from these results is that the link between the intentions, as embodied in the course aims, and the coursework is somewhat tenuous and that coursework is not seen as an integral part of the curriculum. **More consideration, therefore, needs to be given to the kinds of activities that could strengthen the role of coursework in developing some of the aspirations of the course.** For instance, it was notable that some schools restricted the choice of books for the critical account of scientific reading and, as the course develops over time, perhaps some assessment of the quality of readings and science topics should be made to determine if they do address the course aims. There is a trade-off, of course, in that limiting choice may negate aspects of students' interest and motivation. Alternatively, the structure of the study of a topical scientific issues might be reconsidered so that there is a stronger link between course aims and the activities required of the student.

Table 18: Responses of students to probe asking how course aims had been achieved

COURSEWORK	**Numbers recognising aim as feature of this aspect of the course**
Enjoyment	10
Media reports	9
Developing a personal view on S & T	11
Use S & T in decision-making	3
Group work	2
Power of science	8
Limitations of science	2
Ability to make arguments	4
Relationship between S & T	3
SCHOOL WORK	
Enjoyment	18
Media reports	15
Developing a personal view on S & T	16
Use S & T in decision-making	14
Group work	17
Power of science	17
Limitations of science	18
Ability to make arguments	14
Relationship between S & T	14

[4] This is a marked contrast to the GCSE coursework which is commonly held in low opinion by many teachers and students. Evidence submitted to the House of Commons Enquiry described its effects as 'stultifying' and overwhelmingly undertaken by pupils for its instrumental value in obtaining a good mark (Keiler & Woolnough, 2002).

Teachers' views of the attained curriculum

5.27. Teachers were asked what they thought students were attaining from the course. Inevitably the answers to such a question were broad rather than detailed, but three themes came through clearly. One was interest and engagement, illustrated in two examples by references to parent feedback:

A broader outlook on various scientific aspects. If we take … well, I'll give you an example of how it affected it. Last Monday was parent teacher evening and we had some parents in, discussing it, and in fact that day, that very day, I had been covering the introduction of radiation, radioactivity, and in particular the effects of radiation on the body. So I did a little quiz, I said – these are the various levels of background radiation we have, what is the cause of them? And then we did another one – how much radiation causes damage? And all this sort of thing. And that evening one of the parents had said that she'd picked up a student from the college in the evening, and apparently he'd been talking about it all the way home in the car, about this whole aspect of radiation and how it sort of burnt you or caused cancer, all this sort of thing. So obviously something had got across. *(Male science teacher, FE college)*

Also illustrated by the previous quotation was a broadening of their perspective on science, with the opportunity to study much more topical science than they would have done at GCSE or in any A-level course. The contemporary nature of the course also makes it possible for students to raise issues that are in the media and bring their own queries and knowledge to the classroom. The second aspect mentioned by teachers was a development of students' ability to think critically about science and its implications, such that they were less likely to adopt positions that were commensurate with either blind acceptance or irrational distrust of scientific ideas.

5.28. The third aspect was less tangible and more associated with the key skills that the course aims to foster. In their presentations, students had developed their IT skills and been given an opportunity to recognise and develop the skills needed to talk and present information to others. The course required group work, developing their skills to work collaboratively. More generally, it had developed their confidence with science:

I think it gives them a confidence that they didn't have … . There was probably a tendency initially to sign for it thinking oh yes this will be a nice easy one. But they do seem to have developed, quite a few of them in fact, you know. You see that light come on and you think yes they have got it and I do think that they do feel that actually they can do some areas of science that they didn't think they could before.

(Female teacher of science, FE College).

Teachers' views of effective learning

5.29. Teachers were also asked for their views on what constituted an effective lesson and how they judged it to be successful. The more or less universal criterion for such a lesson was a positive response from the students. Lessons were considered to have been successful when they stimulated student engagement and response, as exemplified by the two extracts below:

Teacher: Well whether they have contributed, whether they have … well they often smile which is important, you know students these days sit there like that and I do do some form of you know assessment at the end, not full, but I always try and do something to check whether they have understood what I am talking about and that sort of thing, but they don't always want to rush off at the end of the lesson you know. I think you just know. I teach quite a broad range of areas to different ages and you know I think if a student isn't enjoying it. Just by the body language.

Int: You can't always assume that enjoyment equals learning.

Teacher: Yes, I think there is … because they will come back six weeks later and come up with something that you have mentioned. So if they have remembered that and they can perhaps apply it and then they will say oh there was something in the newspapers, on a TV programme and that was what we were doing that sort of thing you know. I think that is important. If you enjoy yourself you are happy with your learning, well that is my experience anyway. Proof of the pudding will be in the results I suppose. But they do seem to have fun. (Female teacher of science, sociology background, FE college).

