Improving science in colleges

A survey of good practice

In spring 2011 Ofsted conducted a survey of good practice in science in general further education and sixth form colleges in England. Inspectors visited 15 college science departments to observe teaching and learning and evaluate the quality of provision and departmental leadership and management. This report identifies the factors which helped these colleges to maintain the high standard or improve the quality of their science provision and makes recommendations for further improvement.

Age group: Post-16

Published: October 2011

Reference no: 110081

The Office for Standards in Education, Children's Services and Skills (Ofsted) regulates and inspects to achieve excellence in the care of children and young people, and in education and skills for learners of all ages. It regulates and inspects childcare and children's social care, and inspects the Children and Family Court Advisory Support Service (Cafcass), schools, colleges, initial teacher training, work-based learning and skills training, adult and community learning, and education and training in prisons and other secure establishments. It assesses council children's services, and inspects services for looked after children, safeguarding and child protection.

If you would like a copy of this document in a different format, such as large print or Braille, please telephone 0300 123 1231, or email enquiries@ofsted.gov.uk.

This publication is available at www.ofsted.gov.uk/resources/110081.

To receive regular email alerts about new publications, including survey reports and school inspection reports, please visit our website and go to 'Subscribe'.

Piccadilly Gate
Store Street
Manchester
M1 2WD

T: 0300 123 1231
Textphone: 0161 618 8524
E: enquiries@ofsted.gov.uk
W: www.ofsted.gov.uk

No. 110081

Contents

Executive summary

Science education is seen as a key contributor to providing a highly skilled workforce for the continued economic development of the United Kingdom. Although recruitment to science courses in colleges has improved in recent years, the quality of provision remains variable and in 2009/10 the inspection outcomes for science were poor. In spring 2011 inspectors visited 15 college science departments, 12 of which had been judged good or outstanding at their last inspection. A further three colleges were visited either because their provision was in areas of significantly high deprivation or because they had an especially wide range of science courses. This report identifies the factors which helped these colleges maintain their high standard or improve the quality of their science provision and makes recommendations for further improvement.

Science teachers in the colleges visited were well aware of the prior attainment and socio-economic backgrounds of their students and were skilled in developing a common foundation of understanding in science. Taking an interest in the students as individuals from the outset and demonstrating a personal enthusiasm for science created a positive environment for the students and encouraged them to want to succeed. The most effective teachers drew on their experience in science education well to adapt syllabuses to students' needs. Well-devised sequential schemes of work ensured a good balance of theory and practical activities which took account of students' starting points and allowed them to make good progress.

Students made best progress in practical lessons when the teachers actively supported them in setting up apparatus, making observations, and were enthusiastic about the results of their investigations. When teaching the theory aspects, most teachers used questions well to enable students to develop their understanding of scientific concepts and to use scientific terminology accurately and with confidence. However, in a small number of lessons, not all students made contributions and activities were not always differentiated to take into account the full range of students' abilities.

Students could see that their teachers were creating a more adult environment in which they could learn effectively, but were also keeping them on task and working productively. Many science departments had policies that specified the amount of work that students needed to complete each week and when students could expect their work to be returned to them.

Successful support, both formal and informal, was in place in the best colleges visited to make sure that students gained in confidence and made progress. The mathematical content of advanced science courses was seen as a significant difficulty by the students and teachers surveyed. Some students also found difficulty in making the transition from the short written answers commonly required at GCSE to the more lengthy explanatory text needed for advanced study in science. Additional support sessions in these and in other science-specific areas were provided all year, not just in the run-up to module tests. The performance of those attending was monitored closely.

Ofsted

Information learning technology was used well by science teachers in these colleges to strengthen students' grasp of key concepts and as a means of presenting the results of students' experiments to their peers. The best virtual learning environments contained a wealth of support materials including teachers' guidance notes, examination questions by topic (including answers and mark schemes) and up-to-date web links with explanatory notes.

Many students worked online at home and valued both the easy access that virtual learning environments gave them to trusted science resources and the ability to communicate more easily with their teachers. In the colleges visited it was becoming increasingly common for students to submit their work for assessment online and to receive their feedback in the same manner.

The best colleges had a full range of well-attended science enrichment activities, including industrial and employer visits and field trips to stimulate and interest students. Regular meetings of a discussion forum or science café encouraged students to become part of a community of scientists and familiarised them with the ways in which scientists discuss and communicate informally with each other.

The highly successful science departments visited had well-motivated subject teams that developed high-quality resources and agreed joint approaches to assessment and support for students. They innovated by sharing ideas and practice with each other and actively looked for improved ways of working. In the colleges visited, biology and chemistry teachers were relatively easy to recruit, but it was more difficult to recruit physics teachers. Continuing professional development provided by examination awarding bodies was seen as very useful by science teams, as was the experience of teachers who were also examiners.

National data analysed by Ofsted indicate that colleges with large numbers of students taking science courses have higher qualification success rates when compared with colleges with small numbers taking sciences. Larger science departments had greater potential for innovation and for sustaining improvements. Managers in colleges had to be prepared to support small science departments much more than larger departments.

Science departments in the best colleges visited were actively involved in encouraging local school pupils, especially girls, to consider science courses post-16. However, in some cases colleges were not always able to ensure that school pupils received information about the full range of post-16 science courses available to them in their locality.

The science curriculum in colleges across England is broad at advanced level and offers a wide range of academic and vocational opportunities. However, the number of pathways for students at foundation and intermediate level continues to be limited. In the colleges visited, guidance for students on the wide spectrum of careers opportunities in science, technology, engineering and mathematics was underdeveloped. Such guidance usually depended on the personal experiences of subject teachers and the local knowledge of careers staff.

Key findings

The following factors helped to maintain or improve the quality of science provision in the colleges surveyed.

- In the examples of best practice seen, teachers were very aware of the background of the students and were prepared to identify students' starting points and go on from there. For example, a good proportion of successful teaching in the early stages of science courses was aimed at familiarising students with specialist terminology.
- Teachers were skilled in translating the syllabuses into schemes of work and lesson plans that were meaningful for their students. The most successful teachers were very aware of the sequential nature of learning in the sciences. They encouraged their students to make connections between topics and to make sure that they understood fundamental principles and equations that they would use over and over again.
- The successful science teachers observed were skilled at using questions to generate discussion. The best teachers not only guided students through topics by the use of questions but also allowed them the freedom to take the discussion further and link it to other related areas of interest.
- In the best departments visited, interactive whiteboards were often used very well to present information to students through a wide range of media such as video, internet information, and animations; also to illustrate worked solutions to problems especially where mathematical formulae were involved. Many teachers were adept at getting students to show their calculations or to use the interactive whiteboard to support a presentation.
- Virtual learning environments in science were a trusted resource which students accessed in order to work at their own pace from home. However, in a minority of colleges visited, the virtual learning environments were underdeveloped and contained few links to additional learning materials.
- Additional subject-based support sessions were common in the good and outstanding colleges; they were provided all year, not just in the run-up to module tests. Students without a strong background in mathematics often found the content of advanced science courses difficult. Many students also found writing reports a real challenge. Teachers and managers in the best science departments successfully developed students' writing and algebraic proficiency by extra-curricular support.
- The best colleges offered enrichment activities that were attended by good numbers of students. Examples of good practice included well-organised fieldwork, presentations by employers, trips to field centres and extended project work to broaden students' perspectives on their studies.
- By putting on interesting events and visits for local secondary pupils, science departments in a number of the colleges visited were successfully encouraging pupils, especially girls, to study and succeed in the sciences.

- Training by examination awarding bodies was very useful to science teachers as they gained helpful insights into common misconceptions of students and how they could be further helped to gain good marks in examinations. Where teachers were examiners themselves, the benefits to colleagues and students were clear.
- Analysis of national performance data indicates that colleges with large numbers of students taking science courses generally have higher qualification success rates than those colleges with smaller numbers of students.
- Outstanding leadership and management in science education were characterised by the nurturing of highly effective curriculum teamwork and staff who enjoyed working together, and who shared and developed high-quality resources.
- Successful strategies to improve outcomes for science students included: curriculum teams developing agreed approaches to assessment and support for students; effective initial assessments of students' literacy and numeracy needs specific to the sciences; and staff who were examiners training colleagues in good assessment practice.
- In the colleges visited, close attention was paid to the analysis of success rates and value added data. Subject teams had ready access to management information and regularly analysed and discussed students' attendance, retention and assessment scores.

The survey identified aspects of science provision in the colleges visited which needed further development, even though the overall quality was good or better.

