National Curriculum Review – Call for Evidence

A SCORE response to the Department for Education's call for evidence on the review of the National Curriculum

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Cc Annette Smith (Association for Science Education)
Professor Peter Main (Institute of Physics)
Libby Steele (Royal Society)
Professor Jim Iley (Royal Society of Chemistry)
Rachel Forsyth (Society of Biology)

SCORE

SCORE is a collaboration of organisations, which aims to improve science education in UK schools and colleges by supporting the development and implementation of effective education policy. SCORE is currently chaired by Professor Graham Hutchings FRS and comprises the Association for Science Education, Institute of Physics, Royal Society, Royal Society of Chemistry, and Society of Biology.

Association for Science Education

The Association for Science Education (ASE) is the largest subject association for education in the UK. Members include teachers, technicians and others involved in science education. The Association plays a significant role in promoting excellence in teaching and learning of 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 ideas and tackle challenges in science teaching, develop resources and foster high quality continuing professional development.

Institute of Physics

The Institute of Physics is a scientific charity devoted to increasing the practice, understanding and application of physics. It has a worldwide membership of around 40,000 and is a leading communicator of physics-related science to all audiences, from specialists through to Government and the general public. The Institute's Education Department works in policy, teacher recruitment and retention, teacher support and student support.

Royal Society

The Royal Society is a Fellowship of more than 1,400 outstanding individuals from all areas of science, mathematics, engineering and medicine, who form a global scientific network of the highest calibre. The Society is committed to an evidence-based approach to supporting responsible policy-making within science and education, drawing upon high quality information and advice from its Fellows and Foreign Members, the wider scientific and education communities and others to achieve this.

Royal Society of Chemistry

The Royal Society of Chemistry is the UK professional body for chemical scientists and the largest organisation in Europe for advancing the chemical sciences. Supported by a worldwide network of over 47,500 members and an international publishing business, the Society's activities span education, conferences, science policy and the promotion of chemistry to the public.

Society of Biology

The Society of Biology is a single unified voice for biology: advising Government and influencing policy; advancing education and professional development; supporting its members, and engaging and encouraging public interest in the life sciences. The Society represents a diverse membership of over 80,000 – including, students, practising scientists and interested non-professionals – as individuals, or through learned societies and other organisations. The Society supports and recognises excellence in biology teaching and champions a biology curriculum that challenges students and encourages their passion for biology.

SCORE
SCIENCE COMMUNITY REPRESENTING EDUCATION

1. Executive summary

1.1. This response

1. The SCORE member organisations have worked together to provide the Department for Education (DfE) with evidence on the sciences[1] for the National Curriculum review. This response is therefore supported by each of the organisations forming SCORE.

2. The response is in two parts. Part 1 includes SCORE's guiding principles for developing the National Curriculum[2] for the sciences and the fundamental features of a National Curriculum for the sciences.

3. The Institute of Physics, the Royal Society of Chemistry and the Society of Biology have each drawn on the expertise of their memberships to produce guiding principles for the development of the curriculum in each subject area. These can be found in Part 2 of our response.

4. The SCORE partners all support these separate subject contributions which continue to be developed towards a consistent and coherent National Curriculum for the sciences.

1.2. The importance of the sciences

5. SCORE welcomes the decision to continue to include the sciences within the core of the National Curriculum. The sciences develop rational explanations for understanding the world around us. Scientific understanding is a fundamental part of human culture and development and knowledge of the sciences, and an ability to think scientifically, are vital for engaging fully in modern life. The sciences are powerful: they help to provide solutions to the complex social and environmental challenges the world faces and improve human health and wellbeing. The sciences are a major driver of economic development[3,4,5].

1.3. Headline messages

6. In this response, we provide guidelines on how the curriculum content for the sciences (biology, chemistry and physics) should be included in the National Curriculum and how this content should be sequenced[6]. In the next stage of the National Curriculum review, subject expertise will be required to write and sequence the curriculum content for the sciences, informed by the evidence received in this review and the research undertaken by the DfE and others.

7. We believe that SCORE partners are best-placed to undertake this role and moreover it is very hard to imagine which other organisations could provide the breadth of subject specific and education expertise it will require. As stated above, member organisations of SCORE are already in the process of undertaking curriculum mapping exercises, which look explicitly at content and sequencing.

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[1] Although the current National Curriculum content is specified for *science*, we prefer the term *the sciences* as this reflect the breadth of scientific endeavour and emphasises that different disciplines can have different characteristics and approaches.
[2] The National Curriculum will specify core content that students are entitled to have access to. Schools will teach beyond this curriculum, possibly by a substantial amount. We refer to this wider curriculum as the 'school curriculum'.
[3] Royal Society 2010 *The Scientific Century* http://royalsociety.org/The-scientific-century/
[4] Royal Society of Chemistry 2010 *The economic benefits of chemistry* http://www.rsc.org/ScienceAndTechnology/Policy/Documents/ecobenchem.asp
[5] HM Treasury 2011 *'Plan for Growth'* - http://cdn.hm-treasury.gov.uk/2011budget_growth.pdf.
[6] *Sequencing* is the term used in curriculum development to describe the order in which statements of content are laid out in a curriculum.

8. An effective National Curriculum for the sciences will be: cultured, coherent, consistent and authentic. It will also foster scientific thinking, encourage laboratory and field work, and provide progression without needless repetition. [See Section 3.]

9. The relationship between the Key Stage 4 National Curriculum and GCSE examinations must be clarified before further work is done on defining and sequencing content statements[7] in the National Curriculum for the sciences. We would like to discuss this issue further with the DfE at the earliest opportunity.

10. The members of SCORE are concerned about the impact of curriculum reviews on teachers and learners. The scientific content contained in the National Curriculum should be stable and widely accepted. This stability would ensure the need for less frequent revisions of the curriculum and hence enable refinements in teaching practice to develop. Teachers should also be allowed and encouraged to teach beyond the core curriculum content, broadening and deepening students' experiences.

11. The new National Curriculum could and should be better balanced between flexibility and precision. Content should be included only if it is intrinsically useful in enabling pupils to develop their understanding of one or more fundamental ideas in the sciences (ie "earns its keep"). The focus of the review should be on identifying key outcomes for the National Curriculum in terms of knowledge, understanding and procedural skills[8] and then appropriately sequencing content relating to these key outcomes. Further detail, including contexts, could and should be added by teachers and other curriculum developers.

