THE PRIMARY REVIEW
The condition and future of primary education in England

A SUBMISSION OF EVIDENCE FROM THE ASSOCIATION FOR SCIENCE EDUCATION
April 2007

EXECUTIVE SUMMARY

1. The Association for Science Education (ASE) welcomes the opportunity to make this submission to *The Primary Review* and has consulted widely with its members who are drawn from all phases and areas of science education in order to bring together a range of evidence from a variety of perspectives. The key messages are summarised below.

Purposes and Values

2. For all children Primary Education should engender an enthusiasm for learning that will stay with them throughout their lives. Through nurturing their curiosity, developing their skills and increasing their understanding of the world around them, Primary Education enables young children to engage with a broad balanced and meaningful curriculum and experiences that will provide a basis for future learning which in turn will lead to the health, safety, achievement, economic well-being and enjoyment of all young people as members of, and contributors to, the communities in which they live.

3. The ASE believes that science is a distinctive form of creative human activity that involves a way of seeing, exploring, understanding and explaining the natural and physical world. In science, ideas are exposed to refutation through experimentation and as such science has a unique contribution to make to primary education. All pupils, therefore, should experience, and have access to, a broad, relevant science curriculum, which puts understanding of scientific concepts and their applications in a social and ethical context. Pupils should be encouraged to evaluate the nature of evidence from science and elsewhere in making judgments about the use of science. All pupils have an entitlement to a broad, relevant science education.

4. **Learning and teaching**

- In essence, a school's most valuable resource is not its equipment or facilities but a cadre of well-qualified, enthusiastic teachers who are justly remunerated for their skills.
- Teachers have aspirations to improve the quality of their own teaching but they have concerns and perceive barriers which inhibit them taking appropriate action.
- Recognition and reward for teachers who demonstrate high quality professional expertise is essential for retention.
- The time available for preparing high quality teaching of science is limited and greater attention needs to be given to ensuring that programmes for trainees, their subsequent induction year, as a newly qualified teacher (NQT), and CPD opportunities are integrated much more closely.
- NQTs would benefit from a staged introduction to full-time teaching and a planned programme for their continued development.
- A blended approach to CPD, especially around increasing teacher confidence with subject knowledge, is required which has the support and commitment of all parties – the Government, school management and individual teachers.
- Enquiry and hands-on activities are central to teaching and learning in primary science but it must be well planned and resourced appropriately.
- Making science more relevant to children's everyday lives is key to engaging them with science and helping them to become active and informed citizens, who

understand and take decisions about the impact of scientific and technological developments.

- Pupils' views and existing ideas cannot be ignored. The teacher's role in adopting such a constructivist approach to learning requires support and professional development for teachers if they are to teach and assess an enquiry based creative science curriculum effectively and have the confidence to innovate and move away from recall of facts.

5. **Curriculum and assessment**

- If the core curriculum is to be maintained the core subjects, including science, should have genuine parity in terms of status, curriculum time, support, access to CPD and funding.
- The effect of a science curriculum taught through hands-on, investigative activities with a good balance between process skills and appropriate science content makes a significant contribution to pupil engagement and enjoyment of learning.
- To meet pupil needs we must build flexibility into the curriculum otherwise risk ending up with another 'one-size fits all' model and many of the problems we face today will simply return at some point in the future.
- 'Teaching to the test' with a focus on content and factual knowledge leads to a narrowing of not only teaching approaches and activities but also to the quality of knowledge and understanding gained by pupils and their engagement with science as part of their overall learning.
- A change in policy with regard to testing and target setting is the essential first step in providing our primary pupils with the experiences that will develop their understanding, interest in and enthusiasm for science.
- A greater focus on assessment for learning and assessment of skills, and valuing the teachers' role in assessing pupil progress is required to support learning and give a meaningful measure of progress.
- There is a need for the primary science curriculum to more explicitly relate ideas to contemporary contexts and introduce, at an appropriate level, some of the major issues of this century such as global citizenship and sustainability.

6. **Structure and phases**

- As part of a wider curriculum review, work needs to be done to more clearly identify what characterises primary science and the experience for pupils, and how these contribute to seamless transitions with true continuity and progression through and between phases or key stages.
- Transition issues that arise when students move from one to phase to another must be addressed and the lessons learnt from new transition initiatives must be brought together and acted upon by relevant parties.
- There is a need to address the disengagement which appears to be increasing during Yrs 5/6 and seems to be linked, at least in part, to an overemphasis on SATS.
- More effective links are required between numeracy, literacy and science in order to maximise the synergies and opportunities that such links support.

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Introduction

7. The Association for Science Education[1] (ASE) welcomes the opportunity to make this submission to *The Primary Review* and has consulted widely with its members who are drawn from all phases and areas of science education in order to bring together a range of evidence from a variety of perspectives. In particular, in addition to the information from external sources, this submission has drawn on first hand contributions from members of ASE Council, our Primary, 11-19 and Research committees plus our two Special Interest Groups (National Advisers and Inspectors Group for Science[2] (NAIGS) and, Association of Tutors in Science Education[3] (ATSE). This submission also draws on the findings of a series of nationwide seminars with primary and secondary science teachers held last year under the heading of *Engaging teachers, Engaging pupils, Engaging Science*[4].

8. The Association's submission focuses on some of the questions raised in four of the Primary Review themes; Purposes and Values, Learning and Teaching, Curriculum and Assessment, and Structures and Phases.

Purposes and Values

Key Messages

9. *For all children Primary Education should engender an enthusiasm for learning that will stay with them throughout their lives. Through nurturing their curiosity, developing their skills and increasing their understanding of the world around them, Primary Education enables young children to engage with a broad balanced and meaningful curriculum and experiences that will provide a basis for future learning which in turn will lead to the health, safety, achievement, economic well-being and enjoyment of all young people as members of, and contributors to, the communities in which they live.*

10. *The ASE believes that science is a distinctive form of creative human activity that involves a way of seeing, exploring, understanding and explaining the natural and physical world. In science, ideas are exposed to refutation through experimentation and as such science has a unique contribution to make to primary education. All pupils, therefore, should experience, and have access to, a broad, relevant science curriculum, which puts understanding of scientific concepts and their applications in a social and ethical context. Pupils should be encouraged to evaluate the nature of evidence from science and elsewhere in making judgments about the use of science. All pupils have an entitlement to a broad, relevant science education.*

What core values and principles should it (primary education) uphold and advance?

11. Primary education should meet the ideals of the 'big picture of the curriculum' (QCA 2007) in order to enable all young people to become successful learners who enjoy learning, make progress and achieve, to become confident individuals who are able to lead safe and healthy lives, and to become responsible citizens who make a positive contribution to society. Science, as a key part of primary education, should value informal learning as much as formal

[1] Appendix 1 provides a summary of the aims of The Association for Science Education
[2] Appendix 2 provides a summary of the aims of The National Advisers and Inspectors Group for Science
[3] Appendix 3 provides a summary of the aims of The Association of Tutors in Science Education
[4] Appendix 4 provides a discussion document prepared at an interim stage of the seminar series and highlights some of the findings.

learning, encouraging children to develop as individuals, showing independent thinking and initiative, creativity and innovation as well as reflection. Shayer, M. & Adey, P. (2002).