- Although most of the teachers observed used questions well, in a small number of lessons discussions were dominated by a few students and teachers did not ensure that all class members were following and contributing to the discussion.
- The science curriculum in post-16 education is broad at advanced level and provides students with a number of well-established pathways to higher education. However, the number of pathways in science for students at foundation and intermediate level is limited and does not provide the choice or opportunities that other subject areas offer.
- Students at Key Stage 4 did not always have free access to objective guidance on the range of further education science courses available in their area, or on the full range of science careers that was open to them after their studies.

Recommendations

The Department for Education and the Department for Business, Innovation and Skills together with awarding bodies should:

- continue to encourage and develop clear foundation and intermediate level science pathways for post-16 students.

Schools, colleges, post-16 partnerships and careers services should:

- work together to make sure that all Key Stage 4 pupils get access to independent advice about the full range of post-16 options available to them
- develop their staff so that the full spectrum of science, technology, engineering and mathematics (STEM) career pathways is available for students to consider.

College managers should:

- continue to develop teaching and learning in science so that lessons always contain appropriate differentiated tasks to meet the needs of all students; in addition, they should help staff to develop techniques to ensure that everyone in a class can contribute and follow discussions
- make sure that contents of virtual learning environments in science are interesting and attractive and not simply lists and examination criteria, with links to the rich wealth of science materials now available online
- be aware of the need to implement strategies that assist small science departments to achieve higher and more consistent outcomes for students.

College managers and teachers should:

- provide rigorous initial assessments for science students, especially for literacy and numeracy skills, to ensure effective enrolment on the right courses
- make sure that practical work is not just focused on achieving examination grades; the full spectrum of investigation skills should be actively developed by a programme of laboratory investigations
- ensure that all science students have access to a stimulating range of visits and lectures from visiting speakers to encourage them to put the sciences that they are studying into a wider context.

Contextual information

1. In the recent past, STEM courses in further education colleges have experienced declining recruitment. This has been a concern to industry and government departments as well as to those in education because students qualified in STEM subjects make a significant contribution to the British economy. However, recruitment to STEM subjects, and in particular the sciences, has shown an encouraging increase over the past two years. More students are taking science courses at advanced and intermediate levels in general further education and sixth form colleges than in the recent past. In addition, recruitment to undergraduate courses in the sciences has also shown an increase. There is, however, a mixed picture of students' achievements in the sciences in further education. In 2009/10 success rates on long science

courses were five percentage points below the national average for all other subject areas.

2. Since success rates for science courses are below national averages, not enough students gain qualifications and the outcomes from inspections confirm this. However, recent data from the Department for Business, Innovation and Skills note continued, albeit small, shortages of qualified people in science, technology and engineering occupations, particularly in health care and the electricity industry.[1]

3. Further education colleges recruit a wide variety of students from across different age groups and socio-economic backgrounds. Courses and programmes range from English for Speakers of Other Languages and basic skills to highly technical and advanced engineering and technology qualifications. Where school sixth forms and sixth form colleges recruit largely well-qualified students to A-level science courses, general further education colleges tend to recruit less well-qualified students to some A-level science programmes and vocational courses at intermediate and advanced level. These colleges also cater for adult returners who seek to gain professional, science-based qualifications or to access higher education opportunities.

4. The proportion of colleges judged to have inadequate provision for science and mathematics at their institutional inspection has increased. In 2007/08 two out of the 17 colleges inspected were found to have inadequate science and mathematics provision and in 2009/10 this rose to around a quarter.[2] It should be noted that a more proportionate approach to inspection was introduced in 2009/10, with priority given to inspecting weaker providers.[3] Nonetheless, the proportion of science and mathematics provision judged to be inadequate in 2009/10 was much higher than in any other subject area.

5. In the light of these findings HMI undertook this survey in order to identify good practice in post-16 science education in colleges and to make a contribution to the sharing of good practice.

---

[1] *Skills for jobs: today and tomorrow*, UKCES, 2010; www.ukces.org.uk/publications/nssa-vol-2.
[2] *Her Majesty's Chief Inspector's Annual Report 2009/10,* Ofsted, 2010; www.ofsted.gov.uk/resources/annual-report-of-her-majestys-chief-inspector-of-education-childrens-services-and-skills-200910.
[3] *Handbook for the inspection of further education and skills* (090105), Ofsted, 2010; www.ofsted.gov.uk/resources/results/090105.

Range of curricula

Colleges offer science curricula that reflect their size, their location and the local competition. However, a number of patterns of provision are commonly found.

6. A previous Ofsted good practice survey of science found that there were insufficient progression routes for students in the sciences at foundation and intermediate level.[4] This continues to be the case. In 2009/10 around 6% of all further education enrolments in science were at entry or foundation level compared with 19% at intermediate level and 74% at advanced level. In most other subject areas the proportion of foundation and intermediate provision is considerably higher.

7. Very little foundation provision was offered in any of the colleges visited in the survey. Only two general further education colleges in our sample had any provision at foundation level and the others offered little at intermediate level. A West Yorkshire general further education college in the survey offered a foundation science qualification and also helped local schools by providing elementary science for those pupils in the local referral unit and those who had been excluded from school. One college in the survey had discontinued foundation provision in the immediate past due to low recruitment and another was developing foundation provision for the next academic year.

8. At intermediate level, GCSEs in science subjects and mathematics are offered by most colleges in England. Generally, they offer a small number of GCSE repeat courses, either during the day or in the evening. The main entrants are those who need GCSE to enrol on courses such as access to higher education, those intent on qualifying to teach, or 16–18-year-olds who are keen to be better qualified in the hope of being accepted for advanced courses or entry to the police, Army or similar professions. In general, further education colleges recruit well for both day and evening GCSE courses. Typically, several groups are taught each year in the separate sciences. Except in the largest sixth form colleges, it is rare for there to be more than two or three GCSE science groups. The BTEC first diploma is a popular and growing alternative to GCSE sciences for some school pupils. However, the BTEC first diplomas in animal care and in food safety are overwhelmingly taken in further education settings.

9. Most general further education colleges have vocational provision at intermediate level – principally the BTEC first diploma in applied science. No sixth form college visited in the survey offered vocational courses at intermediate or advanced level, which is in line with the national picture where intermediate vocational science courses are rare. It is clear that progression

[4] *Identifying good practice: a survey of post-16 science in colleges and schools*, Ofsted, 2008; www.ofsted.gov.uk/resources/070027.

opportunities at intermediate level are limited, but better developed in general further education colleges.

10. Most further education GCE A-level science courses are taught in sixth form colleges, but not exclusively, as some general further education colleges have successful A-level provision. Sixth form colleges usually offer GCE A-level biology, chemistry and physics and these subjects often recruit well. However, applied science, electronics, geology and environmental science are also offered, but take-up is low and provision never exceeds two or three groups for each subject in the largest colleges. Occasionally, AS- or A-level Science in Society is offered to broaden students' programmes, but again take-up is low. Nearly three quarters of the A-level courses in electronics and geology, and just under half of the environmental science programmes are taught in further education colleges. Generally, the gender balance in A-level biology, chemistry, applied science and geology is approximately even, and it is only in A-level physics and electronics that female students are in the small minority.

11. The International Baccalaureate (IB) is taught in a small number of further education colleges – mainly in some sixth form colleges. Numbers in colleges remain small, usually less than 50 students, but in a few centres the course has proved popular and cohorts of over 200 study for the qualification each year. Since each student on the IB must take a science course, one of the outcomes from this provision is an increase in the proportion of female students who take science. In the IB it is often the case that female students outnumber male students in all science subjects. The largest IB sixth form college centre in England has 192 entries for IB science in its current cohort, over and above substantial numbers taking AS- and A-level sciences each year. However, much of the IB recruitment in sixth form colleges is limited and this curriculum initiative has yet to develop fully.

12. Many general further education colleges offer some A-level sciences, but the provision is only substantial in the largest colleges. The mainstays of general further education science provision are the BTEC national diplomas and the Access to Higher Education provision. The majority of advanced BTEC science courses are taught in further education. Most of the larger colleges offer professional qualifications at advanced level, such as dental technology and pharmacy and optical qualifications. In fact, many general further education colleges with origins as technical institutes successfully provide local communities with advanced training and the opportunity to gain qualifications to meet the recruitment needs of local science and technology-based industries.

13. An interesting and recent curriculum development is that of BTEC courses in forensic science. Five of the general further education colleges visited in the survey were running national diploma courses in forensic science and four were running intermediate diploma courses. These have proved very popular over the past few years and this has often been attributed to the success of television programmes which have brought the work of forensic scientists to the attention of a wider audience. Teachers, curriculum managers and the students

were well aware that completion of a BTEC advanced course does not automatically open doors to forensic science courses at universities. However, the qualification, if taught imaginatively, can provide a highly relevant general introduction to vocational science which the students then use to progress to a variety of STEM subject areas. The most successful further education colleges visited were using the BTEC forensic science courses in just this way.

