OFFICE FOR STANDARDS IN EDUCATION

Inspecting post-16

science

with guidance on self-evaluation

THE OFFICE OF HER MAJESTY'S CHIEF INSPECTOR OF SCHOOLS IN ENGLAND

HMI 319

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Reference number: HMI 319

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Contents

Introduction

This booklet aims to help inspectors and staff in schools and colleges to evaluate standards and quality in science for students post-16. It complements the *Handbook for Inspecting Secondary Schools* (1999), the supplement *Inspecting School Sixth Forms* (2001) and the *Handbook for Inspecting Colleges* (2001). It replaces the earlier guidance *Inspecting Subjects and Aspects 11–18* (1999).

This guidance concentrates on issues specific to science. General guidance is in the *Handbooks*. Use both to get a complete picture of the inspection or evaluation process.

This booklet is concerned with evaluating standards and achievement, teaching and learning, and other factors that affect what is achieved. It outlines how to use students' work and question them, the subject-specific points to look for in lessons, and how to draw evaluations together to form a coherent view of the subject.

Examples are provided of evidence and evaluations from college and school sixth-form inspections, with commentaries to give further explanation. These examples are included without any reference to context, and will not necessarily illustrate all of the features that inspectors will need to consider. The booklets in the series show different ways of recording and reporting evidence and findings; they do not prescribe or endorse any particular method or approach.

Inspectors and senior staff in schools and colleges may need to evaluate several subjects and refer to more than one booklet. You can download any of the subject guidance booklets from OFSTED's website www.ofsted.gov.uk.

Our Inspection Helpline team, on 020 7421 6680 for schools and 020 7421 6703 for colleges, will be pleased to respond to your questions. Alternatively, you can email schoolinspection@ofsted.gov.uk or collegeinspection@ofsted.gov.uk.

OFSTED's remit for this sector is the inspection of education for students aged 16–19, other than work-based education. In schools, this is the sixth-form provision. In colleges, the 16–19 age-group will not be so clearly identifiable; classes are likely to include older students and, in some cases, they will have a majority of older students. In practice, inspectors and college staff will evaluate the standards and quality in these classes regardless of the age of the students.

The courses on which this booklet focuses are General Certificate of Education (GCE) Advanced Subsidiary (AS) and Advanced levels (A levels) in biology, chemistry and physics and general vocational courses in science. In colleges, you are likely to encounter in addition a wide range of vocational science courses.

This booklet concentrates on the most commonly found courses in or related to science for students 16–19. However, the principles illustrated in this guidance can be applied more widely.

For students, GCE AS/A-level and Advanced Vocational Certificate of Education (AVCE) courses assume previous knowledge of the double science General Certificate of Secondary Education (GCSE) programme of study to grade CC. Some subject specifications are explicit about the previous knowledge of each module. A2 modules generally build on AS modules and, in some specifications, the required previous knowledge is explicitly stated. General National Vocational Qualification (GNVQ) Intermediate and Foundation specifications usually set out necessary previous attainment. Typically, this is a science qualification at Foundation or Entry level respectively, together with requirements for literacy, numeracy and work experience. Specifications for Advanced Extension Awards (AEAs) in biology, chemistry and physics are in preparation; they are targeted at the top ten per cent of candidates but relate largely to the content set out in advanced GCE subject criteria, which are common to all specifications.

Common requirements

All inspectors share the responsibility for determining whether a school or college is effective for all its students, whatever their educational needs or personal circumstances. As part of this responsibility, ensure that you have a good understanding of the key characteristics of the institution and its students. Evaluate the achievement of different groups of students and judge how effectively their needs and aspirations are met and any initiatives or courses aimed specifically at these groups of students. Take account of recruitment patterns, retention rates and attendance patterns for programmes and courses for different groups of students. Consider the individual goals and targets set for students within different groups and the progress they make towards achieving them.

You should be aware of the responsibilities and duties of schools and colleges regarding equal opportunities, in particular those defined in the Sex Discrimination Act 1957, the Race Relations Act 1976 and the Race Relations (Amendment) Act 2000, and the Special Educational Needs and Disability Act 2001. These Acts and related codes of practice underpin national policies on inclusion, on raising achievement and on the important role schools and colleges have in fostering better personal, community and race relations, and in addressing and preventing racism.[1]

As well as being thoroughly familiar with subject-specific requirements, be alert to the unique contribution that each subject makes to the wider educational development of students. Assess how well the curriculum and teaching in science enable all students to develop key skills, and how successfully the subject contributes to the students' personal, social, health and citizenship education, and to their spiritual, moral, social and cultural development. Judge how effectively the subject helps prepare students aged 16–19 for adult life in a culturally and ethnically diverse society.

1 See Annex *Issues for Inspection arising from the Stephen Lawrence Inquiry (Macpherson Report)* in *Evaluating Educational Inclusion*, OFSTED, 2000, p13.

1 Standards and achievement

1.1 Evaluating standards and achievement

From the previous inspection report, find out what you can about standards and achievement at that time. This will give you a point of comparison with the latest position, but do not forget that there is a trail of performance data, year by year. Analyse and interpret the performance data available for students who have recently completed the course(s). Draw on the school's *Pre-Inspection Context and School Indicator* (PICSI) report or, in the case of a college, the *College Performance Report*. Also analyse the most recent results provided by the school or college and any value-added information available. When numbers are small, exercise caution in making comparisons with national data or, for example, evaluating trends. For further guidance on interpreting performance data and analysing value added, refer to *Inspecting School Sixth Forms,* the *Handbook for Inspecting Colleges* and the *National Summary Data Report for Secondary Schools.*

Where you can, form a view about the standards achieved by different groups of students. For example, there may be data which enable you to compare how male and female students or different ethnic groups are doing, or how well 16–19-year-old students achieve in relation to older students.

Make full use of other information which has a bearing on standards and achievement, including success in completing courses, targets and their achievement, and other measures of success.

You should interpret, in particular:

- trends in results;
- comparisons with other subjects and courses;
- distributions of grades, particularly the occurrence of high grades;
- value-added information;
- the relative performance of male and female students;
- the performance of minorities and different ethnic groups;
- trends in the popularity of courses;
- drop-out or retention rates;
- students' destinations, where data are available.

On the basis of the performance data and other pre-inspection evidence, form hypotheses about the standards achieved, whether they are as high as they should be, and possible explanations. Follow up your hypotheses through observation and analysis of students' work and talking with them. Direct inspection evidence tells you about the standards at which the current students are working, and whether they are being sufficiently stretched. If the current standards are at odds with what the performance data suggest, you must find out why and explain the differences carefully.

As you observe students in lessons, look at their work and discuss it with them, concentrate on the extent to which students:

- recall, select and use their knowledge of science facts, concepts and techniques in a variety of contexts; for example, appreciating the dependence of chemical equilibrium on ambient temperature and, for AEA students, extending concepts about equilibrium constants to partition coefficients and solvent extraction of uranium salts in nuclear fuel production;
- use technology competently, appropriately and innovatively; for example, in freeze-framing camcorder tapes of falling objects to find gravitational acceleration and the linear dependence of air resistance on velocity (by spreadsheet);
- present a logical explanation of phenomena, drawing on fundamental principles; for example, using Fick's Law to explain the countercurrent system of gaseous exchange in fish;
- recognise the limitations of theories and methods; for example, being aware of the assumptions in the kinetic theory of gases and in the Lincoln index method of population sampling;

- evaluate critically experimental data and other information; for example, examining inconsistent sequential radioactive 'half lives' where background radiation has not been discounted and, for extension students, overcoming the identified difficulty by taking gradients of the activity curve;
- find pathways through a problem; for example, multistage synthetic routes between aromatic compounds;
- go beyond the course to explore scientific articles which interest them.

1.2 Analysis of students' work

Work in science subjects is often characterised by copious notes. Are these simply copied out or compiled by the student after discussion and guidance? When looking at students' work, disentangle the routine notes, which will give an indication of the level of work and nature of teaching, from work which shows students' insights into the subject. Pick out features which characterise whether students are working at an average standard for the course, beyond it, or at a lower level.

This applies also to examples of work for internally assessed modules. Your assessment should not be over-influenced by the presentation of such coursework projects. Effective use of information and communication technology (ICT) to present projects needs recognition as demonstrating key skills, but your main duty is to assess how well the students know and understand the science.