12. The new National Curriculum should be specified consistently from Key Stage 1 to Key Stage 4, and biology, chemistry and physics are appropriate categories to use when specifying the curriculum. However, we would expect the curriculum to be taught as 'the sciences' in Key Stages 1 and 2 (and potentially early secondary), and as separate subjects by appropriate specialist teachers thereafter. This structure will ensure and make explicit the coherence between the sciences within the statutory curriculum documentation. The document should be laid out so that the way ideas build, and how they relate across the disciplines and with mathematics, is explicit.

13. It is essential that existing staff are supported through subject specific continuing professional development (at primary and secondary levels). In terms of recruitment of the future workforce, efforts must be made to improve the number and balance of subject specialists in secondary schools[9].

[7] Content statements are often called *constructs* by curriculum developers.
[8] P*rocedural skills* - the skills associated with practical laboratory work and field work and analysis.
[9] Royal Society 2007 *The UK's science and mathematics teaching workforce* http://royalsociety.org/State-of-the-Nation-The-UKs-Science-and-Mathematics-Teaching-Workforce/

Part 1

2. Guiding principles for developing the National Curriculum for the sciences

2.1. Aims of the National Curriculum

14. The inquiry's remit states: 'The new National Curriculum will be developed in line with the Coalition Government's stated principles of freedom, responsibility and fairness – to raise standards for all children. The National Curriculum should have the following aims at its heart:

    - to embody rigour and high standards and create coherence in what is taught in schools;
    - to ensure that all children have the opportunity to acquire a core of essential knowledge in the key subject disciplines; and
    - beyond that core, to allow teachers the freedom to use their professionalism and expertise in order to help all children realise their potential.'

15. We understand that the new National Curriculum will specify the core content that children will encounter in the classroom. We interpret this as meaning that teachers will have greater freedom to broaden and deepen the curriculum in their schools. For example, they will be able to teach the National Curriculum for the sciences using relevant contexts.

16. In addition, SCORE member organisations believe that the National Curriculum must:

    - enable students to make informed choices about progression onto the next stage of education and employment;
    - be a stimulus for personal achievement; and
    - foster informed and responsible citizenship.

2.2. The importance of stability

17. SCORE member organisations welcome the decision the Government has made to review the National Curriculum holistically (5-16) rather than in piecemeal fashion. However, SCORE partners are concerned about the impact of curriculum reviews on teachers and learners. Less frequent revisions would enable refinements in teaching practice to develop, allowing teachers to focus to a great extent on 'how to teach' rather than simply on 'what to teach'.

18. In the current National Curriculum and its accompanying documentation, there is an overemphasis on specifying particular topics in cutting edge science and its societal impacts. This results in the necessity for too frequent revisions of the curriculum (and also of related qualifications). The National Curriculum should therefore specify underpinning science. Teachers should enable children to engage with cutting edge science through the contexts used to teach the National Curriculum and by extending their school curriculum beyond the National Curriculum.

19. SCORE recommends that the National Curriculum should:

- include only content that develops the key scientific principles, providing students with a solid scientific foundation;
- allow and encourage teachers to draw on a wide variety of relevant, current, and cutting edge science in the contexts they use to deliver and extend the National Curriculum;
- not be reviewed as extensively, or as frequently, as it has been since the 1990s, and it should always be reviewed holistically;
- require cross-party agreement before being reviewed; and
- be subject to appropriate monitoring and evaluation of its effectiveness in order to inform the next cycle of review.

2.3. Strengths of the current science curriculum

20. The current science curriculum has many strengths that should not be lost as a consequence of a curriculum review.

21. The sciences are a core curriculum entitlement for all students across all four key stages. This minimizes the influence of any gender bias in terms of choice of science disciplines. The core entitlement for balanced science at Key Stage 4 also keeps options open for progression with studies in, and related to, the sciences post-16.

22. By the age of 16, the National Curriculum for the sciences provides the majority of students with enough scientific knowledge to enable them to engage with some of the important scientific issues they are likely to meet in everyday life. It also encourages students to evaluate data and critically consider the validity of any research findings they may encounter.

23. The current National Curriculum promotes awareness that the sciences develop a constantly evolving series of models by which we attempt to explain the natural world.

2.4. Improving the current science curriculum

24. There are issues with the current (and previous) science curricula that this review should seek to address. These are described below.

25. The coherence of the National Curriculum should be improved. A new National Curriculum should ensure that ideas are introduced and then developed with due regard for the sequencing both within a discipline and across the sciences. Repetition within the current National Curriculum can lead to students disengaging with the sciences.

26. The National Curriculum should be written precisely and unambiguously so that it is difficult for any user[10] to corrupt the intent of the National Curriculum.

[10] *Users* of the National Curriculum include awarding organisations, text book publishers, teachers and other curriculum resource providers.

27. The National Curriculum should be designed with a 'big picture' in mind, and presented in such a way that these principles of design are clear. Teachers, parents and pupils should have a clear overview of the sciences and mathematics within and across the key stages. For example, the presentation and communication of the National Curriculum should encompass:

- how content has been selected, for example how it relates to fundamental ideas of science;
- sequencing - how ideas/concepts within a subject develop (where appropriate) across the key stages - to facilitate understanding of progression and ease transition;
- the links between the sciences and mathematics; and
- the expected outcomes for all learners at 16.

28. While scientific understanding is continually developing, sometimes at a rapid pace, the fundamental scientific principles that underpin current research have remained stable throughout the existence of the National Curriculum[11]. The potential to improve the effectiveness of the National Curriculum for the sciences therefore lies in the application of clear principles for curriculum design. More specifically, this could be addressed by considering how the content for all the sciences and mathematics is selected, worded and presented within the new National Curriculum.

29. The current attainment targets[12] for science in Key Stages 3 and 4 include 'How Science Works'. During the 21 years of the National Curriculum, there have been, and currently still are, a variety of terms used to summarise similar content (for example it is currently 'scientific enquiry' at Key Stages 1 and 2). While we have concerns about the structure, content and assessment of How Science Works[13], there are many principles, concepts and procedural skills contained within this attainment target that are central to the National Curriculum.