Teacher: The level of interest. Their ability to … their willingness to contribute and the sort of points that they were able to bring in which showed that they had developed some understanding. So the fact that they were interested to bring them in shows that it was a topic that triggered their interest and they were able to draw on stuff they had already learned. (Female head of science, FE college)

5.30. Specific material referred to by the teachers that had been successful in producing this kind of engagement was the study of genes and genetic manipulation and cosmology. The former raised a number of ethical dilemmas and the latter many fundamental existential questions about human existence:

The cosmology stuff I suppose those lessons provoked a lot of debate I suppose about how science impinges on religious ideas and I suppose in terms of making students really think about what they believe and questioning their own ideas, those have been the most successful lessons. (Head of science, sixth-form college).

5.31. Other lessons were considered to have gone well because the teachers had used an innovative strategy with particular success.

Int: Can you think of a lesson that went better than others. And why?

Teacher: Well a very fun lesson that springs to mind from the last year's group, they did a role play about animal rights when we were doing that part and they did it a la Jerry Springer show. So we had somebody took the part of Jerry Springer and then they all had their little role to play and so we had the extreme activists and scientists and the person who added some genetic problem and that was really nice and then of course they prepared that beforehand. And I actually videoed them doing that. And we watched them afterwards and that was a real hoot, but it was good too. It just made them think about how extreme people's views can be and you have got to listen haven't you and not make too many judgements. But they enjoyed doing it. It was good, so that was nice.

(Female head of science, comprehensive school)

Teacher: It was just a thing they developed last year. I went on a SPU course and while we were there we developed some resources to go on this website. That was the idea. And one of them was this like … and someone said well a good thing to do with lessons is just like a good teacher and you write things like questions on cards and answers and you give them out to students and they read out the questions and someone gives an answer… Say that one reads the question and the other thinks they have got an answer and they read their answer and it is a good resource if there is an order that you want them to do them in. That went quite well because it just challenged their ideas. They all had an idea. They had never questioned life before. Like what order of life came in and I made them say if you are going to run any one over which one are you going to run over and that kind of thing, so it was interesting and made them think about it and at the end they came of course with this ladder of life or whatever and so it led quite nicely to what they needed to know for the course so it was quite good.

(Male head of science, comprehensive school)

5.32. Bad lessons were, not unsurprisingly, ones where the students were not engaged with the course. Their causes were various but often due to lack of planning, problems with technical equipment such as computers or videos, or lessons where the teacher resorted to teaching science in a mode that was too like the approach taken in GCSE. There were a few instances observed in the visits to schools where teachers did not know the answers to questions posed by the students. However, they never seemed to be disturbed by this lack of knowledge and would ask the student to investigate further or state that they would attempt to look up the answer. This is indicative of a different kind of relationship between teacher and student, where the teacher's authority is less dependent on the students' perception of them as an authority. Given the authoritarian nature of much standard science education this shift is to be welcomed. The only topic that teachers admitted was problematic because of their lack of background knowledge was astronomy and cosmology. One teacher resorted to getting another teacher with expertise in the area, others chose to muddle through. Given that the majority of science teachers are biology teachers, it is unlikely that their own education will have included any treatment of this aspect. **Hence, any new course may require, at a minimum, more extensive background notes for the teacher on salient aspects of the contemporary astronomical world-view that should be emphasised. It may also be an area in which it would be appropriate to offer in-service or continuing professional development courses whose aim is to improve teachers' background knowledge.**

6. OTHER ISSUES

This section of the report provides details of several other aspects of the findings of the study. Whilst essentially unrelated to our main analytical framework, this section reports important issues that emerged during the course of the research which support some of the recommendations found at the beginning of the report and which need attention.

Training and support

6.1. Currently limited training is provided by the Nuffield Curriculum Centre who in 2001/2 ran two one-day courses – one for teachers starting the course and another for existing teachers. These courses dealt with teaching approaches and teaching resources. In addition, the Nuffield Curriculum Centre has organised one-day conferences on topics such as ‘Evolution v Creationism’ or ‘Xenotransplantation’ with an opportunity to explore teaching approaches. In 2002/3 the Curriculum Centre is offering another training day for teachers, possibly on teaching the Cosmology component.

6.2. The interview with the teachers sought to elicit what kind of training and support would help them to teach the course more effectively. Teachers paused in formulating their response and there was no one aspect that was prominent compared with others. Teachers’ responses referred more to resources than actual training – the largest number mentioning that they would have liked some handbook which gave clear guidance on how the course should be taught and activities that could be used for teaching. Several indicated that they had found the website valuable, particularly as more resources appeared during the course of the year. However, there was a need to develop the resources it offered still further. In this respect, there was a particular request for the SPU site to point to more internet sites for relevant information than it currently did. The second teacher questionnaire shows that over 50% of the teachers found it to be very useful or useful (Table 19) indicating that it is an important resource for this course.