Remember that the analysis of work is important for judging the nature of the demands made on the students and their progress over time. Hence, it can give valuable insights into achievement. Where there is evidence of strong previous attainment, the content, pace and challenge of subsequent work should acknowledge this. In the first year of an A-level course, re-teaching of GCSE work is inappropriate for students who gained high GCSE grades in science. An example in chemistry might be extensive lists of electronic structure, which is a topic covered in GCSE double science. When module results for AS/A2 show that all students have attained at above grade C, work on further modules should not begin at a trivial level. Likewise, where grades in earlier modules are low, new work should not be pitched so high that students are unlikely to cope with it.

From the first to the second year of the course, there should be evidence of opportunities which have been effective in promoting the development of students' skills in sustaining arguments, speculating and researching. For example, understanding of Le Chatelier's principle in the first year might lead in the second year to well-argued speculation about ozone holes in the upper atmosphere and ozone-linked photochemical smog. If students are operating at no more sophisticated a level in the second year than is indicated by their first year work, they are unlikely to be making progress. With the most able, teaching and stretching of students might go beyond the specification to ensure that achievement is satisfactory.

Students' practical assignments should be available for you to review. Again, look beyond description and routine handling of results. Look for evidence of sharp hypotheses, of sensible use of results, of clearly drawn conclusions, and evaluation which goes well beyond the superficial but demonstrates insights into why and how experimental work has been conducted.

Remember, too, that students' results in practical assignments are usually much more generous to the student than other work. Typically, students may achieve a high proportion of the available marks in their practical assessments when their other work may indicate a much lower level of proficiency in the subject overall. Make sure you see a balance of work.

Analyse vocational science assignment portfolios and talk with students about the content of these. Unit 1 of AVCE is subject to internal assessment only. It relates to local science industry, so you are likely to find great diversity of content from one institution to another.

Example 1: evidence from the analysis of students' work; AVCE science in an FE college; first year (February); 6 students present; previous attainment in GCSE: 1 A, 2 Bs, 2 Cs, 1 D.

Unit 1: 'Investigating science at work'.

- *All students have done case studies on a detergent manufacturer and a sewage works. They have had a tour of each work place, supported by videos, practical work and the use of the Internet.*
- *Academic science (rather than vocational aspects) is of an average standard. However, notes on some aspects of the specification are thin or trivial (eg, economics, health and safety legislation, risk assessment, social effects on local community, personnel in the industry).*
- *Work from two higher attainers shows good grasp of hydrophilic/hydrophobic polarisation of surfactant anions and hence 'electrostatic' dirt removal in washing. Most students can account for formation of micelles. The highest attainers can explain orally a demonstration experiment of migration of soot in detergent solution with HT potential difference applied. The best of the six pieces of work includes convincing explanations of foam persistence in terms of 'electrostatic' resistance to bubble film stretching and draining in the presence of surfactant anions. Most explain foam killing by hydrophobic agents with clear understanding of angle of contact effects (practical work powdered PTFE and glass). All have effective investigational work on digestion of gelatine from blackened photographic film using 'biological' washing power. They can talk about temperature/rate of reaction/duration of reaction. All appreciate harmful effects of lipases on workers.*
- *Good microbiology practice evident in water testing (autoclave, dilution and inoculation routines). Eutrophication generally well understood; only the more capable, in discussion, mention effect of nitrates on haemoglobin function and association with stomach cancer. Weaker assignments do not distinguish between oxidation in aerobic conditions and reduction in anaerobic digestion of sludge. Even best do not realise that ammonia is a product.*
- *Achievement is broadly satisfactory on academic aspects in relation to previous attainment. However, there is underachievement on vocational aspects, and the sewage topic is weaker than that on detergents. All considered, achievement appears to be unsatisfactory.*

[Attainment below average (5)]

Commentary

There is a need for caution in judging attainment and achievement on the basis of a small sample; more evidence is required to confirm judgements. Standards of work on the science of detergents vary widely, but all students are probably achieving well on this. While there is some good science in the sewage works project, there are some fundamental errors in understanding – suggesting underachievement, possibly because teaching has not been thorough enough. Coverage has concentrated on academic science and has skimped other areas of the specification. The six samples of work show much lower standards on the sewage topic than on the detergents topic. Hence, students are unlikely to have the overall grades of which they might be capable.

1.3 Talking with students

Structured discussions help to assess the level at which students are working and thinking. Often, opportunities will also be found within practical lessons for talking with the students about their understanding of their work, beginning with questions about their current experiment and moving on to more general topics. With vocational courses, inspectors should take the opportunity to talk with students about the way work experience is integrated with the course and what understanding they have gained from it. Setting small problems gives the opportunity to explore understanding of concepts and students' ability to use them in different contexts. Examples from chemistry might be as follows.

- *How could you find the molar mass of butane, using a refillable cigarette lighter?*
- *Bottles of 'alcohol free' and normal wine have lost their labels; how might you find out which is which?*
- *How could four unnamed white solids - barium carbonate, potassium nitrate, sodium chlorate (v) and sodium chloride – be distinguished, if all you had available was water and a source of heat?*
- *How could you safely find the enthalpy of vaporization of ethanol experimentally? Why would the result differ from the databook value?*

Example 2: evidence from discussion with three Year 13 physics students in a school sixth-form.

The most recent module has included gravitation and kinetic theory. Students are asked to speculate why the earth's atmosphere is losing hydrogen and helium and different planets have different atmospheric composition. Discussion ranges around gravity, buoyancy, centripetal force, kinetic theory and velocity of escape.

Below average student can stay with a line of argument in general terms. He makes links to popular notions, but these are often insufficiently refined to be productive (nature abhors a vacuum; hot air rises). He recognises kinetic theory ideas. He knows that the force of gravity depends on the mass of a planet, but he does not follow through to radius and density. Typical of D/E A-level candidate, with a suggestion that some misconceptions (how does a vacuum suck - where is the force?) have not been corrected by teaching, or the student has been unable to grasp what has been taught. GCSE grade B in science and mathematics: achievement barely satisfactory.

Average student can relate relevant ideas to the context (Archimedes, Boltzmann's constant and orbit of comets) but does not necessarily follow through on these. She is able to refine ideas (mass rather than size with gravity, relationship of velocity to mass for fixed kinetic energy). She is able to generalise (main factors affecting atmosphere retention and possible implications). Typical of C/B candidate with some good appreciation of key physics concepts and methods. Somewhat dismissive of fundamental physics questions (for example, those associated with the Maxwell-Boltzmann distribution). GCSE grade A in science and B in mathematics: achievement is at least satisfactory.

Above average student can manipulate mathematical models quickly and with precision (for example, dependence of average molecular velocity on square root of absolute temperature) and can identify crucial but easily overlooked factors (spin of the earth diluting gravity). He is aware of fundamental macro/micro model difficulties (Boltzmann's factor: temperature and molecular energy distribution). He identifies incisively concepts which advance understanding (velocity of escape and the parameters that determine it). Typical of strong A candidate with comprehensive good teaching. GCSE grade A in science and A in mathematics: achievement is at least good.*

Evidence is limited, so achievement judgements are tentative.

[Attainment average overall (4)]

1.4 Lesson observation

In a lesson, you can assess evidence of students' understanding and, particularly, their practical and investigative skills. There are further illustrations of practical work in the next section. Indications of achievement in different kinds of work are also considered.

Example 3: evidence from a lesson in a sixth-form college; 6 students are studying Foundation GNVQ science and 8 Intermediate.

Foundation level, optional unit: 'Maintaining and repairing things'; Intermediate level, optional unit: 'Generating electricity'.

