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Science in Primary Initial Teacher Training

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Office for Standards in Education
33 Kingsway
London
WC2B 6SE

Tel: 020 7421 6800

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Introduction

1. During the academic year 2000/01, OFSTED carried out an inspection survey of the initial teacher training of primary school teachers teaching science. Recent inspections of primary initial teacher training (ITT) have focused on training to teach either English or mathematics and also training in the trainees' specialist subject. In order to be awarded qualified teacher status (QTS), all primary trainees must also demonstrate the required knowledge, understanding and skills to teach science successfully (the detailed requirements are set out in Circular 4/98—Requirements for Courses of Initial Teacher Training, DfEE—which also sets out the ITT National Curriculum for primary science). This survey was designed to establish the extent to which these requirements were being met.

2. This report is based on the inspection of primary science training at 20 providers of ITT (see annex 1). Fifteen of these were partnerships based on higher education institutions and the remaining five were school-centred ITT (SCITT) consortia. A mixture of twelve undergraduate and eight postgraduate training programmes was inspected. Although the courses inspected reflect the range of provision across the sector, the sample was not chosen to be wholly representative. The findings, therefore, need to be interpreted with some caution. Inspectors visited schools, colleges and universities to observe elements of the science training; scrutinised relevant documentation; held discussions with tutors, school mentors and trainees; trainees completed a questionnaire in which they were asked to assess various aspects of the training; and inspectors visited 77 trainees during their final teaching experience. Around a quarter of these trainees were science specialists. Information from the questionnaires was used to corroborate the inspection findings.

3. The inspections were based on the joint OFSTED/TTA 'Framework for the Assessment of Quality and Standards in Initial Teacher Training' (the Framework). The inspections focused on five 'cells' from the Framework (see Annex 2): the quality of training (T1); the accuracy and consistency of the assessment of the trainees against the standards for QTS (T2); the trainees' subject knowledge (ST1); the trainees' planning, teaching and class management (ST2); and the trainees' monitoring, assessment, recording, reporting and accountability (ST3). However, the inspections did not result in the publication of separate reports on each course.

4. The inspections were carried out by Her Majesty's Inspectors of Schools (HMI), assisted by an additional inspector.

Main Findings

- Overall, the training is very effective in preparing trainees to teach science. In particular, the quality of ‘centre-based training’ is generally good or very good (‘centre-based training’ is training provided in a university or college, or, in the case of a SCITT, sessions taught to a group of trainees at a central venue).
- The structure and content of primary science ITT courses are mostly good or very good. Substantial time in the centre-based training is devoted to science and the content is closely aligned with the requirements of the ITT National Curriculum for primary science.
- There are important weaknesses in the links between centre-based and school-based training in many courses which limit the progress that some trainees make during their teaching experience.
- The majority of courses make relatively little planned use of the expertise of schools’ science co-ordinators, which limits the science input from the schools to the training.
- Providers mostly audit trainees’ science subject knowledge well and make good provision to improve it. Procedures on three and four-year undergraduate courses are generally more effective than on one-year postgraduate courses. School mentors make relatively little contribution, however, to enhancing trainees’ knowledge of science.
- Just over half the trainees observed had good or better subject knowledge in science. One eighth of the trainees were unsatisfactory in this regard. The subject knowledge of trainees on undergraduate courses was significantly better than that of those on postgraduate courses. Trainees generally demonstrated a secure grasp of the teaching and assessment methods and pedagogical knowledge and understanding specified in the ITT National Curriculum for primary science. The weakest area was that of the application of information and communications technology (ICT).
- Nearly two thirds of trainees demonstrated good or better skills in the planning, teaching and classroom management of science lessons. Their teaching strongly exemplified the elements of experimentation and other features of effective science teaching specified in the ITT National Curriculum.
- Although science is a National Curriculum core subject, it occupies substantially less time in primary schools’ curricula than English or mathematics. This restricts the opportunities trainees have to practise teaching that spans all the four science attainment targets, and consequently narrows the opportunity for trainees to carry out assessment in science.
- Half the trainees were good or better in assessing pupils’ progress in science, with higher performance from those on undergraduate courses. The commonest weakness was in their use of the outcomes of assessment to inform planning.
- The procedures for the assessment of trainees against the standards relating to primary science and the accuracy of these assessments are good overall.

Quality of Training (T1)

5. All the courses devote sufficient time to centre-based training in teaching primary science. In most, the time is substantial and equivalent to that in the other core subjects of English and mathematics. The number of taught hours in centre-based training, however, varies considerably. Undergraduate programmes typically provide many more centre-based sessions (around 50) than postgraduate programmes (about 20). Trainees' standards are generally higher on undergraduate programmes, indicating that these trainees are better prepared to teach science.

6. In all the courses, **science training** is divided roughly equally between the centre-based provision and that in the partnership schools, with a slightly higher proportion of centre-based training on undergraduate courses. Trainees are provided with a suitable range of school experiences, with block practices in at least two schools and opportunities to teach pupils across the full age-range for which they are training. Formal teaching of science subject knowledge and how to teach science to primary pupils is usually provided centrally, with school-based training focusing on opportunities to teach science under the guidance of experienced teachers. In the best courses, the integration of centre-based and school-based work is very effective in helping trainees to relate more theoretical perspectives to practice in schools, and school placements are programmed carefully to ensure the effective use of trainees' time. The success of a number of courses, especially undergraduate ones, also lies partly in their developmental structure, where the more straightforward features of topics or aspects of science are introduced at an early stage, and the more difficult features are returned to later on.