12. Furthermore, to contribute effectively in tomorrow's society, primary education should provide children with more languages, scientific and technological awareness and confidence, cultural sensitivity and media awareness (Yapp 2003).

13. Primary science, in turn, should provide opportunities for spiritual development and conceptual awareness through the awe and wonder of the big science ideas that have shaped the world, to explore these within and beyond the classroom in a range of locations and environments. Pupils should have opportunities to develop the skills for an evidence based approach to science, collecting evidence by first hand observation and practical work and from secondary sources. This science enquiry learning can play an important role in reversing the apparent decline in young people's interest and engagement in school science (NESTA Real Science 2005). By looking at science and its applications in social and global contexts, pupils are better prepared to take a positive and active place in tomorrow's world.

14. The ASE believes that all pupils should experience a wide variety of teaching and learning methods, including practical work, in their development towards becoming scientifically literate individuals. By experiencing a variety of methods and approaches (which are transferable across all curriculum areas) pupils will extend, develop and adapt their knowledge, understanding, skills and attitudes. The ability to learn throughout life and adapt to new situations is essential in a changing world increasingly influenced by science and technology.

Learning and teaching

15. **Key Messages**

- *In essence, a school's most valuable resource is not its equipment or facilities but a cadre of well-qualified, enthusiastic teachers who are justly remunerated for their skills.*
- *Teachers have aspirations to improve the quality of their own teaching but they have concerns and perceive barriers which inhibit them taking appropriate action.*
- *Recognition and reward for teachers who demonstrate high quality professional expertise is essential for retention.*
- *The time available for preparing high quality teaching of science is limited and greater attention needs to be given to ensuring that programmes for trainees, their subsequent induction year, as a newly qualified teacher (NQT), and CPD opportunities are integrated much more closely.*
- *NQTs would benefit from a staged introduction to full-time teaching and a planned programme for their continued development.*
- *A blended approach to CPD, especially around increasing teacher confidence with subject knowledge, is required which has the support and commitment of all parties – the Government, school management and individual teachers.*
- *Enquiry and hands-on activities are central to teaching and learning in primary science but it must be well planned and resourced appropriately.*
- *Making science more relevant to children's everyday lives is key to engaging them with science and helping them to become active and informed citizens, who understand and take decisions about the impact of scientific and technological developments.*
- *Pupils' views and existing ideas cannot be ignored The teacher's role in adopting such a constructivist approach to learning requires support and professional development for teachers if they are to teach and assess an enquiry based creative science curriculum effectively and have the confidence to innovate and move away from recall of facts.*

Teacher concerns and aspirations

16. OfSTED has reported improvements in the overall quality of science teaching in recent years but there remain many concerns raised by teachers and their perceptions of their role. Against this background ASE, working with other partners notably the National Network of Science Learning Centres under took a seminar series[5] to explore both primary and secondary science teachers' views on their concerns and aspirations to improve the quality of their teaching and the learning experiences and achievements of their pupils.

17. The main concerns and barriers expressed by both primary and secondary teachers clustered around seven issues: lack of time, narrowness of teaching repertoire, assessment regimes, subject knowledge, lack of confidence and ownership, professional development and school management. As the discussion paper at Appendix 4 demonstrates they all are seen as major constraints to quality teacher and learning.

18. More positively teachers have aspirations in relation to their own teaching and what they feel they need in order to improve their own expertise, support their colleagues and enhance the learning of their students. Their aspirations fall into four areas – pedagogy and resources, assessment, leadership, continuing professional development – all of which need to be addressed. Appendix 4 again illustrates teachers' views. The discussion paper also outlines how, for one group of teachers, the barriers they identified impacted and restricted them in meeting their aspirations.

Professional Development: Initial Teacher Education Programmes (ITE)

19. Professional development for teachers commences with their pre-service training and should continue throughout their career. It is important therefore that the process is seen as a continuum and not as separate elements. The development by the TDA of standards for classroom teachers, which are currently awaiting approval by the Secretary of State for Education, may contribute to supporting a more holistic view of teachers' professional development. However, if used inappropriately such standards could place yet another burden on individual teachers.

20. Current ITE provision has contributed to improvements in the quality of newly qualified teachers entering the profession. However such programmes are not without their shortcomings which include:

    - the time to develop appropriate levels of subject knowledge, especially in science, is inadequate;
    - the balance of time between 'school-based' and 'college-based' work which needs to be reviewed to allow more quality time for reflection and trying out activities, notably practical experiments, with support;

21. In short the time available for preparing good teachers of primary science is brief and greater attention needs to be given to ensuring that programmes for trainees and their subsequent induction year, as a newly qualified teacher (NQT), are integrated much more closely.

Professional Development: Newly qualified teachers and induction

22. NQTs entering the profession take with them their career entry profile which sets out strengths and areas for development. In theory each individual has an entitlement to support during that first year but, in practice, the feedback we have received suggests that many do not receive the levels of support required. NQTs would benefit from a staged introduction to full-time teaching and a planned programme for their continued development.

23. Meeting individual needs of NQTs is a challenge for schools as programmes need, by definition, to be personalised through mentoring (in the region of 4 hours per week) feedback from lesson observations (GTP students often need additional support on pedagogy) and

[5] Appendix 4 *Engaging teacher, Engaging pupil, Engaging Science: a discussion paper.* Was prepared at an interim stage of the seminar series and highlights some of the findings. A full report with recommendations is currently being prepared

opportunities to meet with other NQTs and colleagues. All this takes time, which too often is not made available potentially contributing to higher than necessary 'dropout' rates.

Professional Development: continuing professional development

24. The importance of continuing professional development (CPD) is now widely accepted but, despite a wide range of CPD opportunities that are available through LEAs, ASE, CLEAPSS, NNSLC and others, the uptake, especially in subject-specific CPD, has declined in recent years.

25. From our experience of running the ASE Certificate of Professional Development, CPD needs to by tailored to individual needs in the context of their own school situation (hence making a contribution to the overall objectives of their school), develop classroom management, leadership and career development as well as their subject knowledge and pedagogy.

26. CPD requires a balance of elements including attendance on courses and conferences, time working with colleagues in school and personal reading and reflection. Such a blended approach requires commitment from a range of parties, the government, school management teams and individual teachers. CPD should be an entitlement with appropriate incentives but it also brings with it responsibilities for all those involved. Working towards achieving and maintaining the Chartered Science Teacher (CSciTeach) designation, developed by ASE in partnership with the Science Council (Bell and Lawrence 2006), is one way for individual teachers to demonstrate their commitment and acceptance of their responsibility for their CPD. This in combination with wider developments could make a significant contribution to the status and quality of science teaching by providing both recognition and, where appropriate, rewards. Currently discussions are taking place to explore the development of Chartered status in other areas of teaching.