30. We have considered whether these aspects of the sciences will require a separate strand within the National Curriculum for the sciences, or whether they should be included within the three individual disciplines. The following factors were considered:

- the extent to which these principles, concepts and skills are common across or unique to the science disciplines;
- how these are assessed, which has often been weak in the past[13];
- the impact this may have on the teaching of this vital aspect of the sciences and how learners develop their scientific thinking;
- that these are key to scientific understanding and therefore cannot be decoupled completely – i.e. if they are specified separately, they should be taught in an integrated way; and
- Including these ideas in the individual disciplines [see Section 3.6] would increase the richness of the curriculum for all science disciplines.

[11] The first National Curriculum was introduced in 1989.
[12] The current National Curriculum includes a *Programme of Study*, *attainment targets* and *Levels Descriptors*. The *Programmes of Study* describe the knowledge, skills and understanding pupils are expected to develop during each key stage. The Programmes of Study also map out a scale of attainment within the subject. In most Key Stage 1, 2, and 3 subjects, these "*attainment targets*" are split into eight levels called *Level Descriptors*.
[13] SCORE 2009 *GCSE Science 2008 examinations* http://www.score-education.org/media/3200/score_report_final.pdf

31. The best way of expressing these ideas, and their progression from 5 to 16, should emerge during the development of the statements and structure of the National Curriculum.

32. Prescriptive “investigations” were a component of the first National Curriculum. These caused a major upheaval in assessment and teaching. Eventually, they distorted practical science such that it became formulaic, losing much of its value. The new curriculum should continue to move towards a less prescriptive approach to laboratory and field work.

2.5. Slimming down the curriculum

33. Previous national curricula have been both too restricting (1989), with too much content so its delivery is rushed, and too ambiguous (as in 2004). As a result, the curriculum’s intent gets corrupted. The new National Curriculum should achieve a better balance between flexibility and prescription.

34. As well as addressing the issues of repetition and coherence (see paragraph 35), the following areas may be useful to consider in order to achieve a better balance between flexibility and precision:

- content should be included only if it is intrinsically useful in enabling pupils to develop their understanding of one or more fundamental ideas (i.e. "earns its keep"); and
- the primary curriculum may not need to be balanced in terms of equal coverage of all sciences. There should be an emphasis on ‘authentic experiences’ which provide opportunities for pupils to begin progress towards scientific ideas and for the development of appropriate language/vocabulary that will enable them to communicate their ideas and experiences.

2.6. Time spent on the sciences

35. Specifying curriculum time spent on the sciences could help to address issues related to acceleration[14] through the curriculum and to encourage teachers to broaden and deepen students’ experiences of the sciences. However, until sequencing of the key content in the sciences has taken place, it is difficult to determine appropriate lesson time for the sciences at different key stages or years.

2.7. Biology, chemistry and physics or science

36. The National Curriculum should be specified consistently from Key Stage 1 to Key Stage 4, and biology, chemistry and physics are appropriate categories to use when specifying the curriculum. However, the way ideas develop the interconnections across disciplines must be explicit within the document. This will help to ensure students gain a coherent understanding of the sciences as teachers would be provided with the scaffolding to articulate and demonstrate how the sciences interconnect[15].

37. We would expect the curriculum to be taught as ‘the sciences’ in Key Stages 1 and 2 (and potentially early secondary), and as separate subjects by appropriately qualified teachers thereafter.

[14] *Acceleration* is a term used to describe moving through the National Curriculum in order to progress to the next stage without allowing time for consolidation of ideas or for broadening and deepening learning.

[15] The vast majority of teachers in primary schools are not science specialists and many teachers in secondary schools are also teaching outside their specialism (Royal Society 2010 *Science and mathematics education 5-14*).

2.8. Year-by-year or key stages

38. We are unable at this stage to recommend either a year-by-year or a key stage approach to the National Curriculum for the sciences. Whether the National Curriculum for the sciences is specified year-by-year or by key stages depends on resolving a number of issues, and considering a wide range of evidence. For example knowing whether there will be S*chemes of Work*[16] produced and the timing of National Assessments may affect how the National Curriculum should be specified[17].

39. A key stage approach may be less restrictive for teachers, particularly if schools have mixed-age classes (as is common in primary schools). If this approach is taken, we recommend a review of the length of the current key stages, based on evidence from other jurisdictions, to improve coherence.

40. A year-by-year approach could improve coherence across the sciences and with mathematics, reduce acceleration[12] through the curriculum, facilitate smoother transition between schools and help when defining the level of the National Curriculum content statements. Year-by-year statements can raise expectations for lower attainers (but may depress them for higher attainers) and they may also avoid some of the issues encountered by using sublevels.

41. However, a year-by-year approach could make it harder to deliver personalised science. Given the increase in restrictions it may place on teachers it could also reduce the opportunity for them to make professional judgements about the needs of their pupils.

3. Fundamental features of a National Curriculum for the sciences

42. Below we summarise the features that should characterise the National Curriculum for the sciences. The features should describe the content specified in the statutory National Curriculum.

43. Principles for content in biology, chemistry and physics are provided in Part 2. Subject-specific expertise is required to write and sequence the curriculum content statements for the sciences, informed by the evidence received in this review and the research currently being undertaken by the Department for Education. The SCORE member organisations are best-placed to undertake this role and moreover it is very hard to imagine which other organisations could provide the breadth of subject specific and education expertise it will require. SCORE will of course engage fully with others including the science education research community, the engineering community, other relevant subject associations and science teachers in the process.

3.1. A cultured approach

44. A cultured National Curriculum for the sciences will result in teachers teaching the sciences in a way that demonstrates scientific thinking. Science provides the most rational way of understanding the world around us. It is not restricted to a body of facts (what we know). It also looks at ‘why’ and ‘how’: why we think what we think, how we have arrived at that thinking, why it is useful to think scientifically and how to do so, and why we express understanding in particular ways.

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[16] *Schemes of Work* are non-statutory teaching plans that have been produced in the past to exemplify the way the National Curriculum could be taught to a given year group. These have provided guidance on a year-by-year basis in the past.

[17] For example, if National Assessments take place at the end of Y7, that would require Y7 to have its content articulated explicitly within a Key Stage approach.

45. The remit for the National Curriculum review has a focus on acquiring 'essential knowledge'. SCORE emphasises that 'essential knowledge' in the sciences includes conceptual understanding and the acquisition of procedural skills (particularly those associated with practical laboratory and field work, and analysis), as these are essential for acquiring and testing scientific knowledge.

46. It has been suggested that the National Curriculum could be related to 'big ideas'[18]. However, this is not to suggest that the big ideas would be an organising structure for building the National Curriculum. Instead, they should be thought of as being the measure by which content justifies its place in the National Curriculum.