Table 19: Responses to teacher questionnaire indicating use of the internet

1 Very useful %	2 %	3 %	4 %	5 No use %	 Omitted %
31	25	15	15	2	12

6.3. Nevertheless, one teacher was encountered who did not know of the existence of the SPU website and another two had not looked at it since the beginning of the year. **For any new course, the important message of these findings is that it is essential that curriculum materials are supported by a teachers’ handbook and a website.**

The latter is necessary as it provides a vital means of communication by which disparate teachers can share resources and problems.

6.4. As for training needs, teachers were not very forthcoming. Essentially, we believe that this is because they have managed to teach this course with apparent success and find it difficult to identify ways in which they could make significant improvements. Two mentioned that they would have found it valuable to watch colleagues teaching humanities and the approaches they used with subject matter that was essentially discursive. Three felt that they needed more help in assessing the coursework and determining appropriate marks, and several mentioned that it would be valuable to meet with other teachers of the course and share resources and strategies.

6.5. Our view, given the poor quality of much of the teaching involving discussion, is that such training is essential. Teachers of this course need an opportunity to interact with experienced humanities teachers, to observe the strategies and approaches they use for fostering and stimulating discussion, and feedback on how to improve their own skills. Whilst it is widely recognised that one-day courses do little to improve teachers' skills and practice, in this case, such a course would at least go some way to assisting teachers to identify whether they have a problem and how they might begin to improve. For any new course, such training will be essential. In addition, it is clear that any new teachers for the course would benefit from the opportunity to attend a course at the beginning of the year, where they could meet other experienced teachers of the course who could provide them with vital insights about successful strategies, and what to emphasise and prioritise. Hence, the board's requirement for compulsory attendance at the meeting for coursework moderation is totally justified. For experienced teachers, an in-service course whose predominant focus was on the sharing of strategies and resources, with relatively minimal input, would be valued.

6.6. The other problem for some teachers is a lack of background knowledge in the area of science being studied. As mentioned, the 'Understanding the Solar System' and 'Understanding the Universe' were identified as problematic for some teachers, as was a knowledge of ethical principles. The course team may, therefore, wish to consider whether it would be valuable to run in-service courses on these aspects. **For any new course, however, it will be valuable to have a set of background notes on those aspects with which teachers are less familiar – in particular, the ideas about science. The evidence from the teachers' questionnaire (Table 2 on page 22) is that very few teachers have had any formal education about the nature of their own discipline. Such notes would therefore be invaluable as a first step in improving gaps in science teachers' knowledge.**

Marketing the course

Course name

6.7. The issue of the course name was raised on several occasions on the case visits by teachers and in the student questionnaire. The essential problem is that the title does not convey to students what the course is about or how it is different from the traditional science courses they have experienced. Moreover, the acronym for the course can only be described as rather unfortunate – a fact that was treated more with amusement than with any view that it was a reflection of the course content. One school had taken to advertising the course with the subheading 'Science in the Media' which they felt made it more comprehensible to students. Another suggestion was that it be called 'Contemporary Science'. The problem with the name is not so much for the student doing the course, who does understand the nature of the course, its content and its themes, but for their peers who respond with a measure of perplexity when told that the student is studying 'Science for Public Understanding.' Undoubtedly, the name adds to the difficulty of marketing the course to a new group of students each year. We recognise that the title of the course and the textbook is to some extent set in stone and it is difficult to change a course name. **Nevertheless, our view is that it would not be misleading to add a subtitle to any course promotional material such as 'The study of contemporary science and its implications' which would go some way to redressing this problem. In essence, the subtitle needs to convey in a sentence or less what the course is about.**

6.8. Schools use a variety of strategies to encourage students to take up the course. Some write letters to all the non-science stream extolling the value of the course for careers other than those in science. Others hold sessions for year 11 where details are given about the course or produce leaflets giving the main details of the course. A twofold advantage for the course would appear to be that the general comment received from teachers was that it was more interesting than general studies, which it is often offered alongside. In addition under the current FE funding rules, general studies only receives 20% of the funding that the SPU course does per student, which gives the course a significant financial advantage.

6.9. Increasing the number of schools is a more difficult problem. It was notable that in nearly all the schools or colleges visited, the head of science was the person who had decided to offer the course and was teaching at least one of the modules. This would suggest that any further marketing should be targeted at the heads of science as, without their support and interest, the course is unlikely to be adopted. **Given the success of the course at engaging and interesting young people in science, it would make sense to use this finding as the basis to market the course more widely and to increase the relatively small number of candidates currently studying the course.**

7. TEACHERS' VIEWS OF THE STRENGTHS AND WEAKNESSES OF THE COURSE

Strengths

7.1. Teachers were specifically invited to comment on what they perceived as the strengths and weaknesses of the course. Likewise, whilst this was not a feature of the student interview, students were asked at the end of the questionnaire to make any comments about the course that they wished. From the teachers' perspective there were a number of perceived strengths, of which the most frequently mentioned was the contemporary salience and relevance of much of the material.