Foundation	*Intermediate*
Students have wired three-pin plugs and are now evaluating one another's work and making notes. They identify faults such as: all three wires same length within plug, inner insulation of live cut in trimming of outer sheath, strands of wire wound anti-clockwise round screw and pushed out on tightening. All examples show correct connection of the three wires and cable grips clamp outer sheath firmly. Students are able to show	*Working in pairs on task with possible outcomes at pass, merit and distinction. 'Home-made' transformers (coupled C-cores) to simulate step-up/down of voltage in national grid, 12v power unit, lamps as load, ammeter/voltammeter readings for power on each side and hence efficiency. All are competent on the given (pass) task. Three pairs are varying coupling of C-cores and turns on each coil, while maintaining ratio, to explore*

from previous work competent soldering of coaxial cable to a jack plug (they can explain safe practice in soldering). Three students can explain treatment of rust with phosphoric acid gel and zinc paint. Two are unaware of toxicity! One has carried out and written up a test of the effectiveness of different commercial brands. (Some confusion by caption 'eats rust alive'.) *All meeting pass requirements, half reaching merit with one working towards distinction. Work in lesson shows peer group learning to improve existing skills: good achievement. NB SAFETY.*	*losses. Two of these are trying other cores, using material to hand (stool leg). Notes of experimental results are of a good standard and they have summarised material from textbooks and pamphlets issued by utilities. Sensible question from one pair asking how resistance of meters affects measurements. One pair has connected 12v supply to the 240v prongs of a student's own (dismounted – no rectifier) mobile phone charger and is about to try the other way round. INSPECTOR INTERVENES.* *All meeting pass requirements. Three-quarters are becoming secure at merit and two of these are confidently working towards distinction. Most students are showing an independent approach and are able to build on what they have learnt in this session and in the past. Most are achieving well. NB SAFETY*
[Foundation attainment above average (3)]	***[Intermediate attainment well above average (2)]***

Commentary

Foundation students are working on a specifically pass grade task (three-pin plug). By the end of the session, all are secure with this, and the learning style has promoted good achievement from the start to end of the session. Most know more and have been able to help others. Rust treatment is a merit task. Those who have done it show competence and can recall the processes. One has carried out a competent investigation to distinction level (misconceptions about rust and phosphoric acid being living organisms do not detract significantly). On balance, attainment is above average for a Foundation group; the students are stretched effectively by the tasks they are given. Intermediate students are generally showing good understanding and purposeful initiative in the task, with which they are apparently given a free hand. They understand what kind of activity is needed to reach merit or distinction levels. They are making good progress.

However, safety is a concern in the work seen here. Students (who have limited literacy) have not understood the label on the phosphoric acid jar 'lethal if consumed'. Those showing initiative with the mobile phone charger unit have not appreciated the possibility of 480v across bare prongs (6v charger). [NB The unit may burn out immediately or have a limited current output.] Inspectors should keep concerns about health and safety in perspective. Possible danger should not be overplayed. However, potentially lethal activities had not been anticipated by the students. The inspector needed to stop the students proceeding. The teacher and management should be informed immediately.

NB Lack of attention to safety means that quality of ‘teaching’ in this lesson cannot be satisfactory.

Example 4: evidence from an AS biology lesson in a school sixth-form (beginning of summer term); one of two parallel groups: this group of 12 has the higher previous attainment: all students with at least grade A in science GCSE.

Mammalian heart.

A group of four students gives a team presentation on the cardiac cycle, describing atrial and ventricular diastole and systole. They explain the cycle elegantly from graphs of pressure against time for left and right side (including artery and atrium pressure), together with cycle of ventricular volume and electrical activity. Another group of four gives a presentation of myogenic stimulation of heart rate: sino-atrial node as pacemaker, AVN, bundle of His and Purkyne tissue, refractory periods and tetanus; all presented in a masterful way with diagrams and graphs of contraction and muscle excitability. A third group presents rigorously on nervous and hormonal control of heart rate, covering medulla, vagus nerves, adrenaline, thyroxine and Starling's Law. Each group contains both male and female students. In the *following plenary, students can speculate convincingly about the function of an artificial pacemaker and stroke volume/heart rate considerations during exercise for trained and untrained people. They can make informed suggestions about the function of the three-chambered heart and two branchial hearts of the cuttlefish. One student has made notes from independent research on the fine structure of the myocardium and electrical syncytium. Another has researched the role of sodium, potassium and calcium in cardiac electrophysiology. However, books show that three weeks have been spent on this topic, with early work repeating that done for GCSE on the structure of the heart and human circulation system. This suggests that achievement is only satisfactory.*

[Attainment well above average (2)]

Commentary

These students show deep knowledge and understanding which is consistent with AEA requirements, though current work offers only marginal opportunity for critical analysis of information and problem-solving. Some have pursued their understanding beyond the requirements of the specification.

Achievement appears to be only satisfactory for this group, whose previous attainment is at least grade A in GCSE. Though attainment is high on this topic, time has not been used efficiently in reaching this standard. (There are implications regarding the time remaining to cover subsequent topics and the consequence this may have on eventual outcomes.)

Example 5: evidence from Year 13 (beginning of autumn term): chemistry lesson in a school sixth-form; previous attainment in the group ranges from GCSE grade C to A*, typically grade B.

Rates of reaction, deduction of the order of a reaction.

Students have done basic work on the effects of concentration, temperature etc, largely repeating Year 11 work. They are all secure with this. Most can explain some methods of tracking a reaction (including titration) and have a grasp of the notion of half-life (in non-mathematical terms). They are very confused about the order of a reaction, particularly the logarithmic manipulation. About a quarter can perform calculations to find orders and rate constants, but they do not really understand what they are doing. Many think the stoichiometric equation should give an indication of order. The reaction of propanone with iodine in acid solution is the subject of today's lesson and students are very puzzled about the zero order and uniform rate. A five-minute digression to the integrated rate equation, apparently for the benefit of AEA candidates, leaves them bemused and the rest of the class dumbfounded. The highest attainers have grasped the concept to a standard compatible with their previous attainment. Those with GCSE grades C or B have attained very little on rates of reaction (though they have sound knowledge of some related easier work): they are achieving little on the work in the lesson. The evidence suggests that achievement is unsatisfactory overall.

[Attainment below average (5)]

Commentary

The majority have grasped elementary ideas. Few are coping with the difficult concept of reaction order and they cannot visualise the significance of order in terms of reaction kinetics and 'how the particles interact'. This is not uncommon; attainment is below average rather than well below. Attainment on this topic compares unfavourably with students' GCSE attainment. Also, there is a suggestion that misconceptions (association of order with the stoichiometric equation) are not sorted out. Meanwhile, teaching is occasionally over the heads of all students in a misplaced attempt to stretch the more able. Achievement is unsatisfactory on this evidence.

2 Teaching and learning

2.1 Evaluating teaching and learning

Inform your views of teaching and learning by reference to the characteristics of effective science lessons, where:

- interest and scientific curiosity are stimulated as teachers demonstrate their own enthusiasm for science – for example, through their own research on cycles in mollusc populations in a local estuary *(subject knowledge, methodology);*
- students' scientific understanding is extended and deepened by questions such as "What if …?" and "Why is …?" which go beyond simple one-word answers, and build on and develop ideas to challenge students to think scientifically – for example, probing on competition for metal cations by different ligands *(subject knowledge, methodology, expectations, assessment);*
- students, where appropriate, are able to learn through models and analogies while being aware of their limitations as well as their advantages – for example, deflection of ball bearing alpha particles by a plaster of Paris 'hill' to simulate Geiger and Marsden's experiments *(subject knowledge, methodology);*
- students learn by the most efficient way, such as through the effective use of demonstration rather than necessarily through class practical work, with a careful balance of methods – for example, students' own research on sex-linked genetic conditions in humans amplified by teacher exposition *(subject knowledge, methodology);*
- in practical investigations, students build on their knowledge and conceptual understanding as well as developing skills of planning, carrying out, drawing conclusions and evaluating, through well-managed and well-supported opportunities – for example, colourimetric and conductimetric analysis of rates of reaction *(subject knowledge, management, methodology, expectations);*
- interest is captured because the teacher shows the relevance of the science being taught – by relating it to everyday applications or to environmental and social contexts – while at the same time sharpening the students' skills of application – for example, damping resonance in washing machines *(subject knowledge, methodology);*
- students extend their knowledge and understanding by use of appropriate terminology and well-reasoned explanations for the results of their experiments and in accounting for phenomena – for example, correct use of terms such as 'allele' and 'gene', and specialist use of words such as 'dominant' and 'expressed' *(expectations);*
- students have the opportunity to apply their scientific knowledge to solving unfamiliar problems and at the same time developing their understanding – for example, the relationship between oxidation states and Curie temperature of titano magnetite in rock samples showing reverse magnetism *(expectations, methodology);*

Be alert to teaching which may have superficially positive features but which lacks the rigour, depth, insights and the command of good subject teaching. Examples might be teaching which:

- includes practical activity but which does not significantly advance students' knowledge and understanding of science – for example, trivial experiments or where students are told what will happen beforehand;
- deals with the large knowledge base by requiring students of limited competence to copy excessive notes, without checking that they have understood;
- provides trivial time-consuming and inefficient tasks which do not help students to make progress in their understanding of science – for example, surfing the Internet for information on factors affecting photosynthesis or spending excessive time making models of chromosomes from pipecleaners;

- pitches work or explanations at the wrong level for the students' present understanding – for example, unnecessary use of calculus in deriving velocity of escape or extensive conformational analysis in early organic chemistry;

- uses questioning to pursue ideas, but the questions are superficial or demand only one-word answers, and discussion never 'gets under the skin' of the scientific concepts being taught;

- involves use of worksheets which, however well-presented, limit students' responses and constrain the scope and depth of science ideas and awareness of applications;

- uses elaborate equipment or resources but fails to make clear the scientific purpose of the activity.