27. The curriculum and assessment requirements have a significant impact on the quality of teaching and learning that takes place and this is no different for science. More importantly the way in which the requirements are implemented has more profound effects on the experiences and learning of students. Put simply 'teaching to the test' leads to a narrowing of not only teaching approaches and activities but also to the quality of knowledge and understanding gained by pupils and their engagement with the subject and their attitude to learning.

28. ASE promotes science for all students and therefore provision must be made for students with special educational needs in order to support those with learning difficulties, physical disabilities, behavioural problems as well as those who are gifted and talented.

Practical work in science

29. One of the key elements of learning in science is the central role of hands on practical work which offers opportunities for the development of a wide range of both subject specific and more general skills that are highly valued and contribute to students' learning and personal development. However in recent years there is evidence that the amount and quality of such activities has declined for a variety of reasons which include:

- the demands of the assessment procedures which have lead to teachers restricting the range of activities undertaken thus reducing the variety and creativity that encourages student engagement;
- the lack of confidence of teachers to undertake practical activities (including fieldwork) because of their own restricted experience,
- lack of time to try out experiments in advance and the perceptions that things are banned[6] on health and safety grounds;
- class-sizes which make management of practical work more difficult;

30. Arguments[7] for the value of outdoor science and the potential for activities have been discussed at some length, elsewhere, and are not reiterated here. However it is obvious that

[6] *Surely that's banned?* A report for the Royal Society of Chemistry on chemicals and procedures thought to be banned from use in schools (2005)
[7] See for example – *Outdoor Science*, School Science Review 87(320) March 2006

there is enormous untapped potential for enhancing teaching and learning in science. The advent of the Outdoor Manifesto, the continuing activities of the Real World Learning Campaign[8] and the drive to address issues of sustainable development in science education all point to the need to encourage greater use to the outdoors in science teaching and learning. This however requires greater support from government and others in order to emphasise its importance and to make it affordable.

As children move developmentally through the primary phase how do they learn best and how are they most effectively taught?

31. Primary education is developmental, and should start with the child in mind as Rousseau eloquently stated in 1911, 'Education should accommodate the child not the child accommodate education.' Rousseau, J. J. (1911) *Emile* London: J. M. Dent and Sons. As individuals, different children think and learn in different ways and the skilled teacher will develop and tailor the different learning experiences accordingly. Gardner, H. (1983) *Frames of Mind: The Theory of Multiple Intelligences.* London: Heinemann

Learning with understanding

32. The aim of learning in a modern education should be for understanding – making sense of what is experienced. Learning with understanding is often contrasted with learning by rote, which is regarded as memorisation rather than understanding. This does not mean that knowledge of facts is unimportant; just that it is insufficient. We know that children can learn lists of facts and names and many enjoy learning the big science words; indeed Bransford et al (1999) point out that 'children can learn practically anything by sheer will and effort'. Information needs to be organised if it is to be useful, so the understanding of principles and development of concepts is a key aim. In relation to floating, for example, the important thing is to understand not just what floats by why some things float. These mental structures cannot be 'taught' as such; they have to be created by the active participation of the learner. The reason why some things float could only be memorised as a form of words unless there is understanding of the concepts involved. But 'big ideas' such as those that explain why some things float and others do not, or why some plants thrive only in particular places, cannot be taught directly. They need to be built up from 'small' ideas, through enquiry based broadly practical activities which, at each developmental step, are within the reach of the children's current ideas and ways of reasoning, but which also challenge them to consider and test out their own and other ideas. An important aim is to help children to reflect upon what and how they learn so that on-going learning helps them to develop effective strategies for learning.

The role of talk and discussion

33. The role of talk and discussion in learning has recently received renewed emphasis (Alexander, 2006) although it was recognised long ago by Barnes (1978). Children need not only to have direct experience but also to develop their understanding through negotiation, exchanging views with others. It is important, therefore, that teachers plan time for discussion into practical work. It also helps to structure that time so that ideas are shared and used to take the understanding of all beyond what each could achieve individually (social constructivism).

34. At each stage they should be able to make sense of their experiences (including what they are told) in some way that satisfies them. There is a good body of evidence 'showing that learners use their current knowledge to construct new knowledge and that what they know and believe at the moment affects how they interpret new information. Sometimes learners' current knowledge supports new learning; sometimes it hampers learning' (Bransford et al, 1999). Learning may be hampered because their existing ideas may contain misconceptions, arising from their underdeveloped logical reasoning. It is therefore necessary for teachers to be aware of the general principle of the importance of children's initial ideas and how they may have been formed. In relation to the particular children they teach they need to be

[8] *Out-of-Classroom Learning; Practical information and guidance for schools and teachers* Real World Learning Partnership (2006)

aware of the particular ideas and reasoning of these children. Gardner, H (1993) and Johnston C (1996).

35. The implications of this for 'how children are most effectively taught' are summed up by Harlen (2006: p 9) as requiring teachers to:

- find out the children's ideas and use these as a starting point for building towards more effective, scientific ideas
- promote interaction of the children with the materials and resources through which they can develop understanding
- help children to develop the skills needed to test out ideas scientifically
- provide children with access to alternative ideas to their own, including the scientific ones
- promote dialogue and the development of shared understanding
- help children reflect on their ideas and on their ways of thinking
- monitor progress and reflect on the effectiveness of the learning experience provided.

What is the proper place of ICT and other new technologies in teaching and learning?

36. Recent studies of the brain, such as reported by Greenfield (2000), have led to 'network' models of learning where the ability to make connections between apparently unrelated ideas (for instance the motion of the planets and the falling of an apple) lies at the heart of early scientific learning in terms of both creativity and understanding. This learning model predicts that when children are engaged in constructivist learning, more pervasive neural connectivity and hence enhanced learning occurs. Using ICT in primary education can facilitate more constructivist learning (Murphy 2005).

37. When used effectively ICT can open up new dimensions for pupils - seeing and wondering at the previously unseen, or bringing the outside world into the classroom. ICT can facilitate faster, more accurate and visual ways of measuring, recording, analysing and interpreting data, and ICT provides effective research mechanisms and visual ways of communicating pupils' knowledge, understanding and ideas about science. Additionally ICT can help pupils develop up-to-date science appreciation and global science perspectives through easy communications with others in different parts of the world. As Ball (2003) summarised, ICT can be used in primary science as a tool, reference source, a means of communication and for exploration.

38. However there is little systematic research on the use of ICT in primary science teaching other than how it is used to support specific projects such as those reported in the ASE journal, *Primary Science Review* (Jan/Feb 2003), (Murphy 2005).