7. The best **course structures** are found on undergraduate programmes. This arises, in part, from the very widespread adoption by schools of the optional 'scheme of work' of the Qualifications and Curriculum Authority (QCA) - (QCA/DfEE, *Science: A scheme of work for key stages 1 and 2*, published by the QCA, 1998). This results in a situation where most primary schools are teaching a topic, such as electricity, to a particular year group in a particular term. On a three-year or four-year programme there are usually substantial teaching experiences at different times of the year, so that trainees have opportunities to teach different elements of science in each, even if working with the same year group. On one-year postgraduate certificate in education (PGCE) courses there is typically only a single extended block of school experience in which trainees are able to teach an extended sequence of science lessons and then only one science topic is commonly taught.

8. All providers recognise the importance to trainees of possessing strong **science subject knowledge**. All the courses include arrangements to audit trainees' scientific knowledge and understanding, as required by Circular 4/98, and these arrangements were judged good or better in all but three courses. One course was judged to provide satisfactory provision and two were judged as unsatisfactory.

9. About half of the providers make use of a **subject knowledge audit** developed by one of the awarding bodies. While this audit is a useful starting-point, it does not probe some aspects of science subject knowledge in sufficient depth and it does not address 'attainment target 1'. Usefully, some providers supplement its use by their own analyses of trainees' understanding of the nature of science and the role of

experimentation and evidence in the development of scientific ideas. Others use a variety of systems they have developed themselves.

10. A few providers have usefully introduced pre-course screening tasks that require applicants attending selection interviews to demonstrate an adequate level of scientific knowledge before being accepted onto the course. The majority use formal examination conditions when trainees complete their initial audit. A few use pre-test support systems to encourage trainees to prepare themselves thoroughly for the formal audit, for example the use of an 'open book' audit and pre-course background reading.

11. A subject knowledge audit is most effective when science tutors review the trainees' responses with individuals, as this provides opportunities to explore their levels of understanding more comprehensively. Most providers use the results from the audits well, alongside other relevant sources of data such as assignments, in order to prepare individual development plans with the objective of remedying gaps in trainees' scientific knowledge and understanding. In the best provision, centre-based trainers use the audit information to inform their own teaching plans; this ensures a good match to trainees' needs. Most trainees value the high-quality support they receive on subject knowledge action planning and comment positively about tutors' high expectations. In particular, trainees appreciate the guidance they receive from tutors who direct them to useful web sites and self-study materials, including commercial publications and science textbooks. One main weakness, however, is that courses make relatively little use of school mentors to develop trainees' subject knowledge. One reason for this is that mentors are rarely supplied with details of the trainees' subject audits.

12. Some courses incorporate self-assessment after each central training session, with the trainees using the outcomes as evidence of improvement in their personal subject knowledge. A small minority of courses, however, do not differentiate sessions successfully to accommodate the range of trainees' scientific understanding. All the courses place high expectations on self-study to improve subject knowledge, with trainees encouraged to undertake regular use of materials such as the support materials from the Teacher Training Agency, 'Assessing your needs in science: diagnostic tasks' and 'Diagnostic feedback'. Three quarters of courses use subject clinics or tutorials to address particular scientific concepts with groups of trainees. These clinics are often optional, with trainees being encouraged to attend. Just over half the courses make good use of some form of peer-group support. For example, three trainees had to observe a burning candle, describe what they saw, and then provide a scientific explanation:

> *The trainees provided an accurate description but lacked sufficient knowledge to explain their observations. They concluded: 'the flame was a physical reaction, and it got hotter because carbon from the candle wick joined with oxygen from the air to form an inflammable gas, carbon dioxide'. They decided on carbon dioxide because they could not think of any other gas that contained carbon and oxygen. On realising that carbon dioxide was used in fire extinguishers, they were dismayed and thought that hydrogen or methane might be involved. They could not explain how the same gas was also used in fire extinguishers. Another trainee joined the group and explained that it was the flammable vapour formed from the melted wax, absorbed by the wick, which burned in air to form water vapour and carbon dioxide and that the exothermic reaction became visible only through the heated carbon particles seen as the flame.*

13. One third of courses, mainly undergraduate ones, require trainees to complete a rigorous final audit of subject knowledge before qualified teacher status is awarded. On some undergraduate courses, different specific elements of trainees' subject knowledge are audited each year. At the end of the year, trainees must achieve a satisfactory result before they are allowed to proceed to the next year of the course. The urgency of the year-long postgraduate course does not readily permit such formal examination-based procedures. Instead, course tutors have to satisfy themselves that trainees have met the required standards. Pressure of time inevitably cuts into the rigour with which this can be done. The relative effectiveness of undergraduate procedures of audit and subject knowledge enhancement is corroborated by the generally higher standard of subject knowledge achieved by the trainees.

14. Courses cover all the more important topics for Key Stages 1 and 2 in science in the National Curriculum. Subject knowledge and how to teach science to pupils are frequently interwoven in the same taught sessions. The additional time available on undergraduate courses is a factor in making the coverage in such programmes more comprehensive. The more limited time on postgraduate courses sometimes leads to sessions that are too compressed, as the example below shows:

> *In a workshop on electricity, a knowledgeable and enthusiastic tutor led the trainees. There was some input of science subject knowledge at the trainees' own level (the structure of the atom and the ability of electrons to move through conductors). The analogy of a battery and a water pump was considered. The tutor discussed conductors and insulators and how to introduce the teaching of simple circuits. Science attainment target 1 (Scientific enquiry) was stressed - prediction leading to hypotheses. There was then an activity in which trainees planned lessons on electricity for Year 2 and Year 6 classes, but by the end of the session little overall was achieved. The key shortcoming of the teaching was that there needed to be more emphasis on the trainees' own subject knowledge. For example, the majority of trainees finished the session without an understanding of voltage and current, and trainees were unclear how progression should be addressed in the teaching of electricity between Key Stage 1 and Key Stage 2. The session was over-ambitious in what could be achieved in the time.*

In such circumstances, trainees can be lulled into thinking that their subject knowledge is adequate, when in fact they have important weaknesses that they need to follow up outside the session.