That students from many backgrounds can be involved. It's very good to see students who are not science students doing it. And are getting a lot from it in that sense. It very obviously is relevant to their lives and you can talk about current issues. The fact that it's a happening course and involves issues which are very much in the news. Almost every day. You know, every day when I listen to the radio something within the specification is in there, just about – which is great. *(Female biology teacher, FE college)*

Another valued component was that the course forced students to think in a critical reflective manner.

7.2. Others saw that the value of the course lay in the opportunity it provided to be flexible and in the space it opened up to pursue their interests with students. Indeed, one lesson observed on alternative fuel supplies became very much a lesson on the teachers' personal enthusiasms for ancient woodlands and their historical contribution to energy supplies.

Its flexibility I think. It gives you … you are given much more time to experiment I suppose. You can try something and if it doesn't work it is not the end of the world, because you can always take another lesson to either go back over it or reinforce or may be try something else. I mean the strength of the course for me is the fact that it is not like GCSE science. It is the content which is nowhere near as much and therefore you have got much more flexibility in how you approach different topics. It is easier to get kids involved. It is easier to get the students saying their bit. You know you can do it at GCSE but you are always conscious in the back of your mind of the time limitations. You know I would love to spend three lessons doing this because they have really got into it, and it is good discussion work, oh no I can't because I need to get that topic finished.

(Female biology teacher, comprehensive school)

7.3. However perhaps the strongest point made was that the course was simply enjoyable. Asked which parts of the course they most enjoyed teaching, teachers mentioned evolution, cosmology and alternative medicines more than other topics but, more generally, expressed the view that most of it was an enjoyable experience because the students liked the course:

Students really like it. Even this group of people who are not … they are not the most diligent or whatever, they really enjoyed it they enjoyed that sort of science, they got quite excited we have just finished the bits on the universe and the solar system and all of that and they really enjoyed it. They really liked it and they asked lots of questions…. why aren't we flying to Mars, and why aren't we this. It was interesting getting to grips with the distances that were involved and it was good. They liked it.

(Female biology teacher, comprehensive school)

Weaknesses

7.4. Asked about what they perceived as the weaknesses of the course, only two issues emerged. One of these was the depth of scientific knowledge required for the course and a recognition of the tension between explaining more science and exploring the implications of its use and application. On the one hand, some teachers complained that the course was not demanding enough for some students, and, on the other hand, that it was too demanding for year 12 students in particular. The dilemma for teachers is that many of the aspects of science can require a level of scientific explanation that goes much further than that indicated in the text. For instance:

I mean, for example, there is nothing on the radiation laws. I prefer to run through very briefly, very simply the radiation laws and give a lecture on those and sometimes I tend to feel that I do that anyway. And some of it is not even on the specification. I run through Wien's law, Franks law, Stefan Boltzman. We could do that very effectively and then of course looking at what is radiation everything a mix.

(Male biology lecturer, FE college)

The module which caused more problems of this nature was the Physical Sciences module which did not raise so many contemporaneous ethical issues and which teachers also commented students found less engaging. Yet, as the teachers recognised, going into greater depth about the science and returning to what one teacher termed 'science teacher mode' was likely to be off-putting to many students who had not enjoyed this kind of teaching at GCSE. Invariably, there are no easy answers to this dilemma. Rather, it is reasonable to expect teachers to make judgements about the depth of treatment of science, and the mode of teaching it, according to the needs and aptitudes of their students.

7.5. Part of the problem is that there is very little flexibility in the course – an aspect which was seen as the other weakness of the course:

Int: What do you perceive as weaknesses of the course?

Teacher: Lack of any sort of options in there. I mean it is very rigid. I know it is only an AS but there is no sort of element of choice in there whatsoever so I think the students have been more interested in some areas than in others. And so I think if there was some kind of flexibility there then may be you could tailor the course a bit to the students' interests.

The contrary view is that the flexibility is provided through the coursework. Providing choice would also mean that some of the major science explanations might not be covered. In addition, there is the question of how the course will respond to whatever scientific issue happens to be prominent at the time. Our view is that this is not a major complaint that was articulated by either the teachers or the students and that it would be inadvisable to make one topic optional. It would, for instance, add an additional level of complexity to the examination. **In general, though, our view is that flexibility does help both teachers and students, as it restores to teachers an element of professional judgement about what are the appropriate elements of a science course for their students and diminishes the perception that they are merely deliverers of somebody else's curriculum. Thus, an element of choice facilitates that vital process of ownership which, as Jon Ogborn has pointed out (Ogborn, 2002), is an essential element of any successful curriculum reform. Any new courses of this nature would, therefore, be well advised to incorporate some optional components.**