39. From our discussions with teachers, it is clear however that ICT cannot and should not replace the hands-on experience: ICT may support investigations but is not the reason for undertaking the investigation. To be most effective ICT should be part of a planned experience and used by students collaboratively. When used less effectively, ICT is not interactive, providing a poor diet of PowerPoint presentations and virtual experiences which replace the first hand experiences needed by learners. There is anecdotal concern also that the positive impact of ICT may not be proportional to the costs involved and the expense of some equipment such as data loggers can lead to more teaching by demonstration rather than direct experience. Teacher familiarisation training with ICT may help improve the situation as, when used interactively, ICT can enhance the whole class learning experience.

In what ways might teaching, and the organisation of classrooms and schools, change in order to enhance young children's engagement and learning and maximise their educational prospects?

40. Our discussions with teachers highlight a general consensus around the following points:

- More active learning would be promoted by reduced class sizes or larger and more versatile classrooms with easy access to appropriate technologies and stimulating outdoor facilities. Johnston, J. (2005).
- Teaching needs to maximise opportunities for children to learn through talking and discussion. As a hangover from their own school days many parents see the good classroom as the quiet classroom where all pupils put their hand up to answer a question but otherwise are writing in silence. There is a need to persuade others of the importance of different ways of working. See, for example, Osborne, J., Erduran, S. & Simon, S. (2004).
- The government's new personalised learning agenda is to be welcomed (DfES 2006), where pupils are partners in planning their own learning through setting targets with their teachers, working with their teachers to evaluate, achieve and set new targets and the classroom is arranged to suit their learning; see Schwienhart L.J, Weikart D.P, & Toderan R. (1993). However this has implications for staffing levels and ways of working in schools.
- Some teachers, especially those with a non-specialist background in individual subjects, may need additional support and CPD to facilitate this agenda.

41. Teachers were also in agreement with the following points made in the Primary Horizons report (Wellcome Trust 2005):

- There should be a review of curriculum content to provide greater opportunities for teachers to focus on topics likely to develop scientific skills and generate enthusiasm. It is hoped that primary science will benefit from the latest moves in secondary science to reduce the prescribed course content in favour of developing broader skills. Complex scientific terminology should be used only when appropriate, for instance, when answering children's specific questions, when explaining the more scientific use of otherwise familiar terms (e.g. insulation) or when children introduce complex language themselves (such as names of dinosaurs).
- The links between science and other subjects should be made more explicit and strengthened to help bring science to life and develop transferable skills.
- There should be wider use of creative and innovative approaches such as role-plays, stories and co-teaching between existing teachers and specialist science training teachers. Many of these techniques have been shown to improve teachers' confidence and skills to teach science and to spark children's interest and enthusiasm.

Curriculum and assessment

42. **Key Messages**

- *If the core curriculum is to be maintained the core subjects, including science, should have genuine parity in terms of status, curriculum time, support, access to CPD and funding.*
- *The effect of a science curriculum taught through hands-on, investigative activities with a good balance between process skills and appropriate science content makes a significant contribution to pupil engagement and enjoyment of learning.*
- *To meet pupil needs we must build flexibility into the curriculum otherwise risk ending up with another 'one-size fits all' model and many of the problems we face today will simply return at some point in the future.*
- *'Teaching to the test' with a focus on content and factual knowledge leads to a narrowing of not only teaching approaches and activities but also to the quality of*

knowledge and understanding gained by pupils and their engagement with science as part of their overall learning.

- *A change in policy with regard to testing and target setting is the essential first step in providing our primary pupils with the experiences that will develop their understanding, interest in and enthusiasm for science.*
- *A greater focus on assessment for learning and assessment of skills, and valuing the teachers' role in assessing pupil progress is required to support learning and give a meaningful measure of progress.*
- *There is a need for the primary science curriculum to more explicitly relate ideas to contemporary contexts and introduce, at an appropriate level, some of the major issues of this century such as global citizenship and sustainability.*

What do children currently learn during the primary phase?

43. There is a wide range of practice in schools across England which includes teachers taking steps to find out children's ideas, observing their skills and providing formative feedback (Murphy and Beggs, 2005). Many schools offer their children an excellent grounding in science and also allow them opportunities to test out their own ideas and challenge evidence, whilst encouraging a sense of amazement of the things around them and the way they work. DfES (2003) *Excellence and Enjoyment. A strategy for primary schools.* London: DfES

44. However, there is far too much practice that is dominated by teachers telling and pupils copying. Teachers themselves recognise that the curriculum content is insufficiently relevant and interesting to pupils. This may result from relentlessly following the non-statutory QCA scheme of work which gives little incentive to build on pupils' questions and interests. Murphy and Beggs report on teachers' views and pupil experiences of primary science highlights the need for greater relevance of science activities to real life. This is more easily achieved in broader topics than when science is taught as a separate subject.

45. A major factor determining teachers' approaches to science is the existence of the national tests in science at the end of KS2. These are tests with 'high stakes' for teachers; pupils' performance in them is used as a basis for evaluating teachers and schools. The impact of this has lead to transmission teaching and drilling in what is tested, and now contributes one third to whole school Contextual Value Added measures, as used by OfSTED to provide a picture of the progress children make from KS1 to KS2. This extends not only throughout Y6 but often in Y5 as well. It is well documented that this happens in any situation where 'high stakes' tests are used. For example, research carried out by Johnston and McClune (2000) in Northern Ireland at the time of the 11+ examination, found that the teachers adopted a teaching style that had negative consequences for pupils' learning dispositions, self-esteem, locus of control and attitude to science. They investigated how pupils preferred to learn and found most with a strong preference for first-hand exploration and problem-solving. The teachers, however, were providing highly structured activities, very little opportunity for interaction with objects and materials and just giving children information. The teachers reported that they felt constrained to teach this way because of the important test. It is perhaps no wonder, then, that decline in pupils' positive attitudes to science, which was well know in the secondary school years, now starts in the last years of primary school (Osborne et al, 2003). This is echoed by many teachers during our discussions with comments such as:

    - By the end of KS2 too many children learn just what is tested - they learn to give 'right' answers though probing questions often reveal significant misconceptions in many of the pupils who score well in the tests.
    - They learn that passing tests is more important than making sense of things.
    - They tend to learn too much factual information and not enough enquiry or thinking skills to allow them to apply or understand the facts. Too many facts that can be acquired without activity and enquiry
    - The current regime of testing is producing superficial success. Unimaginative test preparation (drilling of facts etc) is having a detrimental effect on development of practical and enquiry skills and on pupils' engagement with the subject.

46. A further constraint on providing the kind of experiences that the valued learning requires (see Box under *What should they learn? Page 11*) is the subject knowledge of the teacher. This has been a problem since science has been taken seriously as part of the primary curriculum. Its effects have been well researched (Osborne and Simon, 1996; Turner-Bissett, 1999) and are known to include concentrating on topics where confidence is higher (often biological ones at the expense of physical science), heavy reliance on workcards and text books, emphasis on transmission of information and restricting discussion and pupils' questions (Holroyd and Harlen, 1996). However, changes in the training of primary teachers do seem to have eased this problem for the future (although it should be remembered that there are no national CPD schemes for primary teachers – the valuable GEST funded 20 day courses finished long ago!). Murphy and Beggs (2005) report from their survey that few teachers in their 20s felt that lack of science knowledge was an issue for them, whilst it remained so for over half of those in their 30s or older.