15. Biological topics such as 'Humans and other animals', 'Green plants' and 'Living things in their environment' are mostly well covered. 'Variation and classification' generally receives less attention. 'Electricity' and 'Forces and motion' are well covered, while other physical science topics, such as 'The Earth and beyond', 'Light and Sound', and material on the 'Earth Sciences', are frequently given less coverage. In a fifth of courses, it would be useful to review the timing and coverage of common areas of difficulty, such as electricity, and energy and forces, so that they are revisited later in the course to extend further the trainees' subject knowledge, especially when their initial science background is weak.

16. The requirements of **the ITT National Curriculum in primary science** (annex E of Circular 4/98) and training are generally well integrated, with a fifth of courses having very good coverage. In particular, courses generally provide good training in the nature of science, how pupils' learning in science develops, and children's understanding of science concepts. For example, one course begins with a session entitled 'Science is Fun' which introduces trainees to the idea of how personal views

of science impinge on teaching, and the importance of science in education and of science as a human activity. Most courses address the nature of science explicitly and then embed it in the subsequent training. The effectiveness of this approach is clear both from the trainees' own evaluations and the experiential, experimental and investigative approach to science which they demonstrate in their teaching.

17. The quality of nearly all **centre-based training** in teaching primary science is high. Most training sessions last about three hours, are structured well with a clear focus, relate well to the needs of the trainees and have a good range of activity that balances input from the trainer with trainee participation. The primary classroom context is usually emphasised strongly. Trainees are encouraged to consider and discuss how children's ideas about science develop over time and how to take account of this in their teaching. Most courses alert trainees to the importance of being aware of pupils' common scientific errors and misconceptions, as the example below illustrates:

> *The tutor, in a session on electricity, showed trainees four common ideas that children use to explain current flow in a simple battery/bulb circuit. Through her skilful questioning she enabled several trainees to discover that their own misconceptions were similar to those of children. The ethos of the session was such that trainees were confident to air their views and ask the tutor quite naïve questions before they came to accept the most plausible scientific theory. Understanding was enhanced by the tutor's very good illustrations of modelling, for example the representation of current as a bicycle chain. Much progress was made in relation to the development of the trainees' own understanding of electricity and their insights into the ideas held by children. By the end of the session trainees were much more confident about teaching this topic.*

18. Those responsible for carrying out centre-based science training are well qualified for the task. Many have higher degrees and have published widely. The teaching is often enhanced by the effective use of research findings, in some cases arising from work carried out by the lecturers themselves. Some partnerships sensibly encourage tutors to refresh their school teaching experience. Most teams of science tutors in the larger providers have a good spread of relevant teaching experience both by subject specialism in science and by primary year group. These tutors usually also take the lead in partnership management and thus are fully conversant with their partnership's procedures.

19. Almost without exception, trainers display good generic teaching skills and act as powerful role models of good classroom practice during training sessions. In the very small number of cases where training was weak, the pace of sessions was too slow and trainers lacked enthusiasm or offered little opportunity for discussion and reflection.

20. Based on the evidence of the 77 schools visited during trainees' final teaching experiences, the **partnerships generally place trainees in schools** where there is effective science teaching. Pupils in these schools achieve relatively high levels of achievement in science; Key Stage 2 test performance in science in 2001, for example, was significantly higher in these schools as a whole than nationally. This was true both for performance at level 4 and above and at level 5 and above.

21. Opportunities for trainees to observe good science teaching in schools are variable. In the best provision, trainees are provided with a number of structured observational experiences. For example, trainees are required to note how the

teacher groups the pupils and discover how different pupils or groups respond to particular tasks. They then consider the reasons for, and implications of, these differing responses. Where provision is weaker, trainees' opportunities to see good science teaching by experienced and skilful teachers, including science co-ordinators, are left largely to chance. For example, trainees' observations may be restricted to a single class, rather than across the school. Some programmes have no specific requirement that trainees observe good science teaching. In a small number of cases, trainees' opportunities are severely limited because schools are reluctant to rearrange their timetable and there is little or no science being taught while the trainees are in school. Where this happens, it represents a significant weakness.

22. The trainees' principal contact in schools is their mentor, normally the full-time teacher of the class they are taking. Mentors are generally capable and experienced teachers, often with school management or leadership roles. They are generally committed to the partnership arrangements, at least adequately trained, and communicate well with visiting science tutors from the centre-based organisation of the partnership. They are not, however, necessarily science specialists, nor even usually so; consequently, trainees' weak knowledge or practice in science sometimes goes unchecked. A small minority of mentors lacked the necessary knowledge of the QTS standards and how they are to be interpreted in a science context in order to carry out their role well.

23. In nearly all partnerships, formal training for mentors is considered important and is arranged regularly. Such training normally covers lesson observation and the assessment of trainees against the standards. Specific training of mentors in relation to science is more patchy. This is because, in the generic mentor training, science has to take its place alongside the competing claims of other subjects.