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APPENDIX 1: RESEARCH METHODS AND DATA COLLECTED

A1.1. The questions posed by this study required data which were a mix of factual answers, such as where teachers first heard of the course, what strategies they are commonly using, and which aspects they found particular challenging. In addition, answers were required which offered some deeper insights and explanations from the teachers and students of the views that they held. The research, therefore, required a mix of quantitative survey methodologies to elicit descriptive data to be used in conjunction with qualitative interviews and case studies. The latter two data sources provided deeper insight and illumination of the views and reactions of teachers and their students to the course. The research was, therefore, conducted using the following instruments.

a. A questionnaire survey of all teachers

A1.2. This instrument was used to determine basic data such as the age, educational background, reasons for choosing the course, opinions of the basic course materials provided by AQA, the textbooks, strengths and weaknesses of the course, and any other descriptive information amenable to measurement with straightforward questions and Likert type responses. Two questionnaires were conducted: one early in Sept/Oct 2001 sent to all teachers and centres known to be conducting the course which sought to identify basic factual information such as the qualifications of the teachers, the number of students participating, and the organisation of the delivery of the course. The information gathered from this study was used to determine a sample of schools for the case study visits. 78 responses to the first teacher questionnaire were obtained from 55 centres. In some schools teachers teach both of the modules whilst in others schools, they teach *only* the life sciences or *only* the physical sciences module. Hence, the full number of teachers teaching the course cannot be determined. However, given that 59 centres entered candidates in 2001 and that approximately 50% of centres seem to have teachers that teach both modules of the course, we estimate that this is a return rate of around 80% of all teachers of the course which we consider to be very high. Another estimate of the response rate can be deduced from the fact that the respondents indicated that they were teaching a total of 557 students. 800 students are known to have entered the examination in 2002, which gives a response rate of 70% of all students taught.

A1.3. A second questionnaire was then written and developed which sought much more detailed information about the pedagogic strategies used by teachers, the marketing of the course, the decision on uptake and other aspects which required more deliberation and thought. This questionnaire was trialled with a group of 5 teachers in December 2001 and amended further in the light of comments from the advisory board in January 2002 before being circulated to all known centres and teachers in February 2002. A response rate of 61% was considered to be satisfactory given the number of centres offering the course.

b. A semi-structured interview of 20 teachers

A1.4. In order to explore with teachers in more depth the views and beliefs that they hold about number of issues related to the course, a semi-structured interview was developed. No trial of this interview was conducted, but the schedule was revised in the light of internal discussions and comments from the Advisory Board before use. The schedule explored, through a number of questions, their views about: the strengths and weaknesses of the course including the difficulties of teaching the ideas about science; the issues raised by organising and assessing the coursework; the range of teaching strategies they used and their rationale for their use; their views about the effect of teaching the course on their understanding of what it means to teach science and their views on any CPD that would be beneficial; how they evaluate their lessons; the value of the course to their students; and how they market the course internally to prospective students.

A1.5. In all, 20 interviews were conducted with teachers from 13 schools. All of these interviews were transcribed but one was unfortunately of poor quality due to a failure of the audio equipment on the day. The interviews were then coded using NVivo, a qualitative data analysis package, and a set of codes devised which reflected the main topic of the question. Whilst this does not represent a grounded analysis of the data, it did enable the different components of their answers to be retrieved easily and examined for the emergent issues and themes in the teachers' responses.

c. Case study observations of 10 teachers

A1.6. Case studies of actual practice were essential for two reasons. First, we wanted a set of independent observational data of the classroom practice to corroborate the self-reports obtained from the survey and interviews. Second, they provided an independent analysis of the difficulties, strengths and dilemmas raised by the teaching of this course. Nine case study schools were initially selected to meet a range of criteria. These are shown in Table A1.1 on page 85. Teachers for the case studies were selected according to: science background (physics versus biology); experience (new to teaching the course versus has taught the course from the initial trials); experienced teachers in 11–18 schools versus experienced teachers in sixth-form colleges; experienced older teacher versus inexperienced younger teacher. The intention was to use the case studies to capture the range of contexts in which the course is being taught, and the range of issues and dilemmas that are raised for both the teachers and the course itself by these contexts. To this end, 27 lessons of 10 teachers were visited between December, 2001 and May, 2002. In addition, another 2 lessons given by another two teachers in these schools were observed making a total of 29 lessons visited in all.