> A general further education college in the north of England has successfully worked with local employers and industries to run specialist, professional vocational courses that meet local and national training needs. Currently, the college provides courses in optical dispensing and pharmacy along with physical sciences updates for employees in local science and technology industries. In addition, college managers have successfully collaborated with a nearby university to provide science courses that can lead directly to undergraduate study in areas such as health and the environment.

14. The science curriculum is wider at advanced level and provides students with a number of well-established pathways to further study, as illustrated in the following examples.

> A large and highly successful general further education college in London developed two curriculum pathways for science students, offering them a choice of traditional academic study or a range of equivalent vocational qualifications. One was essentially sixth form provision within the college and offered AS- and A-level biology, chemistry, physics and electronics along with GCSE science. The other, in an applied science academy, offered vocational courses that included an introductory diploma in science, first diplomas (including forensic science), and national diplomas in medical and forensic sciences along with Access to Higher Education provision. The college collaborates extensively with industry and universities to develop courses and to ensure that students gain up-to-date and relevant professional skills.
>
> Over 1,000 students took science courses; around 650 each year took GCE A and AS level. Just over 100 took foundation and intermediate programmes and almost 250 took BTEC national diplomas or Access to Higher Education courses. In all, these students were supported by 26 full-time equivalent teachers.[5]

> In one of the largest sixth form colleges in the country, the science provision has a very good reputation, high success rates and attracts high numbers of students. For example, in 2009/10 around 450 students took advanced biology courses, 340 took chemistry, 220 physics, around 100

[5] Details of the courses and students' attainments can be found at: www.goodpractice.ofsted.gov.uk.

took geology, environmental science and applied science and 70 studied electronics.

15. However, geographical location has an important effect on the curriculum offered. Some colleges are located in close proximity to schools with sixth forms or sixth form colleges and have chosen not to offer AS and A level. In contrast, other colleges find themselves as the only further education provider in a specific location – this often means that they have to provide both academic courses and vocational provision for the area.

Student recruitment and qualifications on entry

16. Where GCE A- and AS-level courses in physics, chemistry and biology are offered, the entry criteria in both general further education colleges and sixth form colleges are broadly similar. However, entry requirements for advanced courses in general further education colleges are slightly lower. There has always been a tension between the desire to widen participation and to give students a second chance, and the reality that inappropriately qualified students are much less likely to succeed.

17. All but one of the colleges in the survey would only allow students with five or more GCSE grades at A* to C, including English and mathematics, to start advanced science courses. In addition, they often asked for B grades in double or triple sciences and specifically asked for a B grade in mathematics to study physics.

18. The following example illustrates the approach taken to recruitment in a sixth form college in the north-east of England. This is situated near a large council estate and is the only college in a coastal town.

> Many of the local schools had poor GCSE results each year and aspirations in the local community were low. As a result the college allowed students to start AS science courses with four GCSE grades C or above. This college had a good record in motivating and encouraging students to work hard and in supporting them well. A-level achievements were good, but the students found the first year of advanced study difficult and this was reflected in low AS results. It took two years of study and support for these students to work to their full potential and to progress to higher education.

19. In contrast, several of the colleges visited for the survey were large, very successful and recruited in areas of intense competition to attract students. They only allowed students with B grades to start AS- and A-level work. In addition, where they also taught the International Baccalaureate, they often asked for even better qualified students.

20. Examples of good practice across subject areas are regularly reported by inspectors and recorded on the Ofsted good practice website.[6] One such report details how a large and very successful sixth form college in the south of England reintroduced AS- and A-level human biology to its curriculum. Clear and specific guidance to prospective students along with accurate information about the scientific content of the course and good teaching led to good recruitment and high success rates.

The key features of effective teaching and learning in science

Engaging students through subject knowledge

21. Good teaching and learning in science depend on the depth of subject knowledge of the teachers and the extent to which they can generate enthusiasm for science in their students. When a science teacher is clearly enthused by a topic, speaks of her or his interest in it and is keen to see the results of the students' investigations, this is contagious. The teacher's interest in the students as individuals and abiding curiosity about her or his subject present a positive role model to the students and encourage them to want to succeed, as demonstrated by the example below.

> A physics teacher in a general further education college was also an expert in astronomy. In an A-level physics lesson on astrophysics he brought his considerable expertise and obvious enthusiasm for astronomy to the course. His enthusiasm and expertise were highly contagious and the students were both interested and stimulated to study this aspect of the course. Students made good progress in understanding parallax and how this led to calculating the distance of faraway objects in parsecs.

22. In the survey, the vast majority of science teachers were well qualified with very good knowledge of their subjects. Most of them held at least a first degree in a science and a teaching qualification. Students reacted very positively to teachers who were confident in their expertise and who still found their subject interesting and fascinating. This did not mean that teachers were expected to know all the answers and the relationships observed between teachers and students were quite mature. For example, students were quite at ease with, 'I don't know that, but I can find out and get back to you', when the teacher was clearly a confident practitioner.

23. Best progress was made in lessons where students were encouraged to explain their thinking, where their responses were treated seriously, and where the atmosphere promoted discussion in depth. This did not happen spontaneously and teachers were skilled at managing group behaviour so that students

[6] Ofsted Good Practice website: www.goodpractice.ofsted.gov.uk.

listened to each other and responded by trying to develop ideas in the context of topics or in the light of scientific inquiry.

24. Many students came to advanced study with little background and general knowledge in science. The limited experience of some students could slow the pace of the group when they did not know about a range of common phenomena. In these circumstances, students were encouraged to read more widely and to talk about science that was in the news to develop their understanding. Teachers were keenly aware of students' lack of technical vocabulary and used discussion to encourage accurate and concise use of terminology. In addition, skilled specialist teachers in general further education colleges successfully managed the wide range of confidence and experience of adult students on day-release courses to enable them to develop the applied knowledge and skills to gain professional qualifications.

25. In the best practice teachers were skilled in placing topics in a social context to engage their students. For example in a BTEC forensic science lesson on bleach, the teacher successfully introduced the role of chlorine in safe, potable drinking water and its use as a poison gas in the trenches during the First World War. One of the popular features of Science in Society courses was their focus on contemporary issues involving science such as ethical dilemmas in medicine or climate change. Teachers did not always take opportunities to put topics in either historic or contemporary contexts.

26. Good progress was also made where the teachers knew the students well and were seen by them as accessible and approachable as illustrated in the following example.

> A small sixth form college in the north of England was located in an area of significant deprivation where young people left school with low levels of attainment. The college devised a highly organised approach to teaching and learning across the sciences that helped to give a tight structure to their courses for those students who were often not used to working methodically. Teachers recognised the students' lack of experience and knowledge, and introduced topics carefully by finding out what they already knew. They set behavioural objectives for the students and concentrated on helping them to develop their verbal and written reasoning. One teacher, for example, persisted in asking questions sensitively of some quiet boys in a class to make sure that they were making progress and to help them develop the confidence to participate in discussions. Teachers used a wide range of resources that helped students to learn for themselves, work with their peers, improve their confidence and become more independent students.

27. Science students made the best progress where teachers set high standards and helped their students to meet these high expectations through careful and encouraging support. In some of the most successful lessons the teachers set very challenging tasks for their students which allowed them to develop their

ideas much further than specified on the syllabus. The teachers knew their students well and had prepared carefully with the groups so that they could respond quickly and make fast progress.

> In a college in the north-west of England BTEC national diploma students in applied science were making very good progress in understanding genetics and the role of DNA. It was clear from discussions that the students understood dihybrid inheritance well and were rapidly developing an understanding of crossing-over values. These topics are rarely dealt with to this degree of depth in further education advanced biology syllabuses.

Topic and lesson planning

28. Nearly all of the science curriculum is examined and leads towards nationally recognised qualifications, so there are very detailed syllabuses for most of the courses offered. Teachers were skilled in translating the syllabuses into sequential schemes of work and lesson plans that were meaningful for their students. In the best schemes of work and lesson plans, learning objectives were expressed in plain English and did not use too many technical terms. In addition, handouts and PowerPoint presentations often contained useful summaries and definitions for students' reference.

29. Teachers made it clear at the outset that science students were expected to complete a lot of study in their own time, alongside a full programme of homework. The most successful teachers were very aware of the sequential nature of learning in the sciences. They encouraged their students to read over their work at home, to make connections between topics and to make sure that they understood fundamental principles and equations that they would use over and over again. Past examination questions formed a substantial part of homework and the routine written end-of-topic assessments. This was an important way for students to see concepts and formulae used to solve problems and also to measure their progress in understanding key ideas.