You should judge teaching by its effectiveness in promoting learning in a time-efficient way.

2.2 Lesson observation

The most effective teaching in science subjects at A level is usually marked by the teacher's mastery of the subject and, in the case of vocational courses, knowledge of relevant applications in industry and elsewhere, for example:

- careful and clear explanations, and an ability to draw on exemplification;
- recognising how and why generalisations break down, and being able to cite and explain exceptions;
- giving answers to questions which reflect not just secure knowledge of the subject but an awareness of the misconceptions which can arise and how they can be dealt with effectively.

Example 6: evidence from second year (autumn term) A-level chemistry lesson in an FE college.

Enthalpy, entropy, and Gibbs' free energy.

Teaching is authoritative and takes students from their existing knowledge of enthalpy through to a good level of understanding of entropy and free energy. Most students demonstrate, in their questions and answers, a grasp of these concepts better than is usually seen for an introductory lesson.

Very good teaching is evident in the timely and skilful use of simple demonstrations and clear explanations. The teacher builds up ideas well and knows just the right time to introduce new concepts when the limitations of earlier ones become apparent. The demonstrations, such as the spontaneous endothermic reaction, are helpful in encouraging the students to challenge earlier generalisations. They see the limitations of predicting, simply on the consideration of enthalpy and entropy, how reactions will proceed.

Students are engaged by the teaching and many quickly recognise the challenge to concepts posed by the demonstrations. A significant minority, some from minority ethnic groups, ask sharp questions (for example, whether temperatures at which reactions become spontaneous can be determined from known entropy changes). They are clearly seeking to secure their understanding. The teacher carefully but confidently answers the questions – for example, with use of an Ellingham diagram to aid explanation. A minor weakness is a gap in explanation in moving from entropy to free energy; here students are for a time left a little uncertain, as is evident in less interaction between the students and the teacher.

[Teaching and learning very good (2)]

Commentary

Here the teacher's mastery of the subject is apparent; she understands the concepts and knows how to explain them well. In discussion afterwards, her reading around her subject is evident from her awareness of the ways in which different authors have sought to approach these difficult concepts. Learning is very good: students are working at full stretch. Whether this teaching should be judged to be very good or excellent hinges on the link between entropy and free energy. To a point, the link between entropy and free energy becomes apparent only when particular reactions are considered, so a hiatus is inevitable. But is there a more significant problem here? The test is this: if you cannot identify anything which the teacher might have done to improve the lesson, teaching should be considered excellent.

Example 7: evidence from Year 13 (summer term) A-level chemistry lesson in a school sixth-form; 5 students.

Revision on environmental chemistry.

Very little direct teaching in this session, but the teacher is on hand to help when students need him. A good rapport between students and the teacher is evident, and he has arranged for sufficient past papers to be available for revision.

Students are willing to 'have a go' at questions, and keen to build up their confidence in dealing with them, but they try to rely on memory of their notes rather than drawing on wider understanding. For example, they do not go back to first principles of equilibrium to explain ozone concentration.

Students are willing to ask questions, but the teacher needs to refer to the book. In effect, learning is advanced by the students. Teacher has too little exemplification and knowledge of the subject at his fingertips to inspire great confidence or help students gain insights into the topic. The pace of work also is too slow; not enough pushing.

Rationale for choosing particular modules should be explored. Teacher says this module was chosen because it was felt that it would be 'interesting', but there seems to be insufficient expertise in the department. There are several indications that achievement on this module is unsatisfactory.

Two of the four students seem destined for low grades (D/E) on this module, although their other work is reported as better. Two are heading more solidly for D.

[Teaching poor (6); learning unsatisfactory (5)]

Commentary

Here the teacher's knowledge is insufficient to deepen student's understanding. This lesson also illustrates the lack of pace that can sometimes be a feature of lessons with very small groups. From this slowness of pace and the teacher's lack of preparedness for the examples being used in this revision lesson, the indications are that time is not being well used. Teaching is poor but, because of students' self-motivation, learning is graded slightly better. The decision to teach this module, even though there is insufficient expertise in the department, reflects on weak management.

Example 8: evidence from AS-level (summer term) chemistry lesson in a school sixth-form.

Learning about the reactions of ethanol through a series of test tube experiments. Module: 'Introduction to organic chemistry'.

The sequence of experiments is well planned to give students experience of the main reactions of ethanol. Materials are all to hand and well organised, so that students are not hindered. The instructions and the purpose of the work are clear. Teacher has a good eye for safety matters. She moves around the group, talking with students about their work. Discussion with some about the (original) breathalyser test and possible ways of faking negative results.

This is an orderly practical, but too closely controlled by the teacher, with little opportunity for students to interpret their observations. Clues to observations and what to make of them are too strong – eg, part of combustion reaction equation written for students in worksheet; interpretation of change in colour of acidified dichromate given. Too little opportunity to draw on previous experience or link practical work with introductory work on alcohols in a previous lesson.

Students work productively, and talk to one another about what they are seeing and what is happening. A few ask the teacher questions which seek explanations of mechanism. Teacher answers the questions knowledgeably, but interaction to help these students would push them on.

Overall, this lesson adequately consolidates theory work, and most students acquire the kind of knowledge expected for this stage in the AS course – but the potential to push them further is not exploited. In particular, this disadvantages those who tend to be more passive.

[Teaching and learning satisfactory (4)]

Commentary

Here the teacher's knowledge is secure, but insufficient is done to encourage thinking and research to push students to higher levels. Students are told too much. Be alert to situations where practical work is merely confirmatory of what students have already learned, and they gain little from it. The above lesson is more than this because it extends what has been done earlier and it serves to consolidate some basic factual knowledge.

The points illustrated above through examples of effective and ineffective A-level teaching in chemistry apply equally to other science subjects. Examples for biology, physics and AVCE science are set out below.

Example 9: evidence from AS-level (March) biology lesson in an FE college; students' previous attainment is GCSE C to A* in science.

Ecology module: use of examination board's specimen data handling question on acid rain, to build on existing ideas.

Students have been given homework tasks and these have been very well marked with annotations suggesting further points or correcting interpretations:

- *(i) summarising gaseous sources of acid rain, with equations where possible; how ozone and ammonia feature;*
- *(ii) interpreting text and graph of sediment depth/acidity for lake (ie date/pH record);*
- *(iii) analysing pair of three-dimensional block graphs for survival of brown trout fry against aluminium concentration and acidity for different calcium levels.*

Teacher asks students whom she knows to have made points well to explain, eg, how sulphur dioxide is formed and how in turn it becomes sulphuric acid (ammonium sulphate). They take pride in explaining points in straightforward terms and are well acknowledged by their peers. Talking through the concepts in this way consolidates understanding for both presenters and listeners.

Teacher clinches important points and gives adroit explanation of ozone as oxidising agent/dissociation promoted by sunlight and catalysis, as this was apparently not well tackled in homework. Quick questions – eg, on source and consequence of nitrogen oxides – confirm general understanding. Differentiated questions well targeted to students of different abilities.

Teacher quickly confirms general interpretations of sediment graph. She makes additional points about non-linearity of sediment depth with time, calling for students' explanations of this (they show good understanding). Nature of ^{210}Pb radioactive dating explained succinctly with sketch graph. Activity/quantity of isotope remaining neatly explained; again, quick probing questions – eg, on reliability for different depths – indicates very good understanding. Alkalibiontic/acidbiontic diatoms dealt with by reference to additional graphs in textbook; again quick questions of students of different levels of attainment to ascertain understanding, possible reasons for, and reliability of diatom concentration.

Appropriate discussion of speculative interpretations about better survival of trout in higher, rather than lower, acidity if calcium levels are high. With weaker students, teacher checks understanding of nature of toxicity of aluminium to fish.