A1.7. The main value of such case studies is a focus on teacher knowledge and their use of effective strategies (Clark & Peterson, 1986; Munby & Russell, 1998). Initially the intention was to use the different characteristics of the teachers and the contexts to attempt to identify particular features that facilitated or mitigated against effective teaching. However, it quickly became clear that it was impossible to draw any distinct conclusions about the influence of such factors of FE college v school, or lack of any background knowledge in the nature of science from visiting three lessons in any given school. Rather, as will be shown, what these visits have illuminated are a number of issues about what enables effective teaching of this course – insights drawn from the range of teachers and their differing styles and approaches, rather than from the study of any one teacher. Essentially, all visits provided an opportunity to study the strategies used, the level of student engagement, and an evaluation of their pedagogic effectiveness. Such insights were gathered through collecting detailed field notes, discussing with each of the teachers their view of the aims and intent of the lesson, and their post-lesson evaluation.

To answer our second principal question (How have students responded to this new science curriculum and what have they learnt?), we used:

d. A questionnaire survey of a sample of 233 students

A1.8. This instrument was drafted in the Autumn term, revised in consultation with the Advisory Board, and distributed at the end of January. The questionnaire explored such things as the reasons the students had for taking the course, what were their expectations of the course, and what were their responses to the content and style of teaching – in particular, what they would like more of and what they would like less of.

e. A semi-structured interview of 20 students

A1.9. 20 students were selected for interview at 4 of the case study schools. Due to practical problems, only 19 interviews were completed. Using a structured interview requiring specific tasks, these interviews focussed on three features: how had the course informed and developed their interest in science; what effect has it had on their conceptual understanding of the major explanatory stories of the course; and how the course has affected their understanding of the nature, processes and practices of science. In addition, this interview explored why the students had chosen to pursue the course, what their opinions were of the course so far, and whether it had met their expectations. An interview schedule was developed and trialled with students in January and used with students between March and April. These interviews were left till as late as possible in order that the students interviewed had covered the bulk of the course material before eliciting their views and attempting to make some assessment of their understanding of relevant issues. Data for the interviews were collected through the use of an interview schedule and audio taping student comments. However, only the recorded comments on the schedule have been used for analysis as there was insufficient time to transcribe and analyse the interviews.

f. An analysis of examination questions

A1.10. Agreement was obtained from the Board to collect data from the examination scripts for the public examination in June 2001. Approximately 700 students entered the examination and a random sample of 10% was selected. Marks for each of the questions and their subsections were then transcribed and the general patterns analysed. In addition, student responses to two questions were analysed for the marks and the quality of argument.

Table A1.1: Contexts for case study research
(see ‘Case study observations of 10 teachers’ on page 83).

SCHOOL/ COLLEGE	*Gender*	*Experienced teacher (>5 years)*	*Inexperienced teacher*	*Nature of Science background*	*No Nature of Science background*	*Physics background – both modules*	*Biology background – both modules*	*Physics: only physical sci*	*Biology: only bio sci*	*Girls only*	*School*	*VI / FE college*	*Group size*
FE college 1 (Surrey)	female	✓			✓		✓					✓	>10
London comprehensive school 1	male	✓		✓				✓			✓		>10
Rural comprehensive school (Glos)	male		✓		✓		✓				✓		<10
Rural comprehensive school (Sussex)	male	✓			✓				✓		✓		>10
FE college (East Anglia)	male	✓		✓					✓			✓	10
London comprehensive school 1	female		✓		✓				✓		✓		>10
FE college (Kent)	male	✓			✓			✓				✓	>10
Girls’ grammar school (North London)	female	✓			✓			✓		✓	✓		>10
FE college (Notts)	female		✓	✓					✓			✓	10
FE college (Surrey)	female	✓			✓	✓						✓	>10

APPENDIX 2: COURSE STRUCTURE

A2.1. The course consists of two basic components – a set of ideas about science and set of science explanations which are taught through a set of teaching topics. Fig A2.1 shows how these are inter-related. The full course specification is published by the Assessment and Qualifications Alliance (AQA, 1999) and is supported by a textbook (Hunt and Millar, 2000) and a website http://www.scpub.org. The latter provides an overview of the course, teaching resources and information on courses and the latest developments.