30. In the well-planned lessons, teachers were clear about what it was they wanted their students to learn and how they were going to get them actively involved in their learning. The most effective lessons consisted of a well-organised variety of relevant and closely linked activities. There was a good rapport between the teacher and students, demonstrated by a common focus on the topic they were studying together. Best progress was made where students could work together in small groups on discrete activities that led to thought-provoking conclusions and where there was room for humour and creativity.

> In a very successful advanced biology class in a large sixth form college, very good use of a commercially available genetics game led to significant gains in students' learning, participation, and enjoyment.

The students used cards and other materials relating to a model organism with a clearly defined genetic make-up – for example eight chromosomes and a set number of genetic characters. The students were all given an identical male and an identical female to use as parents for a number of offspring.

Using their knowledge of chromosomes, cell division and sexual reproduction, they created a number of offspring from the parents. With good humour they constructed models of the offspring from marshmallows, pipe cleaners, plastic buttons and cocktail sticks and put them in a 'nursery'.

The students were surprised by the range of variation shown by the offspring from what was exactly the same genetic material – the two parents. They were able to relate successfully the characteristics of the offspring they had produced to the way sexual reproduction leads to variation and to the raw material for natural selection and the mechanism for evolution.

31. Effective lessons involved a good variety of activities, with lots of opportunities for students to contribute. When the students were busy and saw the relevance of the linked activities, they worked with a will. Often, small groups or pairs worked together on problem solving and then took their turn to complete a short practical exercise. Science teachers were skilled at bringing together what had been completed and giving the students the space to explain what they had learned and what they saw as its relevance. Time was used well and students were productively engaged throughout, as illustrated by the following example.

In a good AS chemistry lesson the students came into the laboratory to find a series of questions on the chemical properties of transition metals by way of a starter and allowing students to arrive from across the college. This was completed well by the students and a lively discussion of the right answers was brokered by the teacher.

The main focus of the lesson was Hess's Law, which was introduced to the students in an interesting way, with a brief history of Hess in order to bring him alive to the students. The teacher then expertly used electronic whiteboard diagrams and targeted questions to help the students understand the underlying principles. This worked well and the students were then engaged in detailed and productive calculations and energy flow explanations.

Through effective support for individuals as they worked and well-produced written materials the teacher kept the pace of the lesson going; the students made good progress in understanding the first law of thermodynamics and enthalpy.

32. In most science departments visited, technical staff were closely involved with teachers in the planning and operation of practical sessions. Communication between teachers and technicians was excellent, practical materials were very effectively laid out and the work was very well-supported. In busy laboratories the technicians are an essential part of students' ability to access glassware and equipment, and to set up apparatus safely in order to get reliable results. Technicians are often crucial to the progress made by students in their extended project work.

33. In the colleges visited, technicians were on hand to help students with project work when the teachers were engaged with other classes. The students appreciated the wealth of experience that technicians could bring to setting up and modifying apparatus. In addition, technicians often successfully supported teachers by searching for and recording useful websites for students to visit in their own time.

Posing and responding to questions

34. Teachers used questions well to check and to direct students' learning. Open questions to the whole group and questions directed at an individual were used well to generate discussions in lessons. Some teachers preferred to ask students to write their answers on mini whiteboards and then to hold them up as this gave them a better idea of how well individuals had understood the questions. Generally mini whiteboards were used very effectively in the colleges that inspectors visited. However, in discussions about effective practice, a minority of teachers thought the use of mini whiteboards inappropriate for post-16 students. They thought that the students would find such boards too reminiscent of school days, and therefore these teachers missed this opportunity to use whiteboards to informally check progress and learning.

35. In the lessons observed, students were often inquisitive and asked questions spontaneously. Teachers with a good knowledge of their subject and a confident relationship with their students made good use of these questions to help the whole group to learn and to stimulate a discussion around the topic. This approach can become conversational and teachers were careful to retain a clear focus and to encourage the use of scientific language, checking that students used and understood the technical terms that form the basis of much of science.

> In a good A-level biology lesson on brain injury, the teacher allowed a class discussion to go on longer than planned as the questions asked by the students were not only relevant but showed where they had misconceptions about, or lacked basic knowledge on, brain structure and function.
>
> The students enjoyed the discussion and above all learned a good deal about the structure and the functions of different areas of the brain.

Through being encouraged to explore ideas together the students were able to correct any inaccuracies in their understanding.

36. Crucially, at points in the observed lessons where students were encouraged to discuss scientific ideas and concepts, they were given time to explain their understanding. The best teachers were skilled in not only guiding students through the topic by questioning, but also in allowing them the freedom to take the discussion outside the topic and link it to other related areas of interest.

37. Teachers often made good links across and between topics to stimulate the interest of more able students. At the same time, they were skilled at getting contributions from the less confident students and checking that they were following the discussion and helping them to take part in it.

In an outstanding A-level chemistry lesson in a sixth form college students made very good progress in understanding the oxidation of alcohols. The lesson was very well-planned and part of it consisted of the teacher using questions and answers and small group discussions to revise previous AS work on alkenes, aldehydes and ketones.

This was hard going at first as some of the students could not confidently recall what had been covered earlier in the course. However, the teacher did not give up and by a combination of persistent questioning, leaving time for students to think, and good clear whiteboard and electronic diagrams, skilfully built up their confidence and knowledge.

The teacher was encouraging but had high expectations of students' contributions, insisting on accurate use of scientific terminology.

The lesson then progressed at a quick pace and the students completed a variety of small group and individual tasks to make real progress in understanding the fundamental chemical processes that the oxidation of alcohols reveals.

38. While most teachers used questions well, in a small number of lessons seen discussions were dominated by a few students and teachers did not ensure that everybody was contributing and following the discussion.

In an otherwise good BTEC forensic science lesson the teacher failed to check students' understanding after showing a short human physiology video clip. The questions asked were too general and the answers were dominated by a few students.

The teacher moved on to the next activity while some students were not sure what they were supposed to have learnt from the video.

Ensuring effective use of practical work

39. In the colleges visited there was generally a good balance of practical work to support the theory aspects of science courses. Practical work was well planned into schemes of work which clearly showed how laboratory activities help students develop conceptual understanding. Lessons that were 90 minutes or more in length usually contained a mixture of theory and some practical work. While there were some longer practical sessions that had no theory element, these were less common.

40. Science teachers spoken to by inspectors would have liked to include more practical work in their courses, but felt that they could not afford the time. In discussion, teachers were concerned that the teaching year was now much shorter as module examinations took place in May as well as in January and June.

41. The standard achieved in practical investigations was particularly high when students were undertaking interesting and challenging activities. The following examples illustrate this.

> In one college, GCE A-level applied science students completed a synthesis of orange-2, an acid azo-dye. This was a complex multi-step synthesis which the students found interesting (and colourful).
>
> Each step was completed carefully and the students felt a real sense of achievement when they produced the dye and it successfully coloured a piece of fabric. In addition, the teacher used the steps in the synthesis effectively to make assessments of the students' skill acquisition by observing the yields at various stages in the synthesis, the final colour and the amount of dyestuff produced.

> In a GCE AS physics practice assessment, the students were measuring the oscillation of a metre rule suspended on two strings. Oscillations about two points were beyond their experience, but not beyond their ability to set up, make accurate measurements and check for systematic errors.
>
> The result was a challenging experience for the students which they completed well. The teacher supported their apparatus set-up effectively and made sure that they undertook the relevant mathematical treatment of the results so that they could graph the data and begin to analyse them.

42. Teachers used a good range of approaches to ensure that practical work helped them to get to know their students and to assess their practical abilities and knowledge and understanding of the subject. Teachers were usually very active in these lessons, helping and observing students at their work.

> In an advanced BTEC pharmacy lesson, the teacher made very good use of a macro video camera linked to a PC and projector to demonstrate to students how to orientate sheep hearts prior to dissection. This was a useful dissection that clearly deepened students' knowledge of heart valves, the cardiac cycle and the double circulation of blood.
>
> This contrasted with a similar dissection of hearts seen by inspectors in an AS biology lesson in a sixth form college. Here the teacher demonstrated the dissection first, but not all the students could see clearly. Some students then had difficulty identifying the coronary arteries and orientating the heart correctly as the dissection instructions were not clear.
>
> The BTEC group made much better progress in relating structure to function in the mammalian heart.

43. Sometimes teachers used short practical activities to introduce a topic and to allow students to review and extend their knowledge before going on to develop the topic further.