24. The vast majority of teachers in these schools have a positive and enthusiastic approach to the support they give to trainees working in their classes. However, the quality of modelling of good practice varies considerably from school to school. Most school-based training sessions consist of feedback to the trainee following a lesson observation by the school mentor. Lesson observation forms are completed carefully and useful targets set to provide clear points for development. A particularly good example of support was provided by a science co-ordinator who gave very high quality feedback to a trainee, which focused on subject knowledge at the trainee's level as opposed to that of the pupils. How to teach science and generic teaching issues were also addressed well. The feedback was underpinned by the co-ordinator's good knowledge of the QTS standards. In another example, the trainee worked with a science co-ordinator to plan an investigation. The dialogue was thorough and challenged the trainee to consider a variety of different approaches to the organisation of the lesson and the recording of assessment data. However, some school-based staff falter in the support they give trainees because of their limited knowledge of the standards.

25. Most schools have a **science co-ordinator** with responsibility for the overall management of science in the curriculum. Such co-ordinators do not feature prominently in the training. Only one in five partnerships give any formal role to the co-ordinator. In most, the involvement depends upon whether the co-ordinator is, by chance, the mentor. In some cases, trainees themselves seek the help of the

science co-ordinator, but frequently this is for little more than a brief interview about the scheme of work of the school and its resources.

26. Where there is an explicit role, the science co-ordinator usually carries it out well. For example, in one partnership the co-ordinators explain their role and responsibilities, go through the scheme of work for science and how it is used, and provide helpful insights into practical aspects of science teaching. Schools do not, however, always allow sufficient non-teaching time for the co-ordinator to carry out this role.

27. Half the courses demonstrated a high degree of **coherence in the science training** provided. Most of the remainder had important weaknesses and two of them were unsatisfactory in this regard.

28. The coherence of the science centre-based training is generally a strength. The ITT National Curriculum for primary science is mostly used well to provide a structure that is understood by trainers and trainees. There are often good links between the centre-based science training and the preparation provided by general professional studies. Some of these are made explicit through documentation and through cross-referencing to the requirements of Circular 4/98. In the best cases, directed tasks and assignments are an integral part of the training and are well timed. Most providers helpfully audit trainees' experiences of teaching different science 'programmes of study' during their school experiences to try to maximise breadth of experience, though the difficulties have been highlighted above.

29. Where there are weaknesses, they are often to do with the relationship between the training centre and the partnership schools. In two courses, in particular, there were important structural weaknesses associated with the use of 'bought in' training. In one, the links between the centre-based training and schools were very undeveloped, with both partners working in isolation, unaware of each other's contribution to the training programme. This lack of communication led to weaknesses. For example, subject audits were not shared with school staff, so that teachers could not help trainees develop their subject knowledge, or school-based tasks were unfocused and not linked to the science tuition trainees had received.

30. Weaknesses such as these were not confined to these two partnerships. Others showed similar, though less serious, weaknesses and it would be helpful for providers to review their links with partner schools, in particular to ensure that requirements are not over-burdensome. Equally, trainees' subject knowledge needs to be under the informed scrutiny and guidance of mentors. Other examples of weaknesses in particular partnerships included: a lack of contrasting school experiences; weak monitoring and following through of reading and directed activities; and tutors' lack of awareness of the science topics trainees were teaching whilst on teaching experience.

31. Lack of opportunity for trainees to **practise teaching** across the different science 'programmes of study' is the most common weakness of the training. The problems of the timing of school experiences, especially on PGCE courses, have already been highlighted. An underlying problem is that typically only about 8% of curriculum time is devoted to science in primary schools, even at Key Stage 2.

32. The science topics that trainees are asked to teach during a particular block teaching experience are frequently a matter of chance. Often, they are simply the next unit in the scheme and take little account of the individual trainee's needs. Consequently, some trainees teach the same science topic to different year groups on two and sometimes three different teaching experiences and have no opportunity to teach science topics from other 'attainment targets'. Occasionally, schools are reluctant to allow trainees to teach particular aspects of the 'programmes of study', believing that some topics, particularly in the physical sciences, are too difficult and that handing over responsibility to a trainee may have a negative impact on the school's end of key stage assessment results. In a few courses, the trainees' school experiences are monitored and audited carefully to ensure that any weaknesses are identified and remedied. For example, a trainee specialising in teaching older primary pupils wanted to observe and gain some early years experience, and had an additional visit organised to enable this to take place.

33. The vast majority of trainees have good opportunities to teach attainment target 1 (scientific enquiry) and to plan investigations that complement other science areas successfully. However, a small number of less confident trainees are reluctant to include scientific investigations in their lessons, preferring to avoid the practical nature of the subject by planning more desk-bound activities for the pupils.

34. The topics of **language and literacy** and aspects of communication are also often linked to the consideration of pupils' scientific misconceptions. This is because many of these derive from an inappropriate use or misunderstanding of words. Several courses make strong links between science and the National Literacy Strategy, and in some cases trainees make their own links, for example by the use of 'big books' in literacy classes such as *The Life History of a Sunflower*. However, such links are not always sufficiently strong. For example, one school-centred course had not considered the specific requirements for writing at each level or age in the National Curriculum and had not incorporated these writing objectives within the writing tasks in science.

35. All courses give some attention to the links between **mathematics and science**, but the emphasis is often insufficient. Although centre-based training commonly provides some appropriate starting-points, too much is frequently expected of trainees in terms of developing their own links to the teaching of numeracy. Tutors and school mentors rarely focus clearly on this aspect in their feedback on lessons taught by trainees.

36. The coverage of **the use of information and communications technology (ICT)** in science teaching is good or better in centre-based training in three quarters of courses, and very good in a quarter of courses. In one four-year programme, for example, an audit of skills is carried out in Year one; thereafter trainees follow an individualised learning package. Later on in the course there is both discrete ICT provision and application of ICT in individual sessions as opportunities arise. Topics such as simulation and modelling, communication, data-handling, the use of the Internet, digital photography, and the use of CD-ROM material are included.