What should they learn?

47. Teachers had many contributions to make to these discussions including:

- an excellent grounding in science ideas and opportunities to test out their own ideas and challenge evidence whilst developing a sense of amazement at the things around them and the way they work
- skills for enquiry, problem solving, thinking, research, how to use technology
- topical science issues which are of interest to them
- minimal core content , taking into account what is appropriate preparation and grounding for the secondary phase, and the rest should be should be agreed at school level with the children.

48. Ideal experiences for primary children learning science are summarised in the box:

- Gathering evidence by observing real events or using other sources
- Pursuing questions which they have identified as their own even if introduced by the teacher
- Raising further questions which can lead to investigations
- Making predictions based on what they think or find out
- Talking to each other or to the teacher about what they are observing or investigating
- Expressing themselves using appropriate scientific terms and representations with understanding both in writing and talk
- Suggesting ways of testing their own or others' ideas to see if there is evidence to support these ideas
- Taking part in planning investigations with appropriate controls to answer specific questions
- Attempting to solve problems for themselves
- Using a variety of sources of information for facts that they need for their investigation
- Assessing the validity and usefulness of different ideas in relation to evidence
- Considering ideas other than their own
- Reflecting self-critically about the processes and outcomes of their inquiry.

49. Current teaching methods are influenced by two opposing influences. On the one hand are the perceived requirements for meeting targets which put pressure on teachers to constrict content and teaching methods as already outlined. There is massive research evidence (some reviewed by Harlen and Deakin Crick, 2003; Black and Wiliam, 1998; Crooks, 1988) of this effect. Influences that would lead to greater emphasis on enquiry, using assessment for learning and developing thinking skills, are much less strong although also evidence-based. They are less influential because they are optional, whilst testing is a statutory requirement. Thus whilst many teachers would like to change their practices (James and Pedder (2006)

provide evidence of this in relation to classroom assessment practices), it is only those who have close local support who are prepared to take the risk of going beyond what is tested.

50. This argument lays the blame with the policy-makers rather than the teachers. This is not to say that change can be readily effected by a change in policy. A generation of teachers has become used to the current situation of perceived prescription in the QCA scheme of work and lack the skills of teaching creatively and building on children's ideas and questions. However a change in policy in regard to testing and target setting is the essential first step in providing our primary pupils with the experiences that will develop their understanding, interest in and enthusiasm for science.

What is the proper relationship and balance of assessment for learning and assessment for accountability?

What are the strengths and weaknesses of current approaches to assessment, both national and local?

How should their (pupil) progress and attainment be assessed?

51. If we are really serious about developing critical thinking, problem-solving, understanding of and about science, etc., then the short answer to this is 'by their teachers'. Teachers we consulted had plenty of comments to add to this discussion, and on the balance of national and local in curriculum and assessment such as:

- Assessment for learning (AfL) should be the prime business of schools - if you concentrate on AfL, with professional development for teachers to support this, then learning will improve and that will mean that everyone benefits.
- Personal learning planning covers both learning and accountability.
- Good teacher assessment requires teachers who have good pedagogical subject knowledge – there are issues of the need for CPD and teacher confidence in their ability to make judgements. Over reliance on summative tests may lead to de-skilling of teachers in assessment techniques, knowledge of level characteristics and ability to plan next steps in learning.
- Within the key ideas there should be freedom to adapt the contexts for teaching of knowledge and skills to the locality and the location specific experiences and concerns of the pupils. This would allow links to local citizenship.
- National is a set core, local is the topical interests of the children/ community. Local sets HOW the national outcomes are achieved.

52. If this is to happen then we must make sure that their progress in these areas is assessed, both in order to help learning (formative) and to report on learning (summative). Using assessment to help learning is central to enquiry-based education and there is evidence of its effectiveness (Black et al, 2003). Similarly, the introduction of thinking skills is known to lead to improved outcomes. In these cases assessment is part of teaching and there is a lesser role for grading, 'levelling', or making judgements. Whilst it is helpful to learners to have levels, understanding of progression of scientific skills and knowledge concepts is key to ensuring that teachers are able to move children on in their learning. The aim is for teachers and pupils to collect and use information that can be used to decide where children have reached, what their next steps are and how to take them.

53. In the case of summative assessment, we should also be able to report on all kinds of learning outcomes. At present this does not happen, because tests cannot do this. Even though tests (at present) only occur at the end of key stages, there are other, sometimes commercial, tests that are given at other times; and teachers tend to emulate these tests when making their own. Moreover, as the work of the Assessment systems for the Future (ASF), reported in ARG (2006) found that a system based on testing is flawed, because:

- It fails to provide information about the full range of educational outcomes that are needed in a world of rapid social and technological change and therefore does not encourage the development of these skills

- It inhibits the development of assessment for learning which is proven to raise achievement levels and reduce the gap between higher and lower achieving pupils (Pollard and Triggs, 2000).
- The data it provides are less reliable than they are generally thought to be. For example it has been estimated that the key stage tests in England result in the wrong levels for at least a third of pupils at the end of KS2 and up to 40 per cent at the end of KS3 (Wiliam, 2001)
- The weak reliability of tests means that unfair and incorrect decisions will be made about some pupils, affecting their progress both within and between schools (Black and Wiliam, 2006) and beyond school.
- There is no firm evidence to support the claims that testing boosts standards of achievement (Tymms, 2004).
- It reduces some pupils' motivation for learning (Harlen and Deakin Crick, 2003).
- It imposes stressful conditions that prevent some children from performing as well as they can (Pollard et al, 2000; Reay and Wiliam, 2000).
- It encourages methods of teaching that promote shallow and superficial learning rather than deep conceptual understanding (Harlen and James, 1997).
- Apart from the anxiety caused by the tests, revision and practise tests take up a considerable amount of time in years 5 and 6 particularly, estimated by the ASF project to be the equivalent of three weeks of learning in each year (Harlen, 2007).

54. Comments from teachers such as these below contribute to the arguments for a reduced emphasis on summative assessment:

- Summative assessment by testing, with results used for accountability, can lead to less creative teaching and learning, a narrower experience for pupils and pupils with less real understanding of or interest in science.
- Skills would be more effectively assessed by using investigative activities with clear assessment criteria and an AfL approach.
- Current assessment is too narrow and does not really assess the important aspects of creativity, thinking etc. at present we are teaching 'exam techniques'.
- Teachers need CPD and continuing support to ensure they have a clear understanding of pupil progress in science skills and concepts.