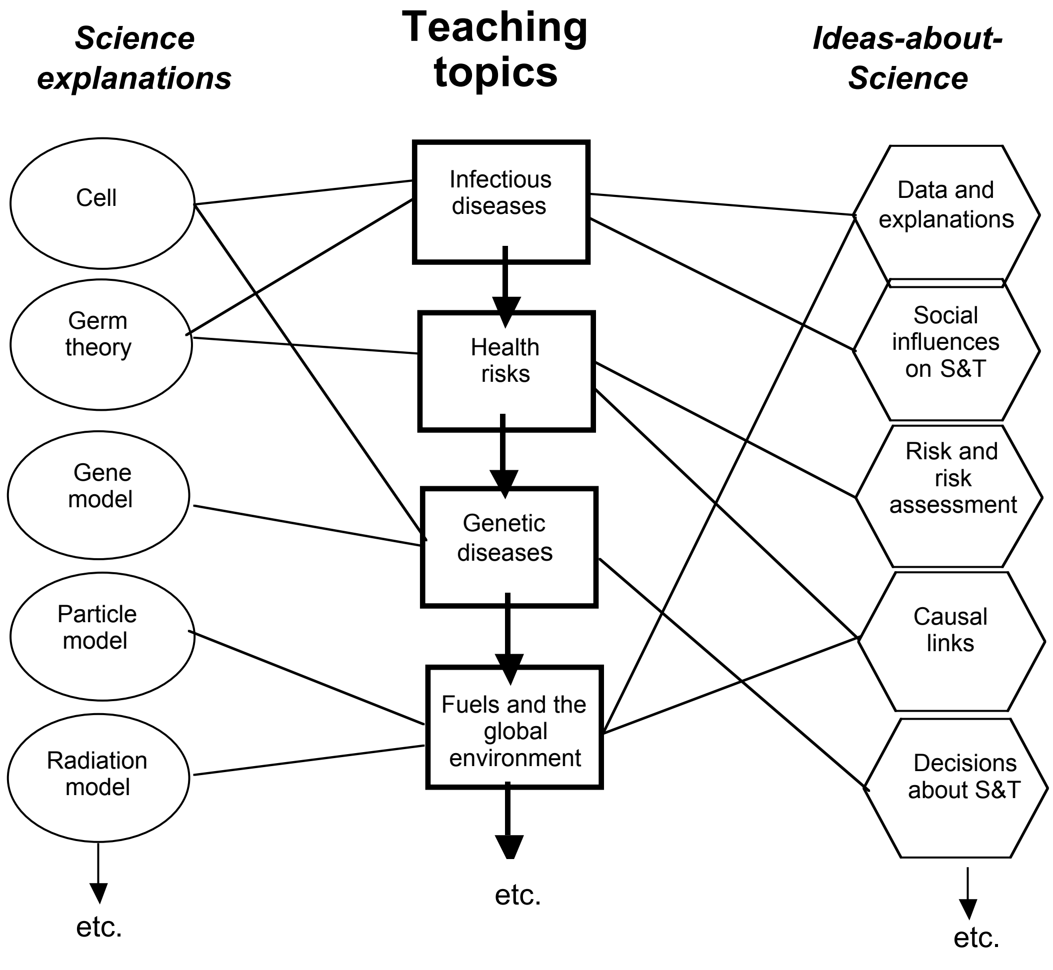

Fig A2.1: The relationship between the teaching topics and the two major themes of the course – Science Explanations and Ideas-about-Science

A2.2. The science explanations are seen as the major explanatory components underlying much of science. In the course, these are:

The particle model of chemical reactions
The model of the atom
Radioactivity
The radiation model of action at a distance
The field model of action at a distance
The scale, origin and future of the Universe
Energy: its transfer, conservation and dissipation
Cells as the basic unit of living things
The germ model of disease
The gene model of inheritance
The theory of evolution by natural selection
The interdependence of living species

A2.3. Such a list is undoubtedly open to contention. There are what we consider notable omissions. There is, for instance, a lack of any component of Earth Sciences and the story of the evolution of the Earth, in particular, the evidence for plate tectonic theory – an idea which has transformed our understanding of the ground on which we stand. **Given that this idea has led to a paradigm shift within the Earth sciences this idea-about-science should normally be a part of any set of major explanatory themes.**

A2.4. The Ideas-about-Science component consists of four sub-components which broadly cover the following ideas summarised in Table A2.1, a fuller version of which can be found in the full specification published by the Assessment and Qualifications Alliance (AQA, 1999):

Table A2.1: The components of 'Ideas-about-Science' *(continued on the next page)*

Theme	Details
Data and explanations	The idea that any measurement always has an element of uncertainty associated with it and that confidence is increased with repetition and replication. The idea that any experiment requires the identification and control of variables. That explanations require the use of creative thought and invention to identify what are underlying causal relationships between variables. Such explanations are often based on models that often cannot be observed. That the goal of science is the elimination of alternative explanations to achieve a single, consensually agreed account. However, data show only that a single explanation is false not that it is correct. Nevertheless, our confidence in any explanation increases if it offers predictions which are shown to be true. All new explanations must undergo a process of critical scrutiny and peer review before gaining wider acceptance.