37. Many trainers incorporate ICT effectively in training sessions and encourage trainees to consider its appropriate use in teaching science, for example by giving trainees opportunities to evaluate different software packages and web sites, and to

experience data-logging and the use of computers for recording and interpreting scientific data. A few trainers demonstrate successfully how ICT can be used to communicate information effectively by using carefully constructed science presentations that engage, excite and stimulate trainees. A small minority of tutors, however, have insufficient expertise and their training gives little emphasis to the importance of using ICT to enhance science teaching and learning in the primary classroom. Weaknesses in provision often occur at the school level, where trainees sometimes have less first-hand experience than is desirable and teachers are not always able to give effective support.

38. Three quarters of courses have good or better training, largely centre-based, in the **assessment, recording and reporting** of pupils' progress in science, and a third of courses have very good provision. In the better courses, training in assessment usefully mirrors good practice found in schools, including: target-setting; the marking of pupils' work; the involvement of pupils in self-assessment; the analysis of test results; the assessment of investigative skills (Sc1); the separate assessment of the other attainment targets (Sc 2, 3 and 4); and the purpose and procedures of moderating standards of work in science. Good courses make skilled use of time by coupling the work in science assessment with that done in English and mathematics. Very good courses also include the interpretation of national and international comparisons in science. Features of weaker provision include only partial links to practice in English and mathematics, poor models of recording, and insufficient experience in school settings of assessing pupils against level descriptions.

39. The greatly increased number of **teaching assistants** in primary schools means that a substantial number of trainees have opportunities to work alongside them in classes. Trainees often make reasonably effective use of the support of an additional adult in the classroom, but are seldom taught explicitly how to work with teaching assistants so as to achieve the greatest benefit from them.

40. The overall quality and quantity of **scientific resources** available for training are good. It is desirable, when trainees are studying science at their own level, that well-quipped, purpose-built science laboratories are used. This is the case in many of the larger providers. Most smaller providers have made provision for the taught elements of their science course to take place off-site in suitable higher education institutions with access to appropriate resources. Other small providers borrow equipment, as and when required, for centre-based training sessions.

41. During centre-based sessions on teaching science, tutors generally demonstrate resources appropriate for primary pupils. Trainees are often encouraged to experiment with the various practical resources through appropriate 'hands-on' opportunities. In some of the larger providers, trainees can familiarise themselves with the use of science equipment when the teaching rooms are open outside normal class time. Many of the providers have accumulated useful science resources that are available on loan to trainees to support their teaching in school. Often the science tutor or technician will respond to trainees' requests for help by offering advice about suitable equipment to use in school. However, in a minority of providers the provision of science resources falls below that commonly available in schools. Also, a few of the smaller providers have a very limited range of their own

science resources available for trainees to borrow to support their teaching in school; this restricts their ability to practise some of the ideas they have learned.

42. Frequently the trainees' working environment in the centre-based training is enhanced by lively and interactive displays of science resources and pupils' work. Such displays are designed to stimulate thinking about science for primary pupils and the standards of which they are capable whilst demonstrating the importance of creating an attractive learning environment. In others, there is a distinct lack of appropriate display material, and hence a valuable teaching opportunity is lost.

43. The quality of **library provision** to support science training is generally very good. Libraries typically hold a wide range of useful science texts, including several copies of books recommended as essential reading, videos, commercially published science schemes of work, journals, recent research and reference material, software, Internet access, posters and a range of classroom teaching materials. An important weakness in a minority of cases is a lack of suitable resources to extend trainees' own subject knowledge beyond the required entry level. Trainees are generally shown the resources available to them and encouraged to make full use of the library facilities. In a number of the SCITTs, library provision for trainees is made available through buying in access to off-site facilities. These arrangements provide generally poor value for money because travelling problems frequently inhibit the full and productive use of these facilities by trainees.

44. The majority of schools used for training are well resourced to teach science and trainees make good use of the resources to support their teaching. In addition, many trainees go to great lengths to supplement school resources with additional materials, some produced by themselves, to enhance the learning experience for their pupils.

45. Many providers make ICT equipment—such as temperature, gas and other sensors, and digital cameras—available to trainees for use during their practical school-based teaching experiences. One provider has provided each trainee with a laptop computer and Internet access to help with the development of relevant and appropriate ICT skills. A substantial number of trainees were, however, limited in their use of ICT in schools because of difficulties of access to computers. Others were constrained by schools which did not recognise the importance of incorporating ICT into science teaching.

Assessment of Trainees against the Standards for QTS (T2)

46. The procedures for the **assessment of trainees** against the standards relating to primary science, and the implementation of these to assess trainees accurately, are good overall. The features of assessment common to all the core subjects were very good in one course and good in a further 17 courses. The two remaining courses had some significant weaknesses.

47. Partnerships require trainees to maintain profiles of their performance throughout the whole course in different aspects of their work. In the large majority of cases, these are directly linked to the standards for QTS. The profiles refer to standards which include science but which span all subjects. In a few courses there

are also science-specific profiles which provide a useful tool for assessment, as well as for monitoring trainees' progress in science. This is most effective when, as a result of regular review meetings, trainees are set targets on which to focus their development. In the most effective assessment, requirements in science are closely linked to the ITT NC for primary science. This is because the ITT National Curriculum embraces all the important features of science training and such assessment has a transparent relationship to the QTS standards.