> In a practical session in a large general further education college, adult GCSE students assembled a fully disarticulated human skeleton as a starter exercise. With good humour they quickly assembled the skeleton and discussed the names and the functions of the bones.
>
> This served as a highly relevant starter activity to a short video that led the students to study the insertion and function of muscle blocks on the long bones and pelvis.

44. Practical lessons were often used to get students to work in pairs or to collaborate in groups. Rotations were also used to encourage students to mix and to help stimulate wider discussions.

45. In the lessons observed, standards of practical work were often good. Students' practical skills were well-developed and they could manipulate equipment, measure, observe and record their outcomes well.

> In an extended piece of practical work for AS chemistry the students successfully treated paper clips with strong acid and converted any manganese present into soluble manganate ions which are purple in colour. They then successfully prepared serial dilutions of a standard potassium permanganate solution and, using colorimetry, constructed calibration graphs in order to find out the manganese content of the paper clips.
>
> The students enjoyed the extended nature of the investigation, the need for accuracy and safety and the range of different techniques needed to answer a simple question such as, 'What is the manganese content of this common paper clip?'

46. Assessed practical work and examinations helped to keep a focus on practical work. While there was usually a good balance of practical work in science courses, there was sometimes a danger of teaching to these tests. In discussion with inspectors, some teachers felt that the practical assessments and their lengthy criteria had an adverse effect on practical work by restricting the breadth and variety of practical work that students could experience.

47. In the best practice observed during the survey, sufficient time was devoted to developing students' laboratory skills, such as microscope technique or handling quantitative glassware, or planning experiments to test hypotheses. This ensured they were confident and well-prepared for practical examinations.

Information learning technology and virtual learning environments

48. In the best departments, information learning technology was used routinely in lessons, especially where interactive whiteboards were standard in the laboratories. Where they were fitted, and this was by no means in all the colleges visited, they were often very well-used to present information to students through a wide range of media such as video, internet information, and animations; also to illustrate worked solutions to problems especially where mathematical formulae were involved.

49. Many teachers were adept at getting students to show their calculations for a problem or to use the interactive whiteboard to support a presentation, as illustrated below.

> In a college in the north of England, interactive whiteboards were used very well by all the science teachers in all the laboratories. Teachers used them as their main teaching tool and showed a wide range of multi-media presentations during lessons, including video clips and animations. Commonly used animations ranged from cell division and protein synthesis to industrial processes, particle collisions and nuclear reactions.
>
> Most of the teachers expected students to use the interactive whiteboard themselves at some stage in the lesson, whether to display their results from an experiment or to take the rest of the group through their working out, for example, of a chemical formula or a calculation.
>
> The virtual learning environment contained a wealth of support materials for syllabus topics, and examination questions by topic, together with answers and marks schemes and relevant, useful websites recommended by the teachers. The students reported that they used it extensively and that their teachers were very good at setting them work and returning it when marked through the virtual learning environment. This allowed students more autonomy over the scheduling of their work and helped them to develop a sense of personal communication with the teacher.

50. In less effective practice, teachers used the interactive whiteboards merely as a PowerPoint projector. In a small minority of the lessons seen, the teacher talked for too long, using an overlong presentation. The students were passive and lost interest.

51. Occasionally, opportunities were not taken to use animations or three-dimensional models and students took longer than necessary to understand structures or bonding. Where molecular models and relevant video materials from the internet were used, students made good progress in relating chemical bonds to the three-dimensional shape of molecules. Too often, diagrams used to show the structure of atoms and molecules were not supported by the use of three-dimensional molecular models. These help students to fully understand the structures of atoms and molecules very effectively but were rarely seen during the visits. Some chemistry students observed by inspectors were clearly unable to relate electron orbitals to the three-dimensional structure of double bonds, seeing the structures only in two dimensions as though printed on a page.

52. Virtual learning environments were well developed in nine of the colleges visited and were a trusted resource which students could access remotely. In the best virtual learning environments PowerPoint presentations of topics, work books, examination questions, examination mark schemes and a host of useful website links provided students with excellent backup for study and revision. The example below demonstrates a successful virtual learning environment.

> In a large science department in a sixth form college the virtual learning environment was very well-developed and well used by the students. Chemistry materials such as assignments and past examination questions were timed to arrive on the virtual learning environment when needed; after completion dates, the mark schemes were made accessible. A wide range of different resources explaining key chemistry concepts was available so that students could easily access explanations no matter what their learning preferences were. In addition, the chemistry team was very active in keeping resources fresh and up-to-date.
>
> The students appreciated the chemistry virtual learning environment; they used it frequently and reported that it was very helpful in the completion of assignments and revision for tests and examinations.

53. However, in a minority of colleges visited, the virtual learning environment comprised no more than lists of syllabus topics, examination criteria and examination questions. Useful though these were, they did not encourage students to take an interest in their subject, provide interesting and engaging materials for them to use, or help them gain useful independent learning skills.

54. Students had good access to computers outside their lessons to support their work. In half of the colleges visited, science departments had a dedicated computer room with a range of machines for students to use. All colleges

provided a more central facility where students could access computers. Many colleges had a good range of science workbooks available online via their virtual learning environment. Often these had been created by the science teachers at the college, but good materials were also available that had been produced by examining boards and other authors. In all these cases the materials were an integral part of the scheme of work and students knew that they had to study and review them if they were to make progress.

55. Many students work online at home and value the easy access that this gives them to science resources, and the ability to communicate more easily with their teachers. For example, in the colleges visited it was becoming increasingly common for students to submit their work for marking online and expect to receive their feedback in the same manner. This had the benefit of individualised work patterns that suited the students and the flexible and efficient use of time by both the teacher and the students

56. Some limited use of mobile phone technology took place, but was not widespread for subject-specific materials. There were a few examples where developments were taking place. For example, in one college where the science students used their mobile phones in revision sessions to download mark schemes, the information technology staff were working with a commercial company to create an application that would help students to organise their work.

> A-level physics students used the camera facility on their mobile phones effectively to record progress in setting up apparatus in their individual investigations. They were adept at using new technologies and also inserted images and text from other sources into their work. This, of course, raised issues of plagiarism which departments were currently using commercial filter software to solve.

57. In colleges, especially those with higher education provision, commercial software was used to identify examples of plagiarism and students were supported in writing their ideas in plain English.

Assessment and feedback

58. In the colleges visited, science students were set homework regularly which was carefully and accurately marked and returned to them with helpful comments that supported them in improving their understanding. Many science departments had policies that specified the amount of work that students needed to complete each week and when students could expect their work to be returned to them.

59. In addition to homework, assessments were often held during lessons. In the best departments, these were a mixture of formal, often longer assessment, and shorter, more informal testing. Written tests occurred as frequently as every week or sometimes fortnightly and were used to monitor progress and to

set or modify individual targets. It was often the results of these tests and homework scores that triggered interventions by teachers, such as recommending attendance at support sessions.

60. The best teachers assessed thoroughly, both formally and informally, throughout the course. They also left plenty of time for revision before examinations, demonstrated by the example below.

> In a group tutorial for science students in a college with a high population of students from disadvantaged backgrounds, the tutor was taking the group very carefully through their revision preparations. Students had to identify precisely how many days revision they had left and what they were going to do on each one of them. Students were well aware of how much time they had before their next examination and successfully plotted out what they had to do to get ready for it.
>
> The whole exercise was based on how well they had performed in the last set of examination modules. Each student had to include, as part of their plan, exactly how they were to catch up with topics they had performed less well on and any module they wanted to retake to improve the grade.

61. Where courses required students to complete a longer piece of individual work as a project, this was often organised to last several weeks and required a sustained piece of report writing that described the work, summarised the outcomes and reached conclusions based on the evidence and investigation. Many students found this an interesting form of assessment and achieved high standards. Generally, projects were completed well and in the best departments they were well organised and allowed students to show their investigative skills off to best effect. In the colleges visited, teachers were very enthusiastic about extended individual practical work. It provided exactly the right format for students to develop their thinking and planning semi-independently.

62. Ensuring that students were performing to the best of their ability and were supported all the way through their course were key features of a successful science department. In the best practice, very close attention was paid to the standard of students' work, including how well they were progressing and understanding the work.

63. Often in these cases there were also very close links to support workshops where needed. In five of the colleges visited, extra support sessions were regarded as compulsory for students who were falling behind or not achieving at their target levels. Registers of attendance at these sessions were maintained and any absence was followed up just as rigorously as any absence from a scheduled class. In this way an ethos of high expectation was fostered, along with the clear message that teachers took the progress of all their students seriously.