55. The alternative to testing is to use teachers' judgments, which have the following advantages:

- Teachers can assess a wider range of achievement and learning outcomes than formal tests. Teachers' assessment can provide information about learning processes as well as outcomes.
- Freedom from test anxiety and from practice in test-taking means that assessment by teachers gives a more valid indication of pupils' achievement.
- With appropriate training and moderation teachers' assessment can reach satisfactory levels of reliability.
- Teachers have greater freedom to pursue learning goals in ways that suit their pupils.
- When teachers are gathering evidence from pupils' on-going work, information can be used formatively, to help learning, as well as for summative purposes.
- Moderation procedures provide valuable professional development for teachers.
- Pupils can share in the process through self-assessment and derive a sense of progress towards "learning goals" as distinct from "performance goals".
- Financial resources are released at the school level by reducing the number of commercial tests purchased.
- Teachers can spend more time teaching rather than preparing for and marking tests.
- Pupils' learning time is increased.

Structures and phases

56. **Key Messages**

- *As part of a wider curriculum review, work needs to be done to more clearly identify what characterises primary science and the experience for pupils, and how these contribute to seamless transitions with true continuity and progression through and between phases or key stages.*
- *Transition issues that arise when students move from one phase to another must be addressed and the lessons learnt from new transition initiatives must be brought together and acted upon by relevant parties.*
- *There is a need to address the disengagement which appears to be increasing during Yrs 5/6 and seems to be linked, at least in part, to an overemphasis on SATS.*
- *More effective links are required between numeracy, literacy and science in order to maximise the synergies and opportunities that such links support.*

Are there problems of coherence, transition and continuity within and between phases?

How can these be overcome?

What can the primary phase profitably learn from developments in the phases which precede and follow it?

57. A key element in the quality of science education must be the way in which the experiences available to students at different stages in their life link together. In terms of formal education this means the continuity and progression that develops between primary and secondary school, pre and post 16, school / college and University as well as, school / college / university and employment. In other words the transition issues that arise when students move from one phase to another must be addressed.

58. In well managed schools, the foundation stage emphasises doing, looking and talking. These foundation principles and practice continue during KS1, ensuring children move gradually and at the appropriate pace for them into a more highly structured curriculum. Pressure on Year 2 teachers to carry out teacher assessment for science, often without adequate training and support can also lead to formalising and narrowing the science curriculum in KS1 with the emphasis on content coverage at the expense of skills development.

59. Over recent years transition between primary and secondary phases has been improved – especially when secondary teachers know the contexts in which pupils had previously learned a concept - but there is still work to be done. It is early days but it is important that the lessons learnt from successful transition initiatives such as those funded by the AstraZeneca Science Teaching Trust must be brought together and acted upon.

60. The proposed changes to the KS3 science curriculum and the recent changes at KS4 with their focus on reduced content, flexibility, different student interests and how science works are all positive directions for future primary science curriculum review.

61. Teachers in our discussion groups made the following observations:

- We still have problems with transition to secondary and that mainly occurs because secondary still believe in a fresh start because primary can't possibly do science properly! We need to seriously talk more.
- Using end of key stage tests to provide data for the next phase of education does not always provide an accurate indication of what pupils can do in science, especially where they have been drilled, or in the case of pupils with SEN or EAL who may have literacy levels below their scientific skills and understanding.
- Pupils who have just revised the entire primary science curriculum do not come to the units of work in KS3 fresh and interested as they do when they have not met a particular area of science for several terms.

- The recognised drop in pupil engagement Y7-9 is now being seen in Y5 and 6. It seems that dry test preparation and the lack of a broad and balanced curriculum are major contributory factors.
- Transition projects often have limited success because they facilitate primary and secondary teachers working together for set up purposes. Successful transition is much more robust when teachers work together on a regular basis.
- Transition problems may be overcome by following a more skills based curriculum. This would still require a core of knowledge and common practical and investigative experiences to avoid repetition (context rather than detailed content).
- Better use of AfL could free teachers from needing to know in detail what had gone before; they could use elicitation activities/strategies to establish and work from pupils' actual starting points in each unit of work.
- Foundation stage has an emphasis on doing, looking and talking – just because older pupils can write it down doesn't mean they have to!

Conclusion

62. Primary Science Education is not perfect but ASE has substantial evidence that there is much to be celebrated and that there are significant numbers of teachers in primary schools who are engaging students in science everyday. The challenge facing us all is ensure that the high quality teaching that exists is available to all pupils.

63. ASE, in accordance with it aims, is more than willing to continue to play its part in this endeavour and would be very pleased to discuss this submission, and any other issues, with the Primary Review team.

APPENDIX ONE: The Association for Science Education

The Association for Science Education is the largest subject association in the UK, with approximately 18,000 members including teachers, technicians and others involved in science education. The Association plays a significant role in promoting excellence in teaching and learning science in schools and colleges. Working closely with the science professional bodies, industry and business, ASE provides a UK-wide network bringing together individuals and organisations to share good ideas, tackle challenges in science teaching, develop resources and foster high quality continuing professional development.

The objects and purposes of ASE are clearly stated in its Charter of Incorporation as the promoting of education by the following means.

- *Improving the teaching of science;*
- *Providing an authoritative medium through which opinions of teachers of science may be expressed on educational matters; and*
- *Affording a means of communication among all persons and bodies of persons concerned with the teaching of science in particular and education in general.*

In a more modern context,

The Association for Science Education aims to promote excellence in science teaching and learning by:

a. Encouraging participation in science education and increasing both new membership and the retention of existing members.
b. Enhancing professionalism for teachers, technicians and others through provision of high quality continuing professional development and promotion of chartered status.
c. Working in partnership with other organisations, thus maintaining and strengthening its position in influencing policy and its reputation for delivering cutting edge initiatives for its members and, through them, to the wider science education community.

Further details of the ASE and its regional, national and international activities can be found on its web-site (www.ase.org.uk).

In preparing this submission to the Primary Review, ASE has drawn on first hand contributions from members of ASE Council, our primary, 11-19 and research committees plus our two Special Interest Groups (National Advisers and Inspectors Group for Science[9] (NAIGS) and, Association of Tutors in Science Education[10] (ATSE).

[9] Appendix 2 provides a summary of the aims of The National Advisers and Inspectors Group for Science
[10] Appendix 3 provides a summary of the aims of The Association of Tutors in Science Education

APPENDIX TWO: The Association of Tutors in Science Education (ATSE)

This Special Interest Group of The Association for Science Education exists to:

- further the aims of The Association for Science Education;
- support the work of Science Tutors, mentors and others working in initial teacher education throughout the UK;
- facilitate the exchange of ideas about science education, and alert national agencies to issues of concern to the membership.

APPENDIX THREE: National Advisers and Inspectors Group for Science (NAIGS)

This Special Interest Group of The Association for Science Education exists to:

- further the aims of The Association for Science Education;
- support the work of Science advisers, inspectors and others working in a science advisory or support capacity throughout the UK;
- facilitate the exchange of ideas about science education, and alert national agencies to issues of concern to the membership.