48. **Written assignments** were most effective in supporting training where the assessment criteria were precise and clearly linked to the QTS standards. Marking was frequently rigorous and consistent and, in the best examples, trainees received written feedback clearly indicating how well their work met the assessment criteria together with clear comments indicating how improvements could be made. Assessment is enhanced where science specialist tutors mark all science assignments. In contrast, in a few providers, there is a lack of clarity in the assessment criteria used with respect to the standards. Also, there are examples where marking lacks clear feedback and, at times, insufficient guidance is given to trainees on how written work can be improved. In one example of weak assessment, a written assignment in science had been replaced by tasks which trainees had to complete in schools: the written work produced was not marked and little feedback was given.

49. All partnerships arrange for regular and rigorous monitoring of trainees' **progress in practical teaching** with respect to the standards for QTS. In several partnerships, the rigour is enhanced because mentors are specifically trained, or provided with clear and helpful guidance documents, to assess trainees' achievements in science in relation to the standards. Trainees are usually set clear targets to enable them to work towards achieving specific standards. In one partnership, where mentors did not always feel confident in making science-specific judgements, the help of school science co-ordinators provided effective support. In a few partnerships, comments made by school-based staff on trainees' science teaching were not sufficiently subject-specific and targets set were too general.

50. In most partnerships, tutors who are not science specialists carry out the **moderation of the assessment** of trainees' practical teaching, including their teaching of science. In most cases this moderation is carried out effectively. In a few examples, however, trainees were being over-graded by non-specialist tutors or mentors; in one case, the science tutors were aware of this and action was being taken. In another case, science tutors became involved in the moderation process only if a trainee demonstrated subject knowledge difficulties at the mid-point review during the final school experience.

Trainees' Subject Knowledge and Understanding (ST1)

51. Around three fifths of the trainees were judged to have good or better **subject knowledge for teaching primary science**, rather less than two fifths were judged as satisfactory, and one in twenty had significant weaknesses in their science knowledge. Subject knowledge is not simply subject knowledge, but the knowledge and understanding required by trainees to secure pupils' progress in science as specified in the Initial Teacher Training National Curriculum, Circular 4/98, annex E.

A higher proportion of trainees on undergraduate programmes had good or very good subject knowledge than on postgraduate courses.

52. The initial level of knowledge for those on undergraduate routes was typically that of a general certificate of secondary education (GCSE) in Balanced Science (double certificate). A few trainees had A-level qualifications in biology: relatively few had A-levels in physics or chemistry. Of those following one-year postgraduate courses, only a few had science degrees. With this background, the subject knowledge demonstrated by trainees towards the end of their training provides clear evidence of the success of courses in meeting the requirements of the ITT National Curriculum and the needs of trainees. Knowledge derived from the centre-based training of some key areas of science, however, frequently remains rather theoretical because of insufficient opportunities to consolidate it by teaching it in the classroom.

53. Trainees' knowledge of the required elements of biology and chemistry in the ITT National Curriculum was good or better in three quarters of cases. Physics was a relatively weak area. Trainees mostly coped well with subject-based questions. The nature of questions which can arise, particularly in the physical sciences, is, however, such that even the most scientifically able trainees can find themselves drawn into discussions in class in which the limits of their knowledge are tested. Typically this happens as arguments lead deeper into concepts more commonly addressed at Key Stage 3 and beyond, as the example below illustrates:

> *Year 6: Topic linking the Egyptians and Forces*
>
> *The trainee planned to develop an understanding of the forces needed to move large blocks of stone from a river boat to the pyramids. As an introduction, he asked the class to consider the forces on a car moving at a steady speed. He knew about friction at the wheels, but in the course of discussion with the class he needed A-level knowledge to completely satisfy his own and the class's curiosity of how all the forces acted together. The quality of the lesson engaged the class and led them to ask some very challenging questions. For the trainee it was like coping with a genie that had inadvertently escaped from the bottle!*

54. All trainees had at least a sound knowledge and understanding of the programmes of study for science in the National Curriculum and the relevant level descriptions; for two thirds, this knowledge was good or very good. The majority had a good understanding of the way children's learning in science develops and so were well equipped to match work to their pupils. However, one trainee in eight showed limited awareness of how topics they were teaching would be developed in the next key stage or of what was likely to have been taught in the previous one. This was especially the case when they had only a restricted teaching experience outside their chosen key stage and in these cases their knowledge of teaching science in the other key stage was, inevitably, largely theoretical.

55. Most trainees had some awareness of **research and inspection findings** relevant to teaching primary science. Some, especially on undergraduate programmes, had used such material appropriately and successfully in their assignments. Almost all trainees were aware of aspects of research on children's intuitive ideas in science and of their common misconceptions. The best trainees had used this knowledge to challenge pupils' initial ideas, or to forestall wrong lines of thinking, as in the following example:

> *The trainee was teaching 'humidity' and knew how steam and water vapour are different. She prepared a demonstration for a class, using a bowl of hot water, covered with clingfilm and with*

an ice cube placed on top. On reflection, she decided to replace the ice cube with a cold spoon because she did not want the pupils to think that the ice was melting and dripping through the clingfilm.

56. The weakest area of trainees' subject knowledge related to the **use of ICT** in science teaching. Only two trainees in five had good or better knowledge of how to use ICT and that of one in seven was weak. Key problems were the limited opportunities to use computers in many school placements and to practise skills learnt in the centre-based training.

Trainees' Planning, Teaching and Class Management (ST2)

57. Around two thirds of trainees were judged good or very good at **planning, teaching and class management in science**, about a quarter were satisfactory and less than one in twelve had significant weaknesses. There was little difference in the performance of trainees on undergraduate and postgraduate courses.