64. Target grades were often used well to set aspirational targets and to track students' progress. Science teachers put a lot of thought and care into how they used these grades to encourage better performance, while not discouraging students by giving them grades that were too high and that they constantly failed to meet. Target grades were often linked to the tutorial system and underachievement could lead to required or recommended attendance at extra support sessions. In best practice, performance was monitored after attendance at these sessions to check whether there had been improvements.

65. These approaches were combined with very good support for students from personal tutors, teachers and central support systems that included effective monitoring of attendance and progress. Good systems were in place to report these results to parents and carers. Students were very appreciative of these careful approaches and saw their lessons as hard work but also fun. They could see that their teachers were creating a more adult environment in which they could learn effectively, but were also keeping them on task and working hard. They liked the way that their teachers were available to help them outside lessons and the friendly and supportive approach that they adopted.

Additional subject support for science students

66. In the best science departments there was a lot of very well-organised support for students to help them either with topics they were finding difficult to follow or with more basic skills such as writing and number work. In interviews, students who were taking a range of science programmes at intermediate and advanced level reported that the mathematical demands of their courses took up a great deal of their time and were a barrier to progress.

67. The support was often of high quality and very highly valued by students. They valued especially the access they had to individual teachers and the time it gave them to work with a teacher on their own problems with learning.

68. The approach to providing support varied widely and ensured that the students could be accommodated in a manner that suited them. In some cases, students had learning support assistants with good scientific knowledge with them in lessons. These staff were often linked to one particular student for a substantial part of the working day. As a result the support assistant got to know the student's needs and requirements very well.

69. Much of the support was provided in workshops. These were additional lessons that were often subject-specific. The other common focus was mathematics related to particular subjects, such as algebra for physics students. Students took the initiative to bring their own problems along to these sessions, for example homework questions that they were finding difficult, and to spend individual time with a specialist teacher who helped them to understand the problem better. Initially, students may have been baffled by a problem or not understood a theory, but with skilled support and a range of approaches, they gained confidence in tackling seemingly intractable problems.

70. Some of these workshops were available for students to either drop into or to book into on a voluntary basis; other departments had policies that required underachieving students to attend workshops. The workshops worked best when students' attendance at them was carefully monitored and there were checks to make sure that they had understood the topics they were struggling with in the workshop.

A college in the east of England had regular additional study workshops that enhanced the learning for all science students. The sessions were described as Study Extension Time (SET) and they were available regularly to all students to help them with their learning. Typical SET sessions:

- supplemented classroom learning
- helped individuals with specific study difficulties
- covered revision topics and supported students re-sitting examinations
- helped students who were late starters to their course or who had missed lessons
- stretched and challenged individuals and provided 'master classes'
- provided help for students who were completing coursework.

Each SET session lasted for 40 minutes and took place twice a week in the early afternoon throughout the year. Attendance for students was voluntary, but very much encouraged by staff. Students soon appreciated the value of the sessions and generally attended regularly. Students' attendance was monitored closely.

It was the responsibility of heads of department to plan the SET sessions and monitor their effectiveness. Heads made arrangements for sessions to be held in an appropriate room, taking into account the size of the expected group and any specialist resources required. Staff offices were used for small groups or work with individuals.

71. Teachers and students interviewed by inspectors commented that a higher level of skills in writing marked one of the main differences between GCSE work and more advanced study. When studying GCSE level sciences at secondary school students were rarely required to write more than a few sentences. Some students found the transition difficult between the short written answers at GCSE and the lengthier explanatory text needed for advanced study. Some students required a great deal of support and help from their teachers in order to complete extended written reports. The best colleges provided this support well, as outlined in the following example.

In a general further education college 16–18-year-old students and adults on Access to Higher Education courses were fulsome in their praise of the way the science teachers had recognised their need for help in writing extended text. They received good support in organising their thoughts, using appropriate and accurate terminology and in overcoming the thorny subject of plagiarism.

The support took the form of additional lessons that started at induction and went on all year. Students were given short comprehension tasks to begin with and these were then followed up by longer written exercises. The students were introduced to the conventions of scientific writing and the correct use of specialist terminology and were encouraged to use the sessions to complete their subject coursework. The students, especially those on Access to Higher Education programmes were helped to understand plagiarism and how to avoid it in their writing.

Recruitment initiatives

72. Science departments in a number of the colleges visited were successfully encouraging more female students to take and succeed in the sciences. Much of the recent effort in this area has focused on attracting more women into STEM subjects. The gender balance is nearly equal in all sciences with the exception of physics and electronics.

73. In a large London college with a wide science curriculum, ‘girls only’ taster sessions were held each year for pupils at Key Stage 4 in the local schools. These have proved not only popular but successful in recruiting girls to science courses post-16. Some mentoring is in place with female second year students supporting first years. In at least one college in our sample, sensitive and largely successful arrangements were in place to make sure that female students did not end up as the only woman in a class of men.

74. A small number of the colleges visited were actively involved with school careers staff in encouraging students from local schools to take an interest in science and to think about studying sciences post-16.

A central London general further education college developed very strong links with local schools. Work between science staff from the college and schools promoted the pupils’ awareness of science and potential future careers in science-related areas; this led to an increased take-up of triple science GCSE subjects in the schools involved. This work has also raised awareness among college and school science teachers about ways of ensuring that school leavers make a successful transition from school to college. College staff, along with science consultants, also organise regular training sessions for science teachers from the borough’s schools, exploring practical, innovative ways of teaching biology, chemistry and physics successfully.

The college hosts a science careers day for Year 9 girls from local schools. The event in October 2010 was successful in its aim of informing school pupils about STEM subjects (science, technology, engineering and mathematics) and related careers. Around 300 school pupils attended the day, each pupil attending two 45-minute workshops that offered a 'hands-on' activity in a laboratory covering a broad range of topics, including cosmetics, animal care, forensics, optics, health and medical, electronics, computer science, biosciences, veterinary science and sports science. The sessions were delivered by science staff from the college, and other STEM ambassadors who were working scientists and engineers and had volunteered to do this work in schools and colleges. In addition, a 'speed networking' session gave pupils an opportunity to meet with and ask questions of a range of individuals who worked in science-related careers. A computer session also enabled pupils to research science-based careers on a careers database.

Enrichment

75. In the colleges visited, students' interest and enthusiasm were often captured well through enrichment activities such as guest lectures, clubs and societies and field trips. Both teachers and students reported that the opportunity to meet employers, visit scientific industries, to participate in fieldwork and to take part in more informal after-college investigations was very important in developing enthusiasm for a subject.

76. For example, ecology can be studied in the laboratory and from textbooks, but the insights and knowledge gleaned from fieldwork are invaluable. Extended fieldwork involving 'quantitative sampling in seral successions' or attempts to 'quantify biomass in different trophic levels' provides students with valuable insights into the theory aspects of ecology and, importantly, the practical constraints of making measurements. In the best colleges visits to field centres and local fieldwork provided just such opportunities.

77. Students can show different aspects of themselves and demonstrate hitherto unnoticed skills when taking part in activities outside the laboratory. Many teachers reported better attainment and self-discipline when it came to study after successful enrichment activities. Of particular note was the positive effect that guest speakers had on student motivation.

78. In the best science departments visited, there were forums for discussion organised by teachers outside lesson time. In general these were designed to make sure that science students were able to pursue their scientific interests outside lessons and to help them hone the skills of marshalling arguments and responding to others' views and positions, which are essential skills for scientists.

79. Clubs and science societies were often well attended and allowed students and teachers to spend additional time discussing and debating topics in more detail. They met for an hour or two each week and were used well to generate lively discussions. Some of these meetings focused on particular careers in science such as medicine and veterinary science.

80. In the best practice observed, evening meetings with guest speakers were arranged regularly and a minority of departments organised 'science cafes'. These were more informal gatherings to share thoughts on current, often high profile, topics that were in the news or were inherently controversial.

81. A college in the south-west had successfully set up a number of academies to bring the world of business and technology together with education.

> The science and technology academy aims to raise students' awareness of science and technology careers and to provide skills and experiences for professional progression to higher education or employment. The advisory board includes senior representatives from local and regional technology-based industries and organisations. In the recent past the students had enjoyed presentations from a leading heart surgeon and a forensics expert, and meetings with and mentoring from staff at local technology industries.

82. All the above activities helped science students to become part of a community of scientists and familiarised them with the ways in which scientists discuss and communicate informally with each other.

83. One college encouraged its science students to meet and write magazine articles for their fellow students.

> A college in the south of England produces a high-quality science magazine monthly. The magazine is written by science students from a broad range of science programmes, including GCE A levels, BTEC forensic science and Access to Higher Education (science) programmes. Articles are well researched and informative and many contain very attractive graphics. Staff oversee the production of the magazine, but a committed group of students carries out the work enthusiastically.
>
> Working on the magazine provides a focus for staff and students on science topics, generating much debate and discussion. Science students from different programmes work together very well and derive great satisfaction and pride from their efforts.