From their responses to questions, it is clear that all students have made progress since the homework and show at least good learning in the lesson; about two-thirds show excellent improvement in knowledge and understanding, including those from minority ethnic groups. Their attainment on this topic is better than average for first year A-level students (eg, ozone, phytoplankton census and lead dating for lakes, inter-relation of calcium/aluminium and pH). Students are well motivated by the immediate impression of definite learning specific to the syllabus; they are very attentive and try their best. A few students are operating at a very high level (eg, suggesting exponential relationship between depth and date of sediment, as apposite in relation to decay of organic matter, with inert residual material). All can grasp simple ideas, such as extraneous introduction of diatoms by feeder streams as a complicating factor. Teaching shows excellent subject expertise, well tailored to students' needs, choice of very suitable methods and very effective use of time.

[Teaching and learning excellent (1)]

Commentary

Although this may seem a mundane lesson, it is very effective because of skilful use of assessment before and during the lesson in order to gauge students' needs and ascertain that they are being met. Hence, learning is highly effective and the simple but well-crafted teaching which promotes it is also excellent.

Example 10: evidence from Year 13 (September) A-level biology lesson in a school sixth-form; previous attainment range: Year 12 grades E to B.

Preparatory work on internally assessed module in which use of statistical techniques is a requirement. Practically based tasks with detailed guidance notes. Twenty-min observation after ½ hr and again after 1½ hr of 2-hr session. NB syllabus emphasis is on use of statistical tests, not on understanding of the mathematics. Students paired so that weaker students have a stronger partner. Focus of observation on two pairs.

Pair A	*Pair B*
Daisies within quadrat on front and side lawn of school. Use of Mann-Whitney U-test. Clear instructions – eg, "more than five counts and at least 25 daisies in each of the two samples". Students have quickly read instructions and have soon grasped enough to get under way with data gathering. However, seem to be 'looking for daisies' rather than random sampling, mainly because there are not many daisies in a 50 cm x 50 cm area. Working is correct, showing effective learning at this stage. In later stages, some confusion about use of U table and why null hypothesis is rejected if U is less than that tabulated for 5 per cent significance – showing that, although they can 'do' the test, understanding of why it works is not secure. Have difficulty grasping idea that the test is a comparison of medians. Unclear when to use it (apart from 5 and 25 rubric) – eg, choice chamber experiments. In the main, suitably monitored by teacher, who gives guidance when they are stuck. Suitable drill in application of routine but little depth of understanding gained.	*Maize cobs, smooth/wrinkled, coloured/ colourless. Proformas for dihybrid cross. Teacher outlines the Chi-square test. Access to computer to set up spreadsheet. Student counts and records systematically (double check). Spreadsheet is set up competently for x^2. One student who lacks competence in ICT is picking up the gist of the procedure from the more capable partner. Dihybrid cross is correct and checked by teacher. Correct longhand manipulation of percentages and actual numbers to bring O and E to like base shows that students are learning how to do the Chi-square calculation. Have learnt to handle, but not really to understand, the degrees of freedom and probability tables. They gather that they can use it for other genetics experiments (and dice throwing) but do not become aware that it can be used for rejection of general null hypotheses of 'no difference'. Teacher does not take opportunity to talk through application of this test, though the pair is monitored sufficiently to ensure satisfactory completion of the task.*

The teacher has provided reasonable tasks to illustrate use of these statistical tests and monitors work to ensure that it is completed satisfactorily. Some non-random sampling of daisies that should have been anticipated by the teacher. Students have limited capabilities in generalising what they have learnt but they have gained an effective grasp of the way the tests are carried out in practice: the syllabus requirement has been fulfilled. Students are diligent but not very enterprising.

[Teaching and learning satisfactory (4)]

Commentary

This session gives students sound drill in using the procedure of statistical tests specified in the syllabus. The context for the Mann-Whitney test is not particularly well selected and leads to some weak practice in sampling: a minor problem that the teacher should have expected and dealt with. The mixed-ability pairing allows students to get through the work, possibly led by the stronger partner, and the weaker student makes some headway on use of a spreadsheet for Chi-square. The students successfully develop the ability to apply the tests. They only partially understand why the tests 'work' and their general application to other contexts (they do not realise that Chi-square is a test of independence), but the syllabus does not expect understanding of the mathematics of the tests, only the ability to follow the procedures. Students' work has been monitored but not always as closely as it might have been (daisy sampling). Overall, strengths outweigh the weaknesses, and teaching and learning gains are satisfactory.

In long practical sessions, you must decide how to sample by limited observation. It is generally better to look closely at the work of a few contrasting groups, rather than superficially at everything.

Example 11: evidence from AS-level (beginning of summer term) biology lesson in a sixth-form college.

Transpiration leading to planning an internally assessed investigation.

Learning is only just effective because students of modest previous attainment (some grade Ds in GCSE and none above B) have not assimilated theories (over-complex copied notes) and they have insufficient guidance in their work with potometers.

Learning is limited by confusion about cohesion–tension theory, root pressure ideas and apoplast/symplast/vacuolar pathways. Also have difficulty with the two alternative theories of stomata closure. Students have not learnt effectively from earlier indigestible notes.

Teacher's demonstration of porous atometer in an air stream is courageous but adds little to students' understanding of transpiration or practical skills with potometer. It complicates things and does not help students to learn how to make the potometer work.

Little teacher intervention as students try out potometer experiments for the first time. Two pairs of black female students, working at the back of the lab, receive no support from the teacher at all. Students are not made aware of the difference between rate of transpiration and rate of water take-up. Hence, insufficient time is allowed for conditions to stabilise when environmental conditions are changed, and this limits students' progress. Students are familiar with xerophytic features, but they have difficulty inserting 'lambs-ears' into potometer, as stems have a hard square section core; hence air lock (no suggestions from teacher about achieving a seal [Vaseline and string?]). For comparison in fanned air, provision of hydrangea is reasonable, but no probing by teacher about possible effects of very high air flow (stomata closure). The teacher's plans for use of nasturtium in guttation investigation are unrealistic at this time of year. Teacher suggests weighing 'lambs-ears' leaves for surface area (not the most reliable method, because of uneven thickness). Teacher's explanation of relative humidity is flawed, giving no indication of its relationship with temperature.

Despite these weaknesses in the teaching, students collaborate well in pairs. They show initiative in use of graduated syringe for volume of capillary tube but do not research variation of light intensity with distance (assume it to be inversely proportional). Some ambitious, but unrefined, plans for data logging of diurnal variation of light intensity and water take-up (have seen data logging of evaporation from top pan balance in chemistry). Through their perseverance, students have some acquisition of practical skills and extend their knowledge and experience a little. Attainment is around grade D but probably above this by the end of the topic, so achievement appears satisfactory at this stage in relation to previous attainment.

[Teaching poor (6); learning unsatisfactory (5)]

Commentary

Teaching is insufficient and ineffective. Students have apparently been presented with theories in an indigestible form. Some teaching inputs show that the teacher's grasp of issues and concepts is insecure. To some extent, ineffective aspects of learning are because the teacher has not taught the topic properly before appearing to move on to test it: students are using potometers for the first time. Students do have some reasonable ideas about ways in which plants limit transpiration and environmental factors affecting it. They could build on knowledge and experience (characteristics of 'lambs-ears' and nasturtiums, use of graduated syringe and data logging) to make some headway. Learning is unsatisfactory, but thanks to the students' reasonable perseverance it is not as poor as might have resulted from such teaching.

In the following example, the text in square brackets indicates evaluation of evidence in relation to *Handbook* criteria.

Example 12: evidence from Year 13 (December) A-level physics lesson in a school sixth-form; 10 students with uniform spread of ability.

Hall Effect and revision of electromagnetism, towards end of module.