58. The flexibility for trainees to plan particular units of work was often limited by the requirement to teach the next topic in the school's scheme of work. Trainees' individual lesson plans generally showed clearly the content of the lesson, how it would be taught and which objectives were being covered. All trainees referred appropriately to the relevant National Curriculum programmes of study, with most making cross-reference to the QCA scheme of work. A few made explicit links to the ITT National Curriculum.

59. Most trainees identified **learning objectives** for their lessons. However, there was wide variation in the suitability of those objectives as a basis for assessing children's learning. The best examples were well defined, achievable and matched closely the planned activities, and formed the basis of what would be assessed. For example, one trainee had stated that, by the end of the lesson, the pupils would know that 'light travels from a source to an object'. Weaker examples were characterised by being too general to be useful as a measure of progress. In the worst cases, the stated objectives did not match the content of the lesson.

60. Almost all of the lessons had a clear **structure and sequence**, consisting of a whole-class introduction and a main teaching activity, and ending with a plenary session. All trainees' planning included appropriate activities for the different components of the lesson, the science-specific vocabulary to be used, and the resources needed. The majority of lesson plans usefully outlined how the pupils were to be organised and how they were to be supported at appropriate times. Occasionally, however, planning was weak in this respect. For example, one trainee divided the class into unmanageably large groups, with the result that not all the pupils were engaged in the tasks and learning was unsatisfactory. A few lesson plans also incorporated literacy and numeracy strands into the science framework, achieving a structure for improving pupils' learning in these areas but without detracting from the main focus on science.

61. The majority of trainees' planning took account of the different abilities of the pupils in their classes. Schools commonly provide trainees with useful information about: pupils' prior achievement in science; pupils with special educational needs,

including copies of their Individual education plans; and information on pupils with English as an additional language. Class teachers often support trainees in planning work at an appropriate level for less able pupils. However, trainees rarely planned different activities matched to pupils' needs and assessment planning often had similar weaknesses.

62. Two thirds of trainees taught science enthusiastically and **managed their classes** well. They used a mixture of whole-class, group and individual work successfully. Their lessons followed the planned sequence of activities, with any variations commented upon in their written lesson evaluations. These lessons were generally characterised by brisk introductions which employed question and answer activities with the whole class. This enabled the class to revisit and consolidate previous learning and also set the scene for the day's learning. In nearly a third of lessons, trainees shared the explicit rationale of the lesson with the class. Many trainees highlighted and reinforced sensible health and safety practices in their introduction to science lessons. Successful introductions engaged pupils' interest and scientific curiosity. For example, one trainee working with reception pupils used a chest of historical artefacts as a stimulus to excite the pupils into wanting to find out more about the different materials from which the objects were made. Other trainees read poems, used relevant 'big books' and showed the pupils appropriate picture books which promoted and consolidated work being covered in the literacy lesson.

63. Most of the trainees' science lessons focused upon **practical enquiry**. Two thirds of lessons included individual or group practical work, often requiring the explicit teaching of a particular experimental technique. Nearly two fifths of lessons included some element of hypothesis testing. Some investigations, however, were too trainee-dominated and did not allow pupils the necessary scope to plan and carry out their own practical enquiries. The vast majority of trainees took care to organise practical activities well and ensured that all the necessary resources were readily available. Some trainees sensibly tried out the experimental work beforehand to help them anticipate any difficulties the pupils might encounter. Nevertheless, the more limited curriculum time given to science in primary schools means trainees have less opportunity to teach the subject and thus to develop their skills in managing science activities than is the case in English and mathematics. One consequence of this is that they are often less confident in their response when a science activity does not go exactly as planned.

64. Trainees use a variety of **questioning techniques** in their science teaching. In four fifths of lessons questions were asked which pupils had to answer by factual recall. In addition, trainees used a range of other types of questions. Almost half of the lessons contained questions that required pupils to make an inference from an observation; a third of lessons included questions that needed a direct observation to provide the answer; and a quarter of lessons included questions requiring hypothesising or problem-solving. Trainees generally included an appropriate balance of open and closed questions, were careful to direct questions to individual pupils, and made good use of supplementary questions to develop pupils' answers further.

65. Six out of ten lessons had **plenary sessions** in which trainees consolidated and reinforced the learning that had occurred. Such sessions were often used to

widen pupils' understanding of how their scientific ideas relate to the world outside the classroom. Where plenary sessions were used well, trainees included assessment activities to determine pupils' progress against the learning objectives for that lesson. In a few cases, trainees posed challenging questions for the pupils to consider as a useful link with the next lesson. However, trainees made very little use of formal homework opportunities to develop and extend pupils' learning in science. In a small number of lessons, trainees either simply forgot a planned plenary or did not manage time well, so that they overran the main teaching activity.

66. In most cases, trainees used appropriate **scientific vocabulary** throughout their lessons and expected their pupils to respond accordingly. Some trainees displayed relevant scientific words, for example in 'word banks', to aid and develop pupils' vocabulary, whilst others linked words used in science directly with their literacy work. Many used models and analogies to help to explain difficult science concepts.

67. Links between **mathematics and science** were generally less well developed than those with literacy. Even so, nearly a fifth of the science lessons included some use of mathematics. Where an element of mathematics was explicitly included, such as using measurement or graphical techniques, the pupils benefited from extending and practising their mathematical skills. For example, in one lesson which involved dissolving different types of sugar in water, the trainee worked with the pupils to plot graphs recording the time taken to dissolve different amounts of sugar, so that they practised skills they had recently acquired in mathematics lessons.