Careers and higher education guidance for science students

84. Students reported being well supported during the process of applying to university. The colleges visited had well-developed systems for advising and supporting those who intended to apply to study medicine, dentistry or veterinary science. However, less information and guidance was available on the routes to studying other disciplines such as climate science, food technology or astrophysics. Guidance on the wide spectrum of STEM career opportunities was underdeveloped. Such guidance usually depended on the

personal experiences of subject teachers and the local knowledge of careers staff.

85. In the following example from a visit to a large general further education college in the north of England, students were being prepared well to find out about the range of opportunities that their science courses would allow them to access.

> Group tutorials take place in subject areas. In one highly successful tutorial first year students on advanced courses used mini-laptops to access a number of specified websites that contained information about different STEM careers. Students were asked to look up two or three different careers, to make some short notes on the nature of the profession, what qualifications were needed and where those qualifications could be studied. This was a very successful exercise and the students researched climatology, food technology, weights and measures analysis and a range of other science-related careers that they had not considered as possible routes for the future. The tutorial ended with a lively class discussion in which it was abundantly clear that the students were interested in finding out more about the wide range of options that their courses could make available to them.

86. Survey visit findings in this area are in broad agreement with the findings in the STEM Careers Review, November 2010.[7] The review covered the provision of STEM careers education, information, advice and guidance in secondary schools and further education colleges in England. The report makes a number of recommendations, among which are: students and their parents, as well as teachers and careers advisers need better access to STEM labour market information; and all careers professionals and teachers should be better trained and informed about STEM qualifications and pathways to obtaining them.

87. Some of the colleges visited found it helpful to allocate science teachers as personal tutors to science students. As a result, support and careers guidance were improved and tracking of individual progress was more closely monitored, as illustrated by the following example.

> A West Country general further education college has set up a series of curriculum academies to bring the worlds of commerce and education together. Their aim is to raise careers awareness and help students reach their aspirations by providing employment skills and experiences that are relevant to their aspirations and developed in collaboration with local and regional industries and organisations. The science and technology academy provides advice on employability skills and career development

[7] J Holman and P Finegold, *Report to the Gatsby Charitable Foundation*; www.nationalstemcentre.org.uk/res/documents/page/STEM%20CAREERS%20REVIEW%20NOV%202010.pdf.

through a programme of guest speakers, visits and group mentoring. Over the past year, activities have ranged from presentations by a leading heart surgeon, and a forensics expert, to a ‘speed networking’ careers fair and a successful debate on the environmental aspects of aviation. The academies are popular with the students who appreciate the advice they get to improve their communications and teamworking skills and the way that this is set in a relevant ‘world of work’ context.

88. When interviewed by inspectors, science teachers and managers pointed out the sometimes adverse consequences of competition for post-16 students. In towns and cities where colleges are surrounded by schools with sixth forms, access for college careers personnel to Years 10 and 11 pupils to give them information about post-16 choices can be limited. Indeed it is sometimes difficult for further education college staff to get access to Years 10 and 11 pupils to encourage them to think about the full range of science courses available to them in their locality.

89. Ensuring that secondary pupils have free access to impartial careers advice is seen as key by staff in colleges who believe that students can end up taking inappropriate A-level and AS courses instead of being able to choose from the full range of academic and vocational courses on offer in their area.

Departmental leadership and management

90. One of the features of outstanding leadership and management in the science departments visited was the nurturing of highly effective curriculum teamwork in subject teams. This was characterised by staff who enjoyed working together, and shared and developed high-quality learning resources. It is vital to establish a culture of high expectations and close collaboration between teachers in order to have a consistent approach to teaching and learning.

91. In a sixth form college in the north-west of England, managers and teachers had been very successful in setting up an outstanding ethos and culture of learning. In the sciences, relationships between teachers and students were excellent and played a key role in fostering the high expectations that the teachers had of their students in terms of work, behaviour and respect for others.

Science teachers had time in their schedules in the college learning centre where they taught support sessions for students. This meant that students could access support for their learning throughout the week when they needed it.

Effective collaboration between subject teams meant that schemes of work were very well-planned so as to leave plenty of time for examination preparation. Teaching teams shared resources effectively and produced learning materials for the virtual learning environment. Core resources for students focused on meeting A grade criteria and there was good emphasis on standardisation of marking and assessments.

All in all the science teachers had worked well together to set high expectations of the students who responded very positively to the busy and positive ethos.

Strategies for quality improvement

92. Good, well-organised management was a significant factor in sustaining improvements and developing new and appropriate curricula in the colleges visited. Triggers to improvement varied markedly from college to college according to the context of each provider: curriculum developments responsive to local needs; developing consistent tracking and monitoring practices in teams; rigorous analysis of management information; and setting sharp targets based on evaluative self-assessment brought about the most improvements.

93. There was general agreement across our sample that the following factors led to the most effective improvement of outcomes for students and the quality of provision: developing agreed and effective approaches to assessment; feedback; student support; enrichment; and monitoring of progress.

94. Colleges that provided rigorous initial assessments for science students, especially for literacy and numeracy skills, were able to ensure more effective enrolment on the right courses. In addition, providing a broad and relevant vocational curriculum ensured more choice and appropriate pathways for all students. This was often successfully backed up by standardising assignment briefs and strengthened internal verification procedures. Where staff acted as external examiners and trained other members of staff in assessment, standards were raised successfully.

95. Improvements in high-achieving departments were often driven by wider outcomes such as progression and students' responses to consultations. The successful development of vocational science provision was often in response to changed recruitment patterns and the decline of demand for A-level courses.

96. Effective follow-up and support after lesson observation were key factors in improving outcomes for students, as illustrated by the college below.

The lesson observation system in a north midlands general further education college was used very well in science to improve the quality of teaching and learning. Each teacher had three observations in any year: a formal graded observation and a developmental observation, both carried out by the college observation team; and a peer observation carried out by a fellow science teacher. The formal observation was part of the college-wide quality assurance and appraisal system. The developmental observation was intended to help teachers focus on aspects of their practice that they wished to develop or improve and the peer observation was part of sharing and discussing practice with colleagues.

Following observations, teachers drew up specific action plans that focused on one area for improvement at a time. This proved highly effective and the impact of these actions was shared and discussed at college staff development sessions focusing on teaching and learning.

97. In the colleges visited, close attention was paid to the analysis of success rates and value-added data. Subject teams had ready access to management information and regularly analysed and discussed students' attendance, retention and assessment scores. These data were carefully analysed along with Advanced Level Information System and Advanced Level Performance System data and underperforming groups and individual students were identified and supported.

98. National success rate data indicate that, broadly speaking, larger science departments tend to have better success rates than smaller departments. The data for 2009/10 showed that in sixth form college science departments with more than 800 science examination entries per year, success rates tended to be at or above national averages. Science departments with cohort sizes smaller than 800 had much greater variance in success rates and many had success rates below national averages.

99. The situation is less clear-cut in general further education colleges where larger science departments clearly had science success rates at or above national averages, but smaller departments were much more likely to have greater variation in success rates from year to year. There was evidence to show that larger science departments had greater potential for innovation and for sustaining improvements. This was also related to the previous observations that successful teamworking led to better outcomes for students. High-achieving departments innovated more and looked actively for new and improved ways of working. Successful departments spotted problems early and were adept at finding speedy and effective solutions to them.

100. Looking at the above factors that contribute to the success of larger departments, it would seem that the isolation of single-subject teachers; a lack of colleagues with whom to discuss innovations and curriculum development; and being completely responsible for all operational and management activities are contributory factors to the slow speed of improvement in some small science departments. In order to bring about improvements, managers in colleges may have to be prepared to support small science departments much more than larger departments.

101. Managers and teachers in a large sixth form college in the east of England have successfully developed a highly performing science provision.

Economies of scale were important factors in the maintenance of the successful science provision. Subject teams were large and well organised so that the development of teaching resources was effective. They noticed quickly when groups were making slow progress in aspects of syllabuses and responded creatively. The teachers shared assessments and moderation of students' grades and the bureaucratic burden of examinations was also shared. This gave time to others to produce new teaching resources and to try out different assessment strategies. Teams met regularly. Morale was high and the teachers benefited by sharing marking, planning teaching and assessments, developing resources for the virtual learning environment and running enrichment and support activities.

Recruiting and developing science teachers

102. Good science teaching is always based around a strong team of science teachers. College managers reported that they found it difficult to attract large and strong fields when they were recruiting science teachers, especially for physics. They felt that often older and more experienced science teachers were increasingly less willing to move to a new college if it involved significant relocation expenses.