Teacher	*Students' responses and teacher's follow through*
Checks notes on Hall Effect have been copied as homework. Hall Effect formula (outline diagram on board). [verifies basic understanding efficiently, with good student involvement]	*Lower attaining (LA) five. One called to board. Gives formula and defines terms by annotating diagram. [consolidates learning] Higher attaining (HA) five. [attentive]*
Why only semi-conductors, not metals? [probes understanding of a crucial but challenging concept]	*HA response: because 'n' (charge carrier density) is in denominator and is higher in metals (small effect, not no effect). [superficial learning.]*
So what? Why not a bigger voltage with more carriers? [challenges, showing very high expectations]	*LA student suggests effect swamped by bigger current (teacher asks 'Why, if current is in numerator?') [teacher corrects misconception] HA student asks if it is drift velocity and goes back to Bqv formula. [applies thought, using fundamental concept] Asks about Hall current and effect on voltage. (Teacher tells to think about power sources in general.) [slight put-down, but avoids side-tracking and gives sufficient prompt]*
What about accuracy of field measurement? Apparatus set up. [well-conceived verification of understanding in context]	*LA Errors in dimensions, position, ammeter, galvanometer. [understands obvious points] HA Suggest perpendicularity of field and Hall probe. [more considered understanding developing]*
How about field comparison? Quick demonstration. [suitable methods and use of time] HA realise errors in dimensions and ammeter drop-out. [understanding consolidated and extended]	*HA ask about non-uniform field – to what position does reading refer? (Teacher says 'Bdv, variable field over distance, calculus laddie, do it on the bus and show me tomorrow.') [over time, students not put-off by brusque response; arguably teacher's expectations are appropriately high]*
Has primed students to talk about: right hand rule as corollary of left hand rule (there must be induction if there is a motor effect). [potentially worthwhile but not handled well]*	*LA Idea of moving collection of charge carriers comes through as common to both. Unconvincing explanation. [over-challenged and left a little exposed by teacher] HA some sniggering; unhelpful hand gestures. [attitudes not checked by teacher]*

Oscillating spiral paths of charged particles between earth's poles in Van Allen radiation belts. [cultivates high achievement through high expectations]* ** Not syllabus content but suitable applications of fundamental understanding.*	*LA [seem braced to be bored but attend well as explanation proves clear and interesting]* *HA Again Bqv, argues tightness of spiral with increasing B towards poles (bicycle on tight corner, big central force). Reversal as bouncing dipole, with convincing demonstration of bar magnet dropped on another down glass tube; velocity components and relation to Lenz's law. [rises to challenge in a creative way, showing outcomes of sustained learning]*

The teacher's expectations are very high – effective in promoting very good achievement, particularly for higher attainers.

[Teaching and learning very good (2)]

Commentary

This is a well-planned lesson, by a teacher with excellent subject knowledge. There is good use of time (for example, copied notes on Hall Effect in preparation) and style (student presentations). Differentiation is appropriate. Overall, learning and therefore teaching are very good. Achievement is better for the higher attainers, who are working at full stretch. While the teacher's expectations are very high, there is a pervasive culture of not suffering fools, resulting in a degree of arrogance. This does not deter the higher attainers from chancing novel ideas. Students are willing to put good effort into learning.

Example 13: evidence from second year (March) A-level physics lesson in an FE college.

Sixth module: experimental work, to be tested by practical examination on planning, implementing, analysing and evaluating. It links to topics in the two other modules. With this A-level specification, practical skills are not assessed by teacher assessment. So the purpose of the session is to teach the skills. Observation for 20 min about half-an-hour after start of a 2-hr session and similar observation about an hour later.

Higher-attaining pair, one male, one female, grades A/B in Y12	*Lower-attaining pair, both male, grades D/E in Y12*
First observation *Evaporation causes cooling. Aware of H=ML and H=MCq and Henning's method for L. Want to use data logging for change of mass and temperature over time. Two laptops and sensors available. Considering natural (Newton's Law) cooling and simultaneous M and T logging. Aware of problem of T sensor wires with vessel on top pan balance for M log; similar difficulty with any coupled pump. Conjecture temperature dependence of L from molecular model considerations.* *Initial impressions. They are making effective headway, indicating that the teacher has provided appropriate challenge and stimulus in the task.* *Later observation* *Forced evaporation using filter pump and Dewar vessel. Mass by top pan weighing before and after (the pair of students dispensed with data logging, quite rightly, as too problematic if apparatus is not self-contained). Attempt to take same water down from 90°C to air temperature; use temperature data logging. Only get to 50°C in time*	*First observation* *Efficiency of a motor. Aware of formulae for electrical and mechanical power. Know that efficiency is the latter divided by the former. Have toy electric motor with rubber-band gears, also variable voltage power supply and ammeter. Realise that when motor is 'free-wheeling' efficiency is zero; similarly if load is too heavy to move. Unclear what to vary in investigation. Teacher reviews this knowledge with them and says, 'See what you can find out'.* *Initial impressions. The teacher seems to have provided a suitable opportunity; is monitoring progress. Reasonably enough, the teacher expects them to then get on without too much spoon-feeding.* *Later observation* *Students have a few values for load/height/time/ current/voltage, from which they have calculated some 'spot' efficiencies. However, they have burnt out the motor by increasing the voltage with heavy loads.*

available. No clear evidence of increase in L as there are insufficient results for rigorous analysis and evaluation. Teacher asks probing questions to encourage evaluation of procedures used. Despite the limited results, these students have made good learning gains through problem solving in a context that is new to them.	
Overall impressions *Good challenging task, suitable previous knowledge, suitable apparatus provided at outset and during session. Not much evidence of teacher's guidance – eg, to ensure effective use of time during the investigation. Good learning opportunity. Good initiative by students.*	*Overall impressions* *Task is potentially appropriate in challenge and apparatus is suitable. In the event, it seems there has been insufficient guidance initially and during the investigation to safeguard apparatus and ensure purposeful investigation. Left to their own devices and learn little. Were they bored and 'messing about'? They make satisfactory learning gains (in relation to weak previous attainment) through problem solving in the earlier part of the session, but learning is limited by the motor burning out.*

Not enough intervention by the teacher in the later stages to determine how much headway students are making and to steer them to the most profitable use of the opportunity.

[Teaching and learning satisfactory (4)]

Commentary

The investigations are suitably matched to the capabilities of the students and they are appropriately resourced. However, there is not enough teaching in the later stages of the lesson. Having had satisfactory learning in the earlier part of the lesson, the lower attainers are later floundering; they have broken the apparatus and have no opportunity for significant analysis and evaluation. On the other hand, for the higher attaining-students, the limited amount of intervention by the teacher is mostly well-judged and effective. The teaching has a number of strengths and weaknesses; it is more effective with the higher attaining students. On balance, the strengths just outweigh the weaknesses and both teaching and learning are satisfactory.

This session may have involved more than half-a-dozen pairs of students working on different tasks for a whole afternoon. You must decide on a sensible sampling strategy that yields robust evaluation for the ability-range, while making economical use of time. If the pre-inspection stage has identified issues about any particular group(s) of students, you should take this into account when deciding which students to observe. Observation time here was 40 minutes, dovetailed with lesson observation elsewhere. As with sampling in the analysis of students' written work, judgements from monitoring the work of only a part of the class need to be interpreted with caution. In circumstances where students are all doing much the same practical work, it may be possible in the observation time to interact with a larger proportion of the class. However, in evaluating how they are coping, your observations need to be in sufficient depth for judgements to be reliable.

Example 14: evidence from second year (February) A-level physics lesson in an FE college; mixed-ability group, about half not doing A-level mathematics.

Comparison of capacitor discharge and radioactive decay. Data logging of leakage current from a capacitor and charge measurement by ballistic galvanometer. Calculations from graphs.

Before demonstration, charge/discharge circuit is clearly explained by effective use of OHP diagrams. Competently chosen circuit characteristics give decay with 'half-time' of about five minutes; but students have nothing to do while waiting for the computer to do the recording (so advantage of data logging over meter and stopwatch readings is largely lost). Discharge appropriately stopped after a little more than 'half-time' and remaining charge Q_1 measured by ballistic galvanometer. Repeat charging for Q_0. All this carried out adroitly. Relationship between area under *discharge curve and these Q values is not well explained; through experimental error, area equivalent to Q_1 rather than $Q_0 - Q_1$.*

Tasks set:

- *'half-time' from graph printouts [most can interpolate for half-current time]*
- *time constant by linking 'half-time' to ln2 [most have no idea where the natural logarithm of 2 has come from, but they are able to follow the routine efficiently]*
- *'RC' from graph and galvo reading [many totally lost with simple I=Q/RC relationship in this context, because of: confusion about rate of change of current and rate of change of charge; insufficient explanation by teacher; and students' lack of security on mathematics; however, the teacher gives some helpful assistance to individuals who are struggling]*
- *use of a radioactive decay curve to calculate l [only the more capable, who are also doing mathematics A level, appreciate the exponential decay equation and its differential coefficient with time; only a few who are working quickly get on to this task]*

Throughout this lesson, the higher attainers are attentive, while others are bored and confused, but biddable and trying to follow. The teacher monitors progress during the tasks and jots formulae in books or on the board, but no real explanations are offered. Students' attainment in GCSE science and mathematics ranges from C to A. E to A grades in AS. About half (generally those with higher previous attainment) are doing A-level mathematics. Only those who have a general grasp of exponential functions, logarithms, differentiation and integration make good learning gains. Others copy from more talented neighbours or blindly put numbers into formulae. The demonstration illustrates helpfully for the higher-attaining students but adds to the confusion for the lower attainers (ie, makes things worse).*

[Teaching unsatisfactory (5); learning poor (6)]

Commentary

This topic is likely to distinguish the work of the A and B candidate from that of lower attainers, who are unlikely to cope with some aspects of it. It calls for a high level of previous competence and ability in mathematics. The demonstration was performed competently *(but see reservations below about its effectiveness)* and the tasks set were suitably sequenced and a fair interpretation of syllabus demands. The use of ICT for data logging added nothing to the demonstration; its justification would be to save time in comparison with logging data manually and/or to increase accuracy, but time was not saved, nor were results overall consistent. While initial explanation of the circuit was good, explanation of charge measurements was unconvincing, because of experimental error. If the objective of the demonstration was to serve as a visual aid to promote understanding, calibrations and systematic errors should have been checked beforehand.