3.2. Coherent

47. A coherent National Curriculum should provide a solid, integrated understanding of the key concepts of the sciences. Ideas in and about the sciences should be introduced at appropriate stages/ages. They should be sequenced in a logical manner within a particular scientific discipline. At the end of a given period (eg year or key stage) the content should come together to form a coherent and consistent whole.

48. When writing the National Curriculum, in particular when considering the sequencing of content, the sciences should not be considered in isolation. The content in the sciences should feed into technology and be linked into by mathematics. Content in geography and other science related curriculum areas (for example health education in PSHE) should also be considered.

49. Content that relies on mathematics should be taught at a similar time (or after) the necessary mathematical ideas have been covered in mathematics. That time should be determined by the age at which the mathematical ideas can be securely grasped.

3.3. Consistent

50. A consistent National Curriculum for the sciences should reflect that the sciences provide a set of explanations which are consistent within and across the individual disciplines and are described in a common language. There should be appropriate sequencing of content statements across the sciences so that ideas can be interconnected. Appropriate terminology should be used consistently across the National Curriculum for each of the science disciplines[19].

3.4. Structured to allow progression without repetition

51. The sciences include a set of interconnected ideas and it is not possible to cover a whole topic in one sitting. Understanding some concepts and principles will rely on understanding gained in other topics. Also, the level of challenge of the concepts should be appropriate to the age of the learners.

52. It is therefore necessary to revisit topics in order to avoid simple repetition, and ensure clarity of progression. The National Curriculum should specify content in such a way that it:

- builds on previous understanding;
- develops rather than repeats previous ideas, allowing students to feel that they are making progress; and
- introduces new ideas at the point where they are needed and where they can form part of a coherent narrative.

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[18] Key ideas in and of the disciplines, which could be used to justify which content is include in the National Curriculum are outlined in Part 2.

[19] For example, the treatment of *energy* should be consistent across biology, chemistry and physics.

53. The National Curriculum should support teachers so that they can broaden the content when and where appropriate. This will enable pupils to consolidate ideas without direct repetition of previous content and provide deeper and richer learning experiences.

54. The National Curriculum should allow learners to acquire a deep understanding of the key ideas in and from the sciences.

3.5. Representative of scientific thinking

55. The National Curriculum should enable pupils to develop an analytical approach to solving scientific problems. Students should be familiar with the following:

    a) **Reduction and axioms** – the sciences are always trying to find more, and more fundamental, explanations.

    b) The importance of the sciences as problem solvers by:

       - **Prediction** – using established laws to make predictions in real world situations;
       - **Construction** – using established laws to make things we know will work; and
       - **Explanation** – to get closer to a full understanding.

    c) **Counter-intuition** – some ideas and explanations are not obvious; scientists trust the evidence and logic rather than common sense and pre-existing assumptions;

    d) **Replication and falsification** – scientific claims are replicable and should be testable; it is important to understand why a particular interpretation of evidence may be inconsistent;

    e) **Simplification and modelling** – models and simplifications are used to assist understanding of and to predict phenomena, patterns and relationships[20];

    f) **Mathematical expressions** – scientific ideas are often expressed in the language of mathematics and this is valuable to aid understanding and describing phenomena;

    g) **Quantities** – the sciences deal with quantities; some of them are related or defined by formal relationships;

    h) **Measurement** – the sciences are about observing and measuring phenomena to make predictions and to test theories;

    i) **Risk, repeatability, reproducibility and validity** – the sciences require an understanding of the nature of risk and these aspects of experimentation, which must link with their mathematical and statistical meaning;

    j) **Presenting and evaluating data** – data should be presented and evaluated in an appropriate manner in order to permit valid conclusions;

    k) **Evidence** – acquiring evidence is essential, as is the ability to undertake evidence-based thinking and logical reasoning; and

    l) **Experiments** – high quality, appropriate scientific experiments and investigations are key to the clarification and consolidation of theories.

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[20] National Strategies (Secondary); *Using Models*; First published in 2008: *Refers to the importance of models in supporting pupils' developing understanding of scientific ideas and identifies some of the models that are effective in teaching science*.

3.6. Practical laboratory and field work

56. The content statements in the National Curriculum should be written in such a way that recognises that the sciences are to large extents practical subjects[21]. The statutory guidelines for the new National Curriculum for the sciences should therefore include explicit reference to procedural skills in the laboratory and in the field. The content statements should facilitate and not hinder the undertaking of worthwhile laboratory and field work that develops and enhances[22]:

    a) technical and manipulative skills;

    b) understanding of scientific procedures; and

    c) knowledge and understanding of scientific concepts.

3.7. An authentic approach

57. The content included in the National Curriculum for the sciences should allow students to gain an authentic view of what it is like to study and work in the sciences (including thinking like a scientist). This will enable students to make informed decisions on which route(s) to follow.

3.8. A developmental approach: acknowledging preconceptions

58. Children arrive at school with preconceptions of the world[23]. Some preconceptions are useful as they form a basis on which to develop explicit knowledge. For example, very young children can recognise that objects fall. These recognitory abilities can be developed into explicit understanding. However, some preconceptions do not stand up to scientific scrutiny and will benefit from challenging in a scientific way (for example, the mistaken belief that most of the mass of a growing plant comes from the soil).

59. The National Curriculum for the sciences should build on existing tacit knowledge and should challenge incorrect preconceptions using evidence and reasoning.

4. Assessment: supporting and recognising progress

60. Although the remit of the National Curriculum review does not explicitly cover assessment of the curriculum, the impact of assessment needs to be considered when writing a National Curriculum[24]. However, assessment methodologies should follow, not drive, the curriculum. Assessment should support learning, improve achievement and promote progression.

61. Currently, teachers use some or all of the following documents to structure and develop the curriculum in their schools: the National Curriculum Programmes of Study[12]; the attainment targets and Level Descriptors; Schemes of Work; curriculum resources; specifications and assessment materials such as past examination papers. The relationship between, and purpose or need for, all these separate documents needs to be considered when writing the National Curriculum.