103. Very often in the colleges visited, students were involved quite closely in the selection procedures. The most common approach was for the applicant to teach a short lesson on a required topic to a group of students. This approach meant that college managers could also make their own assessment of the applicants' ability to prepare a lesson, work with students and to explain the topic clearly and well. Students were often asked to score the applicants and to comment on each of them. The colleges handled these approaches well and ensured that students knew that their views were valued by managers.

104. A college in the north summarised its approach to finding and selecting good science teachers as follows:

- Plan early to identify the subject skills needed in sciences and advertise early.
- Actively encourage applications from newly qualified teachers via links with local PGCE providers.
- The interview process should consist of:

A morning session, during which each candidate presents a 20-minute lesson to a group of students, an assistant principal and the head of science. This is followed by a short subject interview with the course or subject leader and another college manager. The morning is completed by a tour of the college led by one of the science technicians and a chance to meet the staff informally.

Shortlisting takes place at lunchtime and students' views are taken into account. The most important activity in the morning is the lesson observation. A candidate must be judged to have taught at least a good lesson to go through to the next stage in the afternoon.

The afternoon interview is with an assistant principal and the head of science. No final decision is made on the day. The team meets and makes its final decision the following day to allow 24 hours to reflect on the candidates. If no highly suitable candidate is identified, no appointment is made and the post is re-advertised.

College managers report that in the past it took four sets of interviews before they found a suitable physics teacher and sometimes no candidate proceeded from the morning sessions. Over the last four years the college has appointed, developed and retained seven biology teachers, four chemists and three physicists. Hence 14 of the current team of 20 science teachers were relatively new to the college.

Resources

105. The quality of accommodation for science lessons varied quite markedly. Many of the laboratories visited provided an attractive and stimulating environment. Displays of posters and students' work enlivened the environment. In a minority of colleges in the survey, the laboratories provided a functional but relatively sparse learning environment.

106. Specialist resources such as glassware and equipment to make measurements were in good supply and students had ample opportunities to use standard scientific equipment. Electronic equipment and data logging units were used more frequently in physics and electronics lessons and internet connected laptop computers were increasingly being used by students across the sciences.

107. Libraries were well stocked with printed materials for the sciences, but too often they still had old and out-of-date books on their shelves alongside newer editions. It is important that these are discarded as students may find themselves using out-of-date terminology or being reliant on inaccurate explanations of scientific concepts.

108. In the colleges visited, good teamwork was facilitated by closely grouped laboratories and staff work spaces. Where staff could gather to work together resources were more easily shared and innovation was better promoted.

Staff development

109. A good deal of the staff development for science teachers in the colleges visited took the form of attendance at awarding body assessment and examination training. These sessions were popular with managers and science teachers as they focused sharply on how students could get better grades and what assessments were most successful for the students. Science teachers then shared their knowledge with other team members and the students. There was widespread use of awarding body mark schemes for examination questions in lessons and students were fully aware of what was required of them to get full marks. In that respect this was a highly effective form of professional development that directly benefited the students.

110. When specific problems were to be solved or new curriculum developments implemented, college managers used local and regional partnerships to negotiate visits by staff to colleges that had successfully addressed the problem or introduced the particular curriculum. Informal college partnerships existed in many forms and successful activities ranged from mini-inspections to shared in-service training.

111. However, where subject teams met regularly, and where the focus was on practice and not just on operational matters such as timetables and deadlines for assessments, agreed approaches to teaching and new ways of sequencing topics did have real impact. In a minority of the colleges visited there was too little emphasis on discussing practice and new ways of teaching topics that students most frequently found difficult.

112. In one college, managers timetabled weekly or even twice-weekly training sessions for teachers at the start of the working day. In this way teachers had time set aside to discuss common approaches to teaching topics, sharing resources and developing practice.

113. It can be a challenge for managers to ensure that part-time science teachers are fully included in decision-making, training and curriculum development. This was solved in the most successful colleges by paying part-time teachers to attend in-service training events and by making sure that team meetings were held at times when part-time staff were likely to attend.

114. Learning and Skills Improvement Service (LSIS) STEM programmes and the nine science learning centres across the country are well-developed points of contact for resources and professional development activities for post-16 science teachers. Together with the learning coach programme and the regional subject networks, the learning centres provide a wide range of updating and training for science teachers. Activities such as small-scale action research in subject departments, bursaries to engage in specific projects related to learning in the sciences, and meetings to share ideas and resources are well-coordinated across England. Some projects are on a larger scale and the development of a STEM centre in the new Peterborough Football Club stadium is an example. STEM managers acknowledge that the work is developing and that the impact of their activities has not yet been thoroughly evaluated.

115. Inspectors found some awareness of the STEM programmes in the survey visits. Thirteen of the 15 colleges visited in the survey were aware of the STEM programmes and seven had taken part in STEM training or activities. Actively participating colleges tended to be those reasonably close to the nine regional science learning centres so that travel was not a barrier.

116. Staff attending STEM activities reported on the high quality of the training and acknowledged that the networks and training had been instrumental in bringing about real improvements in teaching and learning in their colleges. The following example illustrates this.

Following contact and development activities with LSIS STEM and the local science learning centre, a general further education college south of London established a cross-college STEM steering group in order to raise the esteem of science-related subjects. This group, which included STEM managers in the college and senior managers, completed an audit of STEM-related activities and projects that took place in the college. A calendar of activities was drawn up for the academic year and these included training events for teachers, lectures by visiting speakers, STEM competitions for students and ways of celebrating the national science and engineering weeks. They secured funding for STEM-related enrichment activities and were establishing partnership links with relevant external organisations such as universities and the Centre for Alternative Technology in Wales.

Notes

National data on the range of science provision in post-16 colleges were analysed in preparation for the survey. Government data on employment shortages and published work on STEM careers also informed the survey. A review of inspection outcomes for 2008/09 and 2009/10 identified post-16 colleges with good or outstanding science provision and those with sufficient numbers of enrolments in the sciences to make visits worthwhile.

From February 2011 to May 2011, HMI visited 15 colleges: 10 general further education colleges and five sixth form colleges. All of the sixth form colleges and seven of the general further education colleges had been judged at inspection to have outstanding or good science provision. The other three colleges were visited either because their provision was in areas of deprivation or because they had a very wide range of science courses.

During visits, inspectors explored students' achievements in science, the quality of teaching and learning, the range of provision in science and how students' needs and interests were met. In addition, the views of students, teachers and managers were sought at meetings and the quality of management of the sciences was investigated. Inspectors observed teaching and learning in 78 lessons and practical work and scrutinised documentation relating to the science provision.

Inspectors also sought the views of officials in the Department of Business, Innovation and Skills (BIS), LSIS STEM managers and those providing continuing professional development for science teachers through the nine science learning centres in England. Ofsted would like to thank BIS officials and the LSIS STEM staff who supplied data on STEM participation and information on professional development for teachers in post-16 settings.

Further information

Publications by Ofsted

Her Majesty's Chief Inspector's Annual Report 2009/10, Ofsted, 2010; www.ofsted.gov.uk/resources/annual-report-of-her-majestys-chief-inspector-of-education-childrens-services-and-skills-200910.

Identifying good practice: a survey of post-16 science in colleges and schools (070027), Ofsted, 2008; www.ofsted.gov.uk/resources/070027.

Successful science: an evaluation of science education in England 2007–2010 (100034), Ofsted 2011; www.ofsted.gov.uk/resources/100034.

Other publications

Skills for jobs: today and tomorrow, UKCES, 2010; www.ukces.org.uk/publications/nssa-vol-2.

J Holman and P Finegold, *Report to the Gatsby Charitable Foundation*; www.nationalstemcentre.org.uk/res/documents/page/STEM%20CAREERS%20REVIEW%20NOV%202010.pdf.

Websites

Ofsted Good Practice website: www.goodpractice.ofsted.gov.uk.

Annex: colleges visited

Our thanks are due to the colleges listed below for agreeing to participate in the survey.

Provider	Local authority
Bradford College	West Yorkshire
Brockenhurst College	Hampshire
Cardinal Newman College	Lancashire
Cirencester College	Gloucestershire
City and Islington College	Islington
The Sixth Form College Colchester	Essex
East Norfolk College	Norfolk
Hereford Sixth Form College	Herefordshire
Runshaw College	Lancashire
Salford City College	Salford
South Cheshire College	Cheshire East
South Essex College of Further and Higher Education	Essex
Tresham College of Further and Higher Education	Northamptonshire
Uxbridge College	Hillingdon
Wilberforce College	Kingston-upon-Hull