Most students either did not have the appropriate mathematical skills or were insecure in them. A better-thought-out differentiation strategy for the tasks was required. For the middle-attaining students, more headway might have been made by devoting the whole lesson to sharply focused drill in key formulae, key manipulations and key problem types. Teaching was unsatisfactory. While the higher attainers learnt well, overall learning was poor on this difficult topic. Attainment by the class was a little weaker than average for the second year of the A-level course.

Such material must be taught to the higher-attaining students if they are to attain higher grades. If students are in ability sets for physics A level, topics of this kind might be taught thoroughly to the upper set and some aspects skimmed over with the lower set. The dilemma is how to deal with such a demanding quantitative topic in a mixed-ability group. This teacher did not use an appropriate approach, but there needs to be reasonable recognition of this difficulty in evaluating such sessions. Some students here needed more coaching.

Example 15: evidence from second year (February) AVCE science lesson; 9 students in an FE college.

Context

- *Students are comparing rates at which enzymes (from different sources) affect the rate at which whey is produced (class practical in small groups). Unit 5: 'Synthesising organic and biochemical compounds'.*

***Evidence**: (S = strengths, W = weaknesses)*

Teaching and learning:

- *S Very well-planned lesson – assignment covers specification requirements.*
- *S Good provision of background information (Internet well used to obtain up-to-date information from an operational company);*
  - *key skill coverage well signposted within the assignment;*
  - *assignment makes clear what is expected but does not provide too much information (hence, there are opportunities for students to meet planning criteria).*
- *S Teacher has engaged the students' interest well through use of very good subject knowledge to help and prompt – all are working productively throughout. For example, students are prompted to research commercial rennins such as Maxiren and Reninlase. Students take initiative in exploring methods of measuring viscosity and the effect of pH on the reaction rate.*
- *S Evidence in marking that teacher has provided good help in showing them how to improve (particularly planning and evaluation) – also good oral feedback.*
- *S Challenging exercise for this group (entry level was mostly GCSE grade C) and evidence from the students and previous results that course has successfully motivated.*
- *W Minor omissions in students' current work are due to early move to assignment before learning of specification requirements is fully consolidated (eg, comparability of enzyme concentration and commercial relevance of different reaction rates).*
- *Teacher explains that at this stage in the course, with another unit yet to come, there was pressure to get assignments under way.*

[Teaching and learning very good (2)]

Commentary

Over time, learning and teaching have been very good and students show impressive value added from GCSE (pointing to very good achievement). In the lesson, a very well-planned and supported investigation on rennins falls just short of excellent learning and teaching. This is because a few details of the specification have not been securely established.

Example 16: evidence from an independent study session; 3 Year 13 students in a school science resources centre preparing for the AEA in physics.

Task 1: to generate a temperature/time graph for a themistor to demonstrate 'thermal runaway', thus bringing together understanding of resistance, thermal capacity, the cooling law and exponential functions. Students are provided with prompts to various texts on these matters and a data book. They make quite good progress, learning to make links between different elements of knowledge. Students readily combine $v^2t \div R$ with a general exponential expression for the resistance of a thermistor as a function of T and, from $H=MC(T_1-T_2)$, obtain (T_1-T_2) as a function of T and t. They select reasonable values for the parameters. They have difficulty tackling the expression they have obtained, trying calculus methods that do not work (because the variables cannot be separated satisfactorily) and overlook the iterative approach of substituting values progressively to produce a graph. They have not attempted to feed in cooling law considerations. These students will need prompting from the teacher to move the work on; they have got stuck because the task is too open-ended.

Task 2: to present a digest of a journal article (accessed on the Internet) on the gravitational change in photon energy, and hence frequency, as light leaves a star, and the detectability of the effect. Students are able to draw on their knowledge of gravity, mass energy equivalence and wave/particle duality to amplify the article. They discuss *purposefully and make appropriate reference to texts which they select. They can substantiate the $2.1x10^{-6}$ fractional shift from the sun.*

In all this work, students show initiative, are methodical in their work and engage in well-focused dialogue. These are challenging tasks which are compatible with the aims of the AEA. In the main, they are suitable for the capabilities of the students, who are left scratching their heads with the first challenge. The activities promote independent thought and interpretation of concepts and methods from different parts of physics. This is good structuring of students' collaborative independent study time.

[Teaching and learning good (3)]

Commentary

In independent study sessions where work has been set by a teacher, the progress of learning, including collaborative activity between students, should be evaluated. Hence, the appropriateness of the teacher's expectations and guidance can be inferred. These students know more at the end of the session: they have learnt effectively. Moreover, they are aware of specific skills which they still need to learn. The learning and hence the teaching have been of good quality.

2.3 Other evidence on teaching and learning

Lesson observation is usually the most important source of evidence on the quality of teaching and learning, but the analysis of work and discussions with students can also yield valuable information. This is particularly important when the work includes a coursework component undertaken over time. Under these circumstances, the observation of individual lessons may give a very partial picture of the students' learning experience and of the support provided by teachers.

The work analysis will give you a good feel for the overall rate of progress, and, therefore, the pace of the teaching and learning. It will show the range and depth of the work which the students are required to do.

Discussions with students will give you a sense of their motivation and the range of their experiences. You can ask questions to show whether they understand clearly how well they are doing and what they must do to improve.

3 Other factors affecting quality

Other factors need to be considered and reported on only in so far as they have a bearing on what students achieve. Note and evaluate any significant features of staffing, accommodation, resources and, especially, the extent to which management of the subject is directed towards monitoring, evaluating and improving performance.

Management and curriculum

We are concerned here about good management of the curriculum and the extent to which the best options have been pursued. Pertinent points might include:

- the effectiveness of integration of practical investigation and presentation of theory;
- whether free choice for students between optional elements gives equality of opportunity in terms of available apparatus and teaching expertise;
- the efficiency of any combined teaching (such as the physiology element of AS biology and advanced health and social care);
- the quality of provision for retaking modules or dealing with incomplete vocational units (particularly, the practical work implications).

Staffing

Sensible deployment of available staff is a significant issue. It may be difficult to maintain continuity or provide expert teaching where courses are taught by several teachers or additional support is brought in (for example from art to support teaching of the drawing skill in biology).

Resources and accommodation

The efficient use of resources and accommodation is important. Lack of apparatus or facilities such as fume cupboards might limit opportunities to meet specification requirements

4 Writing the report

The following are two examples of post-16 subject sections from inspection reports, the first from an FE college and the second from a school sixth-form. (They do not necessarily reflect the judgements in any or all of the examples given elsewhere in this booklet.) The summative judgements in these reports use, for schools, the seven-point scale: *excellent; very good; good; satisfactory; unsatisfactory; poor; very poor.* For colleges there is the five-point scale: *outstanding; good; satisfactory; unsatisfactory; very weak*. The summative judgements *excellent/very good* used in school reports correspond to *outstanding* in colleges; *poor/very poor* used in schools correspond to *very weak* in colleges.

Science

Overall, the quality of provision is **unsatisfactory.**

Strengths

- Students work well in practical lessons and make good progress with their practical skills.
- The accommodation and resources are good and support learning effectively in practical lessons.

Areas for improvement

- The retention rate is poor on most GCE A-level courses and the proportion of students who achieve higher-grade passes is well below national averages.
- Students do not achieve as well as they should, as indicated by their previous qualifications.
- Teaching overall is unsatisfactory; the teaching of theory lacks stimulation and interest and is ineffective.
- For a significant number of students, provision for tutorial support is inadequate.
- There is a lack of effective leadership and co-ordination of science provision throughout the college.