APPENDIX FOUR

THE ASSOCIATION FOR SCIENCE EDUCATION
NATIONAL NETWORK OF SCIENCE LEARNING CENTRES

ENGAGING TEACHERS… ENGAGING PUPILS…ENGAGING SCIENCE
Teachers' views on teaching science in ways which will get pupils excited about the subject.

DISCUSSION PAPER

Introduction

If you were to walk into a science lesson in any school you may sense a buzz of excitement, observe pupils engaged in their work with enthusiastic, effective and engaged teachers delivering an engaging science curriculum. Alternatively you may experience the opposite - disaffected pupils, tired and dispirited teachers and an utterly tedious science curriculum – or something between these two extremes. You may well ask, "Why this disparity?" and "What can be done to ensure that all pupils (and teachers) are engaged in vibrant and engaging science lessons?"

In his Presidential Address to the ASE in January 2005, Sir Mike Tomlinson emphasised the importance of the role of teachers in developing the curriculum they teach and in making science exciting for their pupils. This idea was echoed by The Nuffield Review of 14-19 Education and Training in its second annual report when it argued that,

The curriculum should be seen as a creative act within schools, not something handed on. Hence the teacher should be a curriculum developer, not a transmitter, translating the national framework into planning in classrooms and at school. This creative aspect of teaching is undermined by the relentless pursuit of targets. (Executive Summary p2).

Despite the pressures, the majority of science teachers want to interest their students in science and there still exists the enthusiasm and determination to improve the situation. The recent revision of the KS4 programme of study and the review of KS3 curriculum in England provide opportunities for revitalising curriculum development at the level of the school and laboratory. Developments elsewhere in the UK offer similar opportunities, as do calls for more creativity in primary schools. These opportunities, however, may be lost if teachers in both primary and secondary schools are unable to take advantage of such changes due to the barriers, perceived or actual, that currently exist.

Aims

This discussion paper, which arises out of a 24 hour seminar held on 17-18 November 2005 at the National Science Learning Centre in York, aims to take the initial debate forward and provide the basis for further discussions throughout the country in order to determine the views of teachers as to how they, as teachers, can work to improve pupils' engagement with science and, crucially, what needs to be done to support them (nationally and locally) in their efforts.

Concerns and barriers

Despite the wide variety of ways of expressing the complex mix of factors that are involved in teaching science there is a fundamental commonality, regardless of phase – primary, secondary or tertiary - in the concerns expressed. In addition to the particular issues listed below it is clear that, for whatever reason, there are some very strong perceptions that are held by teachers regarding what is statuary and what is advisory. Three particular 'myths' are referred to frequently. The first is the belief that the QCA schemes of work at KS1, KS2 and KS3 are compulsory. The second is the misconception that many experiments are 'banned'. The third is the 'requirement' for a 'three-part lesson'.

The main concerns and barriers seem to cluster around seven issues: lack of time, narrowness of teaching repertoire, assessment regime, subject knowledge, lack of confidence

and ownership, professional development and school management. Each of the items in itself can be a major inhibitor to effective teaching and the impact of each one varies from situation to situation. However, as the quotes reported below clearly illustrate, these issues are seen to be significant concerns and barriers for teachers.

Lack of time

"I never get time to think about my teaching."

"Our medium term plans are so restrictive that there just isn't time to experiment with new ideas "

Narrowness of teaching repertoire

"We have to follow the QCA scheme of work in my school. It is really frustrating as I don't think it is the best thing for some of my pupils, but the timing is so rigid that I can't change it."

"If you look at the technician order sheets in my department you'll find some of my colleagues are doing hardly any practicals. Surely science is essentially a practical subject."

Assessment regime

"After Christmas we do 3 or 4 mock SATs papers. No one seems to have the guts to just carry on teaching good interesting science."

"Year 10 and 11 just seem to be on a treadmill of one module exam after another. That wouldn't have inspired me to take science (and it certainly doesn't inspire them)"

Subject Knowledge

"I feel less confident in my science knowledge than with history or geography for example. My science co-ordinator does her best to help but she isn't very confident either."

"I'm all for science teachers teaching science (and not just their specialist area) but one or two colleagues are expected to do this when they obviously don't have the necessary background knowledge. I feel that they are really switching some pupils off."

Lack of confidence and ownership

"There is so much pressure to get results that I just daren't take risks."

"Everyone is so paranoid about results that they seem afraid to innovate in case things go wrong."

Professional development (CPD)

"It is always the same people who seem to go out on courses- those who are "in" with senior management"

"Most of our CPD budget was used up on whole school CPD i.e. getting in visiting speakers"

School management

"Senior management always seem to focus on "whole school" issues. These don't always match the needs of the science department."

"I don't think my head understands the needs of science at all, especially the practical nature of the subject."

Aspirations

Teachers have aspirations in relation to their teaching and what they feel they need in order to improve their own teaching, support their colleagues and enhance the learning of their students. Aspirations broadly fall into four areas – pedagogy and resources, assessment, leadership, continuing professional development (CPD) – all of which need to be addressed if progress is to be made in removing the barriers and allaying concerns. Again the quotes illustrate the issues clearly.

Pedagogy and resources

I would like…

- my job to be creative and have time to try out new ideas.
- to be involved in developing teaching strategies.
- to reflect on my teaching so that I can make improvements myself.
- time to get used to new initiatives and to get them working in my classroom (before being presented with the next).
- the resources I need to make my lessons exciting (i.e. a working fume cupboard, enough beakers etc…).
- our medium term planning to be more flexible so that I had space to experiment with new ideas.

Assessment

I would like…

- assessment to motivate my pupils and reward their success.
- assessment to encourage learning (and not be a full stop at the end of learning).
- to be able to continue teaching engaging science in year 6, rather than feel pressured to do endless SATs preparation.

Leadership

I would like…

- to be empowered to do a good job.
- senior management to support my own professional development as well as the school's.

CPD

I would like…

- to have the right to a certain amount of CPD, without needing to ask for it all the time.
- CPD to support innovation and not just to encourage the following of a recommended method.
- science specific CPD.

Table 1, attached as an appendix, indicates some of the ways in which, based on the discussions at the York seminar, the concerns and barriers impact on the four areas outlined above.

Furthermore it is widely accepted that the quality of teaching and learning is at the heart of any improvement that might be achieved by a school and this in turn is dependent on what constitutes teachers' professional knowledge. This, however, is not always reflected in the way in which priorities are addressed in schools and nationally. One of the difficulties is the lack of a 'common language' for discussing the issues and results in unnecessary tension and conflict which results from misunderstandings rather than fundamental differences in opinion.

APPENDIX: Table 1: IMPACT OF CONCERNS/BARRIERS ON ASPIRATIONS: the notes in the boxes aim to indicate ways in which the aspirations are NOT being met. (The contents of this table are based on the discussions which took place during the 24-hour seminar held at the National Science Learning Centre, University of York on 17-18 November 2005.)