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[21] Practical work encompasses learning activities in which pupils:
 a) have direct, often hands-on, experience of phenomena;
 b) or, where primary data/observations are not possible or appropriate, use secondary sources of data;
 c) to observe, investigate and develop an understanding the world around them. [From Lunetta et al, 2007, p394]

[22] SCORE 2008 *Practical work in science report* http://www.score-education.org/media/3668/report.pdf

[23] Christine Howe 2011 *SCORE Curriculum Conference* http://www.score-education.org/media/7419/ch.pdf

[24] The recent Interim Report of the Bew Inquiry into assessment acknowledges the close links between assessment and the curriculum.

4.1. Attainment targets and level descriptors

62. There are some concerns that Level Descriptors can be confusing to parents and children. There are also concerns that they have in the past been interpreted in different ways: as students having a mastery of that level and also that students were able to do some things within the level. In addition, concerns have been expressed that Attainment targets and Level Descriptors can distort the intended curriculum. The relationship between Attainment targets and Level Descriptors and a National Curriculum that is clearly and precisely expressed, in terms of what children should understand and be able to do at each stage, needs further exploration. It is not currently clear whether they should be retained in any shape, or fundamentally reviewed to address the issues outlined above, but some change is definitely required. If they are retained, Level Descriptors will need an express purpose.

63. Teachers are also increasingly using Assessment for Learning, and Assessing Pupils' Progress (AfL and APP) to support pupils's progress. How AfL and APP connect with a National Curriculum based on fundamental ideas also needs further consideration.

4.2. Key Stage 4 science and the National Curriculum

64. The relationship between Key Stage 4 science in the National Curriculum and the core assessments at this level is complex[25]. At Key Stage 4, teachers base their school curriculum on the examination specifications (along with assessment materials) they are teaching. The role of the National Curriculum document is therefore currently different at Key Stage 4, as it is used to assess the appropriateness of the criteria for certain qualifications, rather than directly impacting a school's scheme of work. If this relationship between the National Curriculum and GCSE criteria is to continue, the Key Stage 4 National Curriculum needs to bear in mind the following:

65. **Core science**: the current National Curriculum effectively specifies the content of GCSE Science. Having all the National Curriculum core content assessed in one GCSE has previously resulted in illogical teaching sequences for those (the majority) going on to do GCSE Additional Science. The review should consider the relationship between the Key Stage 4 curriculum and GCSE science.

66. **'Double' and separate science[26] GCSEs**: the current intention, which we support, is that GCSE Science + GCSE Additional Science taken together provide for progression to A-level science qualifications. The separate sciences also enable progression to A-levels, and give some students the opportunity to cover a wider range of content. The review needs to consider what the relationship should be between the National Curriculum and Additional Science, and the separate science GCSEs, and how any extra content required by these examinations should be specified such that it builds on the National Curriculum.

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[25] All students at Key Stage 4 should cover the Key Stage 4 National Curriculum. GCSE science examinations are structured as follows:

- GCSE science - this covers the entire National Curriculum entitlement and includes biology, chemistry and physics;
- GCSE Additional Science - this extends biology, chemistry and physics content beyond the National Curriculum and when taken with GCSE Science is designed to enable progression to A-levels in the sciences;
- GCSE Additional Applied Science - this also extends biology, chemistry and physics content beyond the National Curriculum; and
- GCSEs in biology, chemistry and physics - these include all the content of GCSE Science and GCSE Additional Science, and also include additional content. Students are usually entered for all three separate science GCSEs, as if they only take two (e.g. biology and chemistry), they have not covered the core National Curriculum.

[26] Separate science GCSEs are sometimes referred to as Triple Science.

67. **Range of qualifications**: There are many lessons to be learned about the proliferation of science qualifications and routes at Key Stage 4, and how they relate to the National Curriculum. We will write a separate response on this following the DfE's response to the Wolf inquiry.

68. **Specifications and examination questions**: for some aspects of the sciences, it would be worth looking at how assessment is carried out in other subjects that require more analytical narrative (eg history) rather than relying on short answer questions[27].

5. How children learn

5.1. Approaches to the sciences as practical subjects

69. It is important for pupils to experience the sciences as practical subjects. Good practical work not only motivates and enthuses children but it also teaches procedural skills, improves understanding of the scientific process and teaches concepts[28].

70. Practical science is an acknowledged strength of the teaching and learning of the sciences in UK schools. International comparisons (such as TIMSS[29]) indicate that in the UK, students spend more time on practical activities than in most other countries. However, SCORE's report on practical work in science[30] noted that, although there is a wide range of good practical work in science taking place across the UK, there were indications that the situation could be improved by extending good practice and focusing on the quality, rather than just the quantity, of practical work. If laboratory or field work is specified in the National Curriculum, in order to increase the focus on quality, its purpose needs to be specified. [See also paragraph 32.]

6. Implementation

6.1. The National Curriculum document

71. The National Curriculum is a vital document for curriculum planners. These can be teachers, the authors of Schemes of Work, and awarding organisations:

- The statutory National Curriculum document should be a valuable document for teachers. It should be a useful port of call when developing the school curriculum. Moreover, the 2004 National Curriculum is too cursory and ambiguous to be a useful document for curriculum development in schools.

- Primary teachers need support with translating any National Curriculum into a coherent teaching programme and unless the National Curriculum is written more like a scheme of work (which we do not advise) they will always need support with this.

- If the current relationship between the National Curriculum and examination criteria is to be maintained, then the National Curriculum needs to be written with this in mind. [See Section 4.2]

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[27] Nuffield Foundation, London, 2009 *Assessing Ethics in Secondary Science: A Report of a seminar held at Nuffield Foundation* http://www.nuffieldcurriculumcentre.org/sites/default/files/Assessing_Ethics_in_Secondary_Science.pdf

[28] SCORE 2008 *Practical work in science report* http://www.score-education.org/media/3668/report.pdf

[29] TIMSS - The Trends in International Mathematics and Science Study - is an international assessment of the mathematics and science knowledge of students around the world.

[30] SCORE 2008 *Practical Work in Science report* www.score-education.org/downloads/practical_work/report.pdf

72. The new National Curriculum document needs to:

- have clarity and precision about what children should understand and be able to do at different stages;
- show how ideas develop in an individual discipline; and
- show the interconnections across disciplines and with mathematics.

6.2. Text-books, examination specifications and examination papers, and published schemes of work

73. While the National Curriculum's primary purpose is to provide teachers with clear guidelines about curriculum content, it will also be the basis for awarding organisations to prepare their specifications and national assessments, and for authors to write text-books. Therefore the National Curriculum needs to be clearly and precisely written.