Scope of provision

There is a wide range of GCSE and GCE A-level science courses on offer. They are available during the day and in the evening. There are also opportunities for students to acquire GCE A-level qualifications in one year, if they are sufficiently motivated and able. Full-time vocational science courses failed to recruit sufficient students to run this year, but have done so in previous years. Part-time vocational courses in science and pharmaceutical science have been maintained and are successful, although minority ethnic groups are under-represented on them.

Standards and achievement

Standards overall are below average. The proportion of students who complete GCE A-level courses is well below the national average for further education colleges. It has declined over the last three years. GCSE and part-time vocational science courses have good retention rates.

For students who reached the end of science courses last summer, the pass rate was above average, and there were several courses with 100 per cent pass rates. This is particularly noteworthy in the part-time vocational courses, where the retention rate is also high. However, in each of the last three years, the number of higher-grade passes by GCE A-level science students, especially female students, has been well below national averages, and students have not achieved as well as predicted from their entry qualifications. Results on the GCSE courses are below average.

The quality of students' work, as seen in lessons, matches this pattern of recent results. Students show a reasonable understanding of the basic facts and concepts, such as atomic structure and periodicity in A-level chemistry, but there is insufficient depth to their understanding of the theory. Adult students have significantly higher levels of skill and understanding than 16–19-year-olds. Science practical work, such as electric circuit experiments in GCSE science and organic chemistry experiments at A level, is generally well carried out and, in some classes, better than expected for the level and stage of the course. Many science students lack pride in their written work, and much of it is untidy and poorly presented, but there are exceptions. Some GCE A-level biology project work, from female students, is word processed and very well organised, with great care taken over the structure and content.

Quality of education

Overall, teaching is unsatisfactory. While individual lecturers plan their programmes effectively to provide a suitable introduction to the subject and to cover the syllabus, and while practical lessons provide effective development of practical skills, the teaching of theory is, by contrast, narrow in approach and lacks stimulus and excitement. There is little variety of method, so that in many cases the learning approach is not well suited to the needs of the students. In several lessons, students were expected to do no more than take notes. The effective use of class time is not well planned in most theory lessons; for example, there were many lessons where students worked through past examination papers, which could more efficiently have been completed in their own time. There has been insufficient analysis of the specific revision needs of students, and no analysis of the learning needs of different groups of students.

Students' learning is generally unsatisfactory. They take a keen interest in practical lessons and develop their practical skills well, but this does not compensate for the inadequate development of their understanding in theory lessons. Some students have poorly organised notes, little understanding of what they mean and insufficient assessed work to support effective preparation for the examination. Although most lecturers set sufficient homework, not all students hand it in.

Marking varies considerably in quality. The best has very clear assessment schemes and the work is carefully annotated with corrections and identification of omissions. Students are well aware of how to improve this work. However, much of the work is accepted – although it is below standard – with little correction on the scripts. There were also examples of work marked in a hurry, with correct answers marked wrong and vice versa. Not all lecturers have appropriate records of students' assessed work to enable effective monitoring of their progress.

Tutorial support is ineffective for a significant number of students. Where students are taught by their personal tutor, they receive interviews to review their progress. However, when that is not the case, students sometimes do not receive such an interview at all. Students' action plans are vague and do not include sharp targets which can be monitored.

Lecturers are academically well-qualified and have a good knowledge of the subject. Science laboratories are spacious, with good furniture fit for purpose. Equipment levels are very good and support learning effectively, contributing to the better quality of work in practical lessons. However, in no laboratory was there any students' work on display to celebrate success and give an incentive to others.

Leadership and management

Science provision throughout the college lacks leadership and co-ordination. Lecturers in the various areas in which science is taught do not meet together regularly or systematically to review courses or the way they are taught. Some staff are isolated, even where they teach the same course, and do not have the opportunity to meet to develop common approaches. There is no overall policy for setting or marking assessed work. Assessment is not used effectively in planning teaching programmes, and there is no effective assessment of the quality of teaching. Action plans lack deadlines, do not identify responsibility for actions, and are not written in a way which allows their implementation to be monitored regularly. More effective monitoring is needed to identify the weaknesses in the provision, particularly the reasons for female students underachieving, and more effective strategies to ensure that there is significant improvement.

Science

The focus was on chemistry and biology, but physics was also sampled. In physics, examination results were above average last summer and students did as expected considering their GCSE results. Two lessons were observed. Both were at least good. In one, excellent teaching included particularly good explanation, regular review and a well-structured sequence of activities. This led to students gaining a very secure understanding of the properties of materials.

Chemistry

Overall, the quality of provision in chemistry is **good.**

Strengths

- Results showed a marked improvement this summer, and were above average.
- Students have a sound grasp of concepts, apply them well in classwork and in answering routine questions, and overall are achieving well.
- Teaching is good; lessons are well structured with a range of activities which help students to build up their knowledge and understanding effectively.
- In small groups, students share ideas freely and work well together.
- The subject is well led and a good range of new learning resources is being built up.

Areas for improvement

- Marking is not as thorough as it could be and some basic errors are being missed.
- The less capable students tend to be passive in class discussions; although well supported in other ways, they are not brought into discussion enough.
- The targets for students that stem from the monitoring of their performance are not sharply enough focused on learning goals.

The GCE A-level examination results this summer showed a significant improvement after some weaker years, and were above average. All students who took the examination gained a pass grade and the proportion gaining the highest grades, A and B, was a little above average. Male and female students did equally well. Very few students did not complete the course. In relation to their GCSE results , they did a little better than expected. A few students with modest GCSE results did very well.

The standards of work of current students are also above average. In Year 13, students are achieving well in relation to predictions based on their GCSE results. In the lessons seen they were doing well as a result of effective teaching which demanded much of them. The lesson structure and activities clearly focused their learning. In one lesson, students drew well on their knowledge and information in books to predict successfully the products of an organic chemistry reaction and explain how and why it occurred. In another, students showed good understanding of transition metal chemistry to explain reactions. Most students recall knowledge well and apply it, but their written work does not always show the same confidence as their work in class.

Students in Year 12 are only a little way into their course, but are achieving much as expected. They show good knowledge and understanding of introductory organic chemistry and basic concepts such as atomic structure and bonding. Students are successfully moving on from their GCSE work into new areas. Most are tackling calculations, for example, to find formulae or concentrations of solutions, with increasing confidence. However, for a few, calculations present difficulties. There is scope, particularly among the male students, for more systematic and rigorous setting out of calculations and naming of organic compounds.

Teaching is good overall, and students learn well as a result. The principal features of teaching are clear objectives, sharp planning, brisk pace, and a range of methods and approaches to bring about learning. Teachers show good subject knowledge in their questioning and explanations and in the tasks they set. The lesson on transition metal chemistry in Year 13, for example, included a demonstration to focus on reactions that needed explanation, opportunities for students to work individually and together to check their learning and formulate new ideas, short experiments to test predictions, and effective explanation and drawing together of ideas by the teacher. Students responded confidently to the changes of activity. Of the five lessons seen, two were not as dynamic, and, although sound overall, did not result in such secure learning.

Much of the written work demanded of students takes the form of structured questions which follow up lessons. Day-to-day marking has improved through the year, but some sets of questions remain unchecked by the teacher or students. In some cases, simple errors, for example in nomenclature, are uncorrected. This is an area for improvement in the context of teaching that has many strong features.

Students learn well. They are attentive, work productively and respond well to the supportive teaching and different learning styles that they experience. They rose to the challenge of predicting possible products and developing explanations for an organic chemistry reaction in Year 13. In lessons, time is used well. Students support and help each other effectively and, in groups, talk and listen to each other maturely as part of their learning. They are not always as confident in offering ideas in more open discussion, and the less capable are not always brought into question and answer dialogues as much as they could be.

The independent work students undertake in the sixth-form learning centre is very well prepared, and tasks complement the content of lessons well. Students are confident in using books and ICT. They approach this work maturely, and most are able to extract information and make their own notes on, for example, the evolution of models of the atom. Some are less confident in seeing the focus of tasks where explanations are needed.

The good teaching and learning result from work in the subject being well led and managed. There is a commitment to building on what has already been achieved and to improving standards. A new scheme of work effectively reflects the subject requirements and sets the stage for good teaching. It identifies a range of approaches to encourage effective learning. A good range of helpful learning support materials is being developed. Target setting, based on careful analysis of students' performance in tests, is becoming well established, although targets are not yet sharply enough focused on specific learning goals.