Table A2.1: The components of 'Ideas-about-Science' ***(continued)***

Theme	Details
Social influences on Science and Technology	Recognise that the focus of much research is influenced by the concerns and interests of society and the availability of funding. That scientists have views and ideas which are influenced by their own interests and commitments. That the personal status of scientists and their standing in the field is a factor which, wisely, or not, is often used in the judgement of their views and ideas.
Causal links	To recognise that many questions of interest do not have simple or evident causal explanations. Rather, that much valuable scientific work is based on looking for correlations and that such a relationship does not imply a causal link. To recognise that confidence in correlational links is dependent on the size of the sample and its selection. Events with very low frequency are particularly difficult to explain causally. To recognise that eliminating causal factors for a correlational link is highly problematic. Rather that much scientific work relies on the identification of a plausible mechanism between factors which are correlated.
Risk and risk assessment	To have a knowledge of different ways of expressing risk and an awareness of the uncertainties associated with risk measurement. To be aware that there are variety of factors which impinge on people's assessment of risk. That risk assessment is central to many of the decisions raised by science in contemporary society.
Decisions about Science and Technology	To recognise that whilst the application of science and technology has made substantial contributions to the quality of life of many people, there has been a set of unintended outcomes as well. That technology draws on science in seeking solutions to human problems. However, a distinction should be drawn between what can be done and what should be done. Decisions about technical applications are subject, therefore, to a host of considerations such as technical feasibility, economic cost, environmental impact and ethical considerations. That certain groups or individuals may hold views based on deeply held religious or political commitments, and that the tensions between conflicting views must be recognised and addressed in considering any issue.

A2.5. The science explanations and the ideas-about-science are taught through three course components: the two taught modules – Issues in the Life Sciences and Issues in the Physical Sciences and through a coursework module. The two taught modules consist of a set of teaching topics shown in Table A2.2.

Table A2.2: The Teaching topics in the two modules

Module	Teaching topic
Issues in the Life Sciences	Infectious diseases Health risks Medical ethics Alternative medicine Genetic diseases Genetic engineering The move away from a human-centred view of the natural order (evolution)
Issues in the Physical Sciences	Using fuels Electricity supplies Air quality Fuels for the global environment Sources and effects of radiation The move away from the Earth-centred view of the Universe

A2.6. The teaching topics are then the means of illustrating both the underlying science explanations and the ideas-about-science. So, for instance, for the ideas-about-science the topic on health risks might be expected to focus on the analysis and evaluation of risk and cause and correlation, whilst for the science explanations it would develop an understanding of the germ theory of disease and cells as the basic units of living things. However, such information has to be inferred, as the lack of a teacher's handbook fails to make the links explicit and may account for the failure to emphasise these aspects.

A2.7. Each of these components is assessed by a modular examination at the end of the year accounting for 70% of the final mark. The other 30% is assessed through the coursework component which consists of two parts, details of which are shown in Table A2.3 on the next page.

Table A2.3: Details of the coursework components

Coursework component	
Study of a topical scientific issue	A study requiring students to investigate any topical scientific issue which requires them to: • research information, select relevant data and discriminate between sources; • present relevant evidence in a well-structured and readable report; • weigh evidence, analyse views and draw personal conclusions. The total length of the final report is expected to be around 1500–2000 words.
A critical account of scientific reading	Students are required to write a critical review based on reading 10,000–12,000 words of a piece of popular scientific writing (either fact or fiction). Their review should include: • a summary of the ideas and explanations in the text; • a setting of the idea in a wider social context and an identification of any wider moral or ethical issues raised; • a personal response to the ideas raised; • a critical discussion of the style and language used and its effectiveness for its purpose and what it conveys to the reader.

A2.8. Traditionally, coursework in science courses has examined students' skill and ability to conduct practical or empirical work in the laboratory. The coursework is, therefore, innovative in that, like the course itself, it requires no practical work. Instead one piece is reliant on students' ability to sift and analyse evidence and data associated with a contemporary scientific issue, whilst the second piece encourages students to engage in writing about science of general interest. In that this second component of the coursework seeks to engage students with writing about science and to examine it critically, it bears some similarity to the study of English literature which seeks to imbue both an ability to review works of literature critically and to develop a love of good writing. Moreover, given that no UK school science course has attempted this before, it is a mark of the gap that lies between this course and traditional science courses. These, in contrast, place a substantial emphasis on developing a knowledge of the basic concepts of the discipline and not of the overarching organising themes. The epistemic basis of such knowledge is often given a cursory treatment, and any examination of the social context in which scientific knowledge is produced and evaluated is simply ignored. This is not a criticism of such courses but rather a comment on their nature.

A2.9. This section has sought to provide a brief summary of the main features of the course that forms the focus of this study and evaluation. The SPU approach to the content with an emphasis on contemporary, and even contentious science, would be sufficient to demarcate it as a different course. However, it is a course which also in its structure makes a serious attempt to teach *about* science and to make use of an innovative and original approach to coursework. Our conclusion is that, at least in its intentions, this is a course which is distinctive and different from that which forms the core of mainstream school science education both in this country and internationally.

APPENDIX 3: INSTRUMENTS USED FOR DATA COLLECTION

For this research a number of instruments were used. These were

Teacher Questionnaire 1
Student Questionnaire
Teacher Interview Schedule
Student Interview Schedule
Code Descriptors for coding Examination Questions.

These documents have not been included in the report but are available on request from:

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