68. Trainees generally made good use of suitable **science resources**. They often went to considerable lengths to obtain sufficient equipment, materials and textbooks to support their lessons. In a fifth of the lessons, trainees used ICT resources to support their science teaching, for example through using a class computer as an extension activity to carry out further research using software resources or relevant Internet web sites. Just over one in twenty lessons included the use of data-logging. Other uses of ICT included the use of a tape recorder to listen to familiar and unfamiliar sounds. In one particularly good lesson, ICT was used in three ways: the teacher used an overhead projector to support some shared report-writing; pupils used a computer to present the results of their investigation in the form of a graph; and a group of pupils made a PowerPoint presentation of their investigation to the rest of the class. However, very often trainees' use for ICT was restricted because of the lack of accessible resources within the school.

69. A substantial number of trainees were supported in the classroom by **teaching assistants** and most identified in their planning how their time would be used during the lesson, usually with the assistant supporting a group of less-able pupils during the main practical activity. Most trainees briefed their assistants by giving them a copy of their lesson plan, which helped them to understand what was expected of them. Trainees' planning only occasionally highlighted how teaching assistants were to be used during the introduction and plenary phases of the lesson to assist with assessment of the pupils' learning.

Trainees' Monitoring, Assessment, Recording, Reporting and Accountability (ST3)

70. Overall, half the trainees were judged to be good or better in relation to this aspect of teaching. The evidence base was smaller than for the other standards because of the relatively small amount of explicit **science assessment** carried out by the trainees. Trainees' performance was better on undergraduate courses, with 57% good or better compared with 37% on postgraduate courses. This difference probably reflects the greater opportunity trainees generally have to teach and assess science in primary schools on undergraduate courses.

71. The majority of trainees review and evaluate how well learning objectives for lessons have been achieved. However, assessments based on imprecise learning objectives or with systems which concerned the achievement of whole classes are less useful. Some trainees restrict their assessment to noting whether work has been completed by pupils rather than by focusing on learning objectives; this results in sequences of lessons in which pupils' learning is restricted. Trainees' **use of the outcomes of assessment** to inform the planning of further work is, in the majority of cases, weak. A few trainees did, however, make effective use of such information, as in this example:

> *Y2/3 class: Topic - Photosynthesis*
>
> *The lesson had been carefully planned to match the prior knowledge of the children, and to draw on the evaluation of the previous lesson. The match became very evident from the initial plenary part of the lesson in which there was an extensive question-and-answer session. The children displayed a very impressive knowledge of factors that might affect photosynthesis, clearly remembering a great deal from the previous week's science lesson. To move them on to the planning and setting up of an investigation, the trainee drew on his evaluation of the previous lesson and the answers he had just heard in the plenary introduction. In doing this he had taken a conscious decision not to stick to the school's scheme of work. By the end of the lesson the class had set up different conditions for the growth of plants at various locations in and around the classroom. Some plants were near a window, others in open spaces and others in a cupboard, and arrangements for varying the amount of water received by plants in any specific location had been decided by the pupils. Overall, very good progress in setting up a science investigation had been made.*

72. Most trainees **plan for assessment** in their teaching through the use of question-and-answer sessions and by marking pupils' work. However, a minority of trainees were unclear how to plan and use assessment during lessons in a way that would inform them quickly and usefully about pupils' progress in science. In some cases, trainees planned, rather ambitiously, to assess the entire class in a single lesson rather than focusing on a specific target group. Another difficulty some trainees encountered was that the criteria they planned to use as a measure of pupils' scientific understanding did not relate directly to their learning objectives. This made it difficult to evaluate the success of the lessons.

73. The quality of **marking of pupils' work** varies considerably. The large majority of trainees regularly mark pupils' written work. A few restrict their marking to ticking the completion of work with a few non-science-related comments. However, there were several examples of effective marking, not only recognising the pupils' efforts but also prompting them to think in more depth. A minority of trainees used their marking to analyse the outcomes of their teaching in order to identify misconceptions

and to assist in the planning of further work. Trainees teaching 3 to 5-year-old children rely, understandably, on oral feedback, with written work often annotated for the trainees' own use and to contribute to record-keeping systems.

74. A wide range of systems was used by trainees in **recording pupils' progress** in science, some of which were used effectively to inform further teaching. For example, following work on shadows, a trainee noted pupils' misconceptions (for instance, 'a common misconception was to draw shadows with details included') and identified, in subsequent planning, how difficulties would be addressed. Frequently, trainees kept brief records on all their pupils while developing detailed records on a few. A significant number of trainees had record-keeping systems which had shortcomings, such as: keeping class records of pupils' experiences, not what they had learnt; not being sure what to record in terms of pupils' learning; and maintaining complex record-keeping systems which were having no influence on the further planning of work.

75. Trainees' understanding of the National Curriculum levels pupils are expected to achieve, and their experience of assessing pupils' work using the level descriptions, were very variable. Although many trainees frequently used the relevant level descriptions to support their teaching of English and mathematics, many were not sufficiently knowledgeable about the corresponding levels in science to attempt to assign levels to pupils' work. Nevertheless, a minority of trainees were able to accomplish this type of work well, often reflecting the good practice of the school where they were placed.

Annex 1: List of Providers inspected

Undergraduate Courses

Anglia Polytechnic University
Bradford College
Bretton Hall
Chester College of Higher Education
De Montfort University
Kingston University
Newman College of Higher Education
Oxford Brookes University
Trinity and All Saints College
University of Durham
University of Surrey, Roehampton
University of Plymouth

Postgraduate Courses

Bexley Primary Schools SCITT
Cumbria Primary Teacher Trainers
Oxfordshire SCITT
University of Leeds
University of Newcastle on Tyne
University of Southampton
Urban Learning Foundation
Wandsworth Primary School Consortium