74. Currently, if publishers want their text-books to be endorsed by awarding organisations they are tightly constrained. Authors are often unable to mention content that is not in the examination specifications. This may result in teachers being less likely to go beyond the examination specification and broaden and deepen students' knowledge and understanding.

75. The new National Curriculum for the sciences must be in schools by September 2012 (first teaching is in September 2013). This means that publishers are very likely to start to prepare new science textbooks during the consultation period in 2012, before the new National Curriculum has been finalised. In this case, text-books will not reflect the intentions of the National Curriculum, or its content, as closely as they should. This may distort the actual curriculum taught in the classroom.

6.3. Continuing professional development

76. A move towards a more precise specification of the core knowledge in the National Curriculum should lead to a better learning experience for students. Teachers should have more freedom to develop areas of interest and expertise with their students. Teachers will be able to adapt teaching strategies to the needs of their students and to their own strengths and experiences. There needs to be a commitment to provide teachers with good, subject specific continuing professional development (CPD) to support the successful introduction of the new National Curriculum. There must also be an entitlement for teachers to undertake such CPD. Without this, there may be a tendency to continue with business as usual. Technicians will also require CPD to support the implementation of the new National Curriculum.

6.4. Teacher recruitment

77. Ultimately, the curriculum in schools will only ever be as good as the workforce that teaches it. We continue to suffer chronic shortages of specialist science teachers, which the recent cuts to teacher allocations in science (the third successive year that they have been reduced) will exacerbate. The National Curriculum has not, of itself, been successful in increasing substantially the numbers taking physical sciences A-levels. Only around 16% of 17 year olds in England took science and mathematics A-levels in 2009[31]. Over and above the formal requirements of the National Curriculum, it is vital that it should be taught by sufficient numbers of appropriately qualified, confident and skilled specialist subject teachers.

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[31] Royal Society 2011 *Preparing for the transfer from school and college science and mathematics education to UK STEM higher education* http://royalsociety.org/State-Nation-Increasing-Size-Pool/

6.5. Exemptions of schools

78. It is worrying that the Academies (and the new Free Schools) will not have to follow the National Curriculum. The Curriculum cannot claim to be truly ‘National’ if different types of schools are to be under varying obligations. When the National Curriculum was introduced, it applied to the 93% of students in the maintained sector. Today, the rapid growth in the number of academies, and possibly free schools, means that within a few years, a substantial proportion of 5-16 year olds are likely to sit outside the National Curriculum. This undermines the perceived value and credibility of the National Curriculum.

79. SCORE is concerned about what content will be taught in the science lessons in schools that are exempt from the National Curriculum. This must be addressed through inspection and other mechanisms.

6.6. Phasing in

80. Key Stage 4 should not be introduced in 2013. If Key Stage 3 is introduced in 2013, Key Stage 4 should follow in 2016.

Part 2

7. Biology in the National Curriculum

7.1. About biology

81. Biology is the study of life and living things including animals, plants and micro-organisms, their relationships to each other and the natural environment. The study of biology involves collecting and interpreting information about the natural world in order to identify patterns and relate cause and effect. Biological information is used to help humans improve their own lives and create a sustainable world for future generations.

7.2. Guiding principles for biology in the National Curriculum

82. In addition to the guiding principles and fundamental features of the National Curriculum expressed above [Sections 2 and 3], the biology content will be expressed in terms of learning outcomes that:

- will give all young people a strong and secure foundation in biology, that allows progress into further study and jobs in and with biology;
- provide opportunities for learners to gain authentic and personal experience of biological thinking and application of knowledge involving appropriate practical experiences and including laboratory experiments and fieldwork;
- can be arrived at through a broad range of different contexts, examples of species and styles of teaching and learning;
- demonstrate the scale of biology from immediate chemical reactions at the molecular and cellular level to changes in ecosystems over millions of years;
- create a framework through which teachers can engage and challenge learners with examples of stimulating, contemporary biology;
- promote intellectual activity that allows biological facts to build into overarching, reusable biological principles; and
- provide opportunities for teachers to develop learners' awareness and understanding of social, ethical and environmental issues associated with the acquisition and use of biological knowledge.

7.3. Ideas in biology

83. The diversity, form, function and behaviour of living things is determined by complex interactions between genes, proteins, organisms and the environment. Although these ideas are presented as headline themes, there are many connections across the themes and the other sciences, requiring differing levels of detail and differing weighting within the biology curriculum.

84. The following overarching statements reflect what a successful biology student should know at the age of 16. Each age/key stage should build towards a deep understanding of these big ideas. They are not intended to indicate sequencing. The ideas have been developed by the Society of Biology in partnership with its Member Organisations and individual members.[32]

[32] This work was based on the following references: Principles and big ideas of science education (Ed. Wynne Harlen) ; 'Enthusing the Next Generation' (BSF) and the QAA Bioscience Benchmarks.

85. These statements should be taught using a range of organisms (including animals, plants and micro-organisms), at a range of levels, using a range of different applications.

7.3.1. Interdependence and interactions

86. Overarching statement: Living organisms interact with each other and the environment.

a) Living organisms exist as individuals and together form populations of single species, communities of many species and ecosystems, interacting with each other and the non-living environment;

b) Living organisms are interdependent and are adapted to their environment;

c) Living organisms interact and communicate within and between species using a variety of mechanisms;

d) The responses of living organisms to their environment and one another create feedbacks that affect them and/or their environment;

e) Ecosystems provide resources and processes that are beneficial to humans; and

f) Interactions between living organisms (of the same and other species), their environment and humans can affect the health of individuals, populations and communities in a variety of ways.

7.3.2. Energy flow and material cycles

87. Overarching statement: All living organisms use energy resources and raw materials in the chemical reactions that are essential to life.

a) Most life on Earth is dependent on solar radiation; the Sun is the source of energy for photosynthesis in which carbohydrates are produced by combining carbon dioxide from the air and hydrogen from water;

b) Organic compounds are broken down in respiration to allow the other chemical reactions necessary for life;

c) Energy is stored in chemical systems in living organisms; some stored energy flows through food webs which are not 100% efficient; ultimately all is dissipated to the environment as a result of metabolism; and

d) The material products of living processes cycle within loop systems.