Concern / Barrier	**Aspirations**			
	Pedagogy and resources: wish to be more creative	**Assessment: should support learning better**	**Leadership: needs to empower more**	**CPD: appropriate to include subject focussed**
Lack of time	Too much to do in the time available	Takes time away from teaching	Focus on results increase pressure to teach to the test	Not enough time for reflection or subject focussed work
Narrowness of teaching repertoire	Pressures to use specific schemes of work	Focus on tests	As above	Little opportunity to find out about and try new ideas
Assessment regime	Results driven pressures restricts activities	Emphasis on summative diminishes impact of formative	Demands of league tables and targets increase central control.	Geared to examination requirements
Subject knowledge	Lack of confidence in subject knowledge restricts range of activities.	Need to get 'right' terms – factual recall rather than understanding	Not always aware of needs at subject level.	Need for sustained study.
Lack of confidence / ownership	Risk averse – play safe in approach and activities	Focus on tests not subject understanding and enjoyment	Sense of needing permission to try something different	Feeling time cannot be taken to leave students (or they might miss something)
Lack of Professional development	Continue with standard activities. Few new ideas.	Re-enforces test focus	Different priorities linked to school targets	Lack of reflection and development
School management	Lack of encouragement to try different things	Demands for further increases in grades and test scores	Pressures on SMT get pushed onto others	Tension between different priorities and availability of staff

References

Alexander, R. (2006) *Towards Dialogic Teaching: rethinking curriculum talk, 3rd edition.* York: Dialogos.

ARG (Assessment Reform Group) (2006) *The Role of Teachers in the Assessment of Learning*. Obtainable from the ARG website: www.assessment-reform-group.org and from the CPA office of the Institute of Education, University of London.

AstraZeneca Science Teaching Trust transition projects

Ball, S. (2003) *ICT that works.* Primary Science Review. 76, 11-13

Barnes, D. (1978) *From Communication to curriculum.* Harmondsworth: Penguin.

Bell, D. & Lawrence, J. (2006) *Recognising professional expertise: Chartered Science Teacher*, Education in Science, April 2006

Black, P., Harrison, C., Lee, C., Marshall, B, and Wiliam, D. (2003) *Assessment for Learning: Putting it into Practice.* Maidenhead: Open University Press.

Black, P. and Wiliam, D. (2006) *The reliability of assessment*, in J. Gardner (ed) Assessment and Learning. London: Sage.

Black, P. & Wiliam, D. (1998a) *Assessment and Classroom Learning*, Assessment in Education, **5**: 1-74.

Bransford, J.D., Brown, A.L. and Cocking, R.R. (Eds) (1999) *How People Learn.* Washington: National Academy Press.

Crooks, T.J. (1988) *The impact of classroom evaluation practices on students*, Review of Educational Research, 58: 438-481.

DfES (2003) *Excellence and Enjoyment. A strategy for primary schools.* London: DfES

DfES, (2006) Personalised Learning www.standards.dfes.gov.uk/personalisedlearning/

Gardner, H. (1983) *Frames of Mind: The Theory of Multiple Intelligences.* London: Heinemann

Gardner, H. (1993) *The Unschooled mind. How Children Think and How Schools Should Teach*. London: Fontana

Greenfield, S. (2000) *The Brain Story*, London BBC books

Harlen, W. (2007) *Assessment of Learning*. London: Sage.

Harlen, W. (2006) *Teaching, Learning and Assessing Science 5-12*. 4th Edition. London: Sage.

Harlen, W. and Deakin Crick, R. (2003) *Testing and motivation for learning*, Assessment in Education, 10 (2): 169-208.

Harlen, W. and James, M. (1997) *Assessment and learning: differences and relationships between formative and summative assessment,* Assessment in Education, 4(3) 365-80.

Holroyd, C. and Harlen, W. (1996) *Primary teachers' confidence about teaching science and technology* Research Papers in Education. 11(3), 323-335.

James, M. and Pedder, D. (2006) *Beyond method: assessment and learning practices and values,* The Curriculum Journal, 17 (2):109-138.

Johnston C (1996) *Unlocking the Will to Learn.* California: Corwin Press Inc.

Johnston, J. (2005) *Early Explorations in Science 2nd Edition.* Buckingham: Open University Press

Johnston J. and McClune, W. (2000) *'Selection project sel 5.1: Pupil motivation and attitudes - self-esteem, locus of control, learning disposition and the impact of selection on teaching and learning',* in The Effects of the Selective System of Secondary Education in Northern Ireland: Research Papers Volume II, Bangor, Co Down: Department of Education: 1-37.

Murphy, C. (2005) *Literature Review in Primary Science and ICT*. A report for Nesta Futurelab Series

Murphy, C. and Beggs, J. (2005) *Primary Horizons. Starting out in Science.* London: Wellcome Trust.

NESTA (2005) *Real Science, Encouraging experimentation and investigation in school science learning*, NESTA

Osborne, J., Erduran, S. & Simon, S. (2004) *IDEAS: Ideas Evidence and Argumentation in Science (IDEAS) Project* London: Kings College London

Osborne, J. Simon, S. and Collins, S (2003) *Attitudes towards science: a review of the literature and its implications*. *IJSE* 25, 1049-1079.

Osborne, J. and Simon, S. (1996) *Primary science: past and future directions*. Studies in Science Education, 27, 99-147.

Pollard, A. and Triggs, P. (2000) *Policy, Practice and Pupil Experience.* London: Continuum International Publishing Group.

QCA (2007) A big picture of the curriculum (draft February 2007)

Reay, D. and Wiliam, D. (1999) *'I'll be a nothing': structure, agency and the construction of identity through assessment,* British Educational Research Journal, 25: 343-345.

Rousseau, J. J. (1911) *Emile* London: J. M. Dent and Sons.

Schwienhart L.J, Weikart D.P, & Toderan R (1993) *High Quality Preschool Programs Found to Improve Adult Status* Ypsilante, Michegan: High/Scope Foundation

Shayer, M. & Adey, P. (2002) (eds.) *Learning Intelligence. Cognitive Acceleration Across the Curriculum from 5 to 15 Years*, Buckingham; Open University Press.

Turner-Bissett, R. (1999) *The knowledge base of the expert teacher*, British Educational Research Journal, 25 (1) 39-55.

Tymms, P. (2004) *Are standards rising in English primary schools?* British Educational Research Journal, 30 (4):477-494.

Wellcome Trust (2005) *Primary Horzons: Starting Out in Science*. The Wellcome Trust

Wiliam, D. (2001) *Reliability, validity, and all that jazz.* Education *3-13*, **29**(3) 17-21.

Yapp, C. (2003) *The Dynamics of Change* Paper presentation at the UCET e-Learning Conference, Belfast, St Mary's University College