7.3.3. Evolution

88. Overarching statement: Populations of organisms change over time as they acquire characteristics gained through gene mutations that make individual organisms better suited to survival and reproduction, and more likely to pass on these characteristics to their offspring. This process leads to evolution.

a) Genes are made of DNA and code for the molecules that control the chemical reactions in cells, and form the physical structures of cells and extracellular material;

b) Genetic information within living organisms is passed to their offspring;

c) The characteristics of a living organism are determined by its genome, proteins and the interaction of the genome with its environment;

d) Genetic mutations generate variation within a gene locus, i.e. it creates different alleles, which can lead to variation within species;

e) Evolution is mainly due to natural selection, which is the result of competition for survival and reproduction between genetically different individuals in populations; and

f) Evolution accounts for biodiversity and how living organisms are related.

7.3.4. Structure and Function

89. Overarching statement: Biological structures (biological molecules, cells, tissues, organs, organisms) reflect their evolutionary adaptation towards better fitness for their functions.

  a) Life processes are carried out by molecules whose function is related to their structure;
  b) The fundamental units of living organisms are cells;
  c) Development involves the growth, differentiation and specialisation of cells;
  d) Cells and multicellular organisms consist of highly adapted structures which enable living processes and functions to be performed in effective ways, this includes (but is not limited to) the reproductive, cardiovascular, respiratory, digestive, skeletal and muscular system; and
  e) Gene expression is the process through which information in the genome controls the functionality in the organism.

7.4. Thinking like a biologist

90. Biology deals with complex systems which can be predictable or unpredictable. Biologists use a range of techniques to analyse complex systems:

  - Identification, classification and studies of relationships – we try to find, image and name organisms and their constituents;
  - Measurement – we measure the properties of organisms including their observable features, their biochemical constituents, their behaviours and their genetic relatedness;
  - Sampling – we cannot observe everything therefore we have to rely on samples to represent whole populations;
  - Complexity / uncertainty – we deal with living things, what is inside them and how they interact in the real world, it is therefore not always possible to reliably reproduce the conditions of biological experiments;
  - Using large data sets – biologists often deal with large data sets generated from multiple experiments, this is not always reproducible in a classroom environment; and
  - Statistical analysis and modelling – these are used to assist in developing biological theories and explanations.

8. Chemistry in the National Curriculum

8.1. About chemistry

91. Chemistry is the study of substances, what they are made of, how they interact and the role they play in the materials and living things all around us. Our quality of life is enhanced by the application of chemical knowledge and chemical techniques, allowing us to: design and make new substances and materials, analyse substances and work out how and why chemical reactions happen. Chemistry is also an enabling science because it underpins other sciences and impacts on a wide range of the latest technological advances taking place.

8.2. Guiding principles for chemistry in the National Curriculum

92. In addition to the guiding principles and fundamental features of the National Curriculum expressed above [Sections 2 and 3], the chemistry content of the National Curriculum should be expressed in terms of learning outcomes that:

- are essential for pupils to develop a strong and secure evidence-based understanding of the material world and chemical processes;
- provide a 'driver' for pupils to engage in effective practical work and teacher-led demonstrations in order to gain direct experience (where appropriate) of chemical phenomena;
- enable pupils to gain procedural understanding and learn the concepts of evidence that underpin chemical investigations;
- enable pupils to gain experience of the various techniques used to safely handle, manipulate, measure and analyse chemical substances and to control chemical reactions;
- provide opportunities for pupils to develop ideas about science;
- are sequenced so that they build on earlier knowledge and so that complexity increases in gradual steps[33];
- are designed to acknowledge and address preconceptions and misconceptions[34,35] at each appropriate stage (informed by up-to-date chemical education research);
- enable pupils to develop an appreciation of the nature of models as used in chemistry and be able to choose and apply an appropriate model; and
- provide a sound basis for students to make informed choices regarding further study involving chemistry and to inform career decisions.

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[33] The National Strategies Secondary Framework 2009 *3.1 Particle models; 3.2 Chemical reactions; 3.3 Patterns in chemical reactions:* Sequencing of learning objectives (by year 7-11) and strategies for progression

[34] RSC 2002, Keith Taber (RSC, 2002) *Chemical Misconceptions Prevention, Diagnosis And Cure; Part 1 Theoretical background and Part 2 Classroom resources*: Key alternative conceptions that have been uncovered by research and strategies for dealing with them in the classroom.

[35] Durham University (2004), *Vanessa Kind Beyond Appearances: Students' misconceptions about basic chemical ideas* http://www.rsc.org/images/Misconceptions_update_tcm18-188603.pdf Significant misconceptions in chemistry, how they originate and how they may be addressed – suggestions for teaching sequences and strategies.

8.3. Rationale for chemistry content selection

93. The Royal Society of Chemistry has identified the future priorities for the chemical sciences in '*Chemistry for Tomorrow's World - A roadmap for the chemical sciences*[36].

94. The *Roadmap* document potentially has two important roles to play:

- **Selection and justification of key chemistry ideas**. To become effective citizens in an increasingly scientific and technological world, young people should be able to engage with, and understand, the global challenges facing our society. Examining the fundamental chemistry underlying the *Roadmap Challenges* provides a high-level rationale for the selection and justification of the essential areas of chemistry that are appropriate for inclusion in the National Curriculum. [See paragraph 95.]
- **Facilitate appropriate contextualisation by teachers**. The National Curriculum should outline the fundamental chemistry content and allow teachers the freedom to contextualise the material as appropriate for their own students and circumstances. The '*Roadmap for the chemical sciences*' provides a powerful link between underlying chemistry ideas and relevant, engaging contexts for the classroom. The Royal Society of Chemistry, with its long standing reputation as a provider of teaching resources, enrichment and enhancement activities, and professional development opportunities, will continue to support teachers in using the *Roadmap Challenges* to enthuse and inform their pupils.

95. Initial work with the Royal Society of Chemistry's members, subject experts and education experts on examining the fundamental chemistry underlying the *Roadmap Challenges* has identified a range of areas of essential chemistry including but not limited to:

- atoms and atomic structure, state of matter, structure and bonding;
- Periodic Table, group patterns;
- properties of materials related to structure, uses of materials related to their properties, development of new materials, assessment of materials related to sustainability;
- chemical formulae, chemical equations;
- quantitative chemistry (including the concept of amount of substance);
- chemical reactions, energy and disorder, rates of reaction; and
- purity, chemical analysis and separation techniques, solubility, acids, bases and salts.

96. It is vital that the chemistry content of the National Curriculum is presented in a way that emphasises the sequence, progression and development of ideas across the different age ranges. In order to facilitate this, the key chemistry ideas identified should be expressed in terms of 'Desired Outcomes' or 'Key Ideas' for the end of the statutory provision of the sciences. [See item 98.]

97. Content for each individual stage should then be selected to deliver on these 'outcomes'. [See item 98]. Using this framework structure would avoid repetition, show that the chemistry content ultimately combines to form a coherent whole and effectively drive teachers to view the content in light of the progression of chemical ideas.

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[36] Chemistry for Tomorrow's World - A roadmap for the chemical sciences
http://www.rsc.org/ScienceAndTechnology/roadmap/index.asp

98. Please note: the example below is **not**, by any means, definitive or complete in terms of the content/progression implied – it is simply presented as one example of an approach to curriculum design that the RSC would advocate and is aiming to develop further.

Example of ideas development →

• objects are made from materials • different materials (natural and made) have different properties • materials can be a single substance or a mixture of substances	• solids, liquids and gases – properties • any substance (not just water) can be solid, liquid and gaseous • change of state and temperature changes	• sense of scale for different sized 'particles' → grains, molecules, atoms etc • solids, liquids and gases –properties in terms of arrangement of 'particles' • any given substance can be solid, liquid and gaseous (in terms of particle arrangements) • change of state and changes in particle arrangements • change of state and energy transfer	• change of state and energy transfer in terms of bonds
• conservation of e.g. matter, mass – during change of form (pouring, moulding etc)	• conservation of e.g. matter, mass – during changes of state, dissolving	• conservation of mass in terms of conservation of atoms during changes of state	
• some materials can be produced, changed and formed into different, often useful, products	• conservation of e.g. matter, mass – when materials are changed into new, different materials	• conservation of mass in terms of conservation of atoms during chemical reactions • formulae (elements & compounds) • balanced symbol equations	• conservation of mass & the quantitative interpretation of balanced equations (reacting masses)

Key ideas (desired outcomes)

The properties of matter and materials can be explained in terms of:

- **atoms and molecules,**
- **structure and bonding**
- **energy transfers**

- During changes of state:
  - there are changes in the arrangements of atoms/molecules
  - the same chemical exists
  - mass is conserved (because no atoms are destroyed or made)
  - energy is transferred and bonds are broken & made

- During chemical reactions:
  - atoms are rearranged to make new chemicals with different properties
  - mass is conserved (because no atoms are destroyed or made)
  - energy is transferred and bonds are broken & made

9. Physics in the National Curriculum

9.1. About physics

99. Physics is a collection of ways of thinking that have led to a number of very successful descriptions and explanations of the way the world works. An education in physics develops these ways of thinking, which are valuable in their own right. It also develops an understanding of a core set of ideas and explanations about the physical world, and aspects of scientific procedural knowledge.

9.2. Guiding principles for Physics in the National Curriculum

100. In addition to the Guiding Principles and Fundamental Features of the National Curriculum expressed above [Sections 2 and 3], the physics content of the National Curriculum should be expressed in terms of learning outcomes that:

- are taken from the domains of physics (see section 9.3);
- are rich - allowing for a deep understanding of an aspect of the subject;
- earn their place – as well as being useful physics content, they should do one or more of the following:
    - provide opportunities for worthwhile practical work, some of which will develop procedural knowledge;
    - provide opportunities to develop ideas about science;
    - give students an authentic experience and flavour of what physics is; and
    - show what it means to think like a physicist – both by seeing it exemplified and by doing it themselves (see section 9.5);
- are part of a logical sequence so that they build on earlier ideas in the same domain or relevant ideas from other domains or disciplines;
- employ knowledge from the mathematics curriculum in a coherent way;
- provide a sound basis for routes through to degrees and careers involving physics and degrees and careers involving engineering;
- be a good preparation for people who follow a technical route from the age of 14 or 16;
- show that ideas in physics are interlinked and part of a consistent and coherent interpretation of the physical world;
- demonstrate the beauty and power of a physics explanation;
- exemplify the success of physics – that we do know a lot – whilst also showing that there are limits to what we do know.

9.3. Domains of physics content

101. The physics content is likely to be made up of knowledge, understanding and explanations of phenomena from these domains. The details of what is included should be determined through international comparisons and a mapping exercise that engages the subject community. The examples are deliberately not yet expressed as constructs or learning outcomes because, at this stage, they are to illustrate the likely areas of study from which the learning outcomes will arise.

9.3.1. Machines, motion and forces

102. Levers and moments; speed and acceleration; forces that act by contact or at a distance (friction, gravity, electricity and magnetism); balanced forces and Newton's first law; unbalanced forces, inertia and Newton's second law; Newton's third law and momentum; using energy and power to do calculations.

9.3.2. Electricity and magnetism

103. Electric charge; electric current in a complete electric circuit; effects of voltage and resistance in a simple circuit; resistors in series and parallel; current in parallel arms of a parallel circuit; potential difference across components in a series circuit; using energy and power to do calculations; electromagnetic effects: electromagnetic induction; transformers and mains electricity.

9.3.3. Waves, radiation, light and sound

104. Properties of sound – how we make and hear sounds; properties of light (brightness, shadows, straight lines, images, lenses and colour); properties of waves (refraction, reflection, frequency, wavelength and amplitude); models of radiation; properties of ionising radiations.

9.3.4. Matter, particles, atoms and beyond

105. The particle model of matter – kinetic theory; density, expansion, floating and convection; solids, liquids and gases; heating and cooling by conduction, radiation and evaporation; the structure of atoms.

9.3.5. The Earth in Space

106. The solar system and the Earth's place in it; the features and origins of elements, stars (including the Sun), galaxies and the Universe.

9.4. Ideas from physics

107. The National Curriculum should provide opportunities that allow students to know and be able to use some overarching ideas from physics which include:

    a. equilibrium – balanced forces; balanced moments; balanced pressures, equal flows in and out; there will be others from biology and chemistry;

    b. the idea of conservation - charge, mass, matter & momentum;

    c. that there is a useful accounting tool – energy – that allows us to do calculations to find out how long sources will last, to predict whether some events can happen and to calculate forces or temperature rises;

    d. non-equilibrium (or differences) make things happen; for example temperature difference, pressure difference, potential difference, differences in concentration unbalanced forces, unbalanced moments;

    e. disorder increases: as systems become more disordered, they are less useful (the second law of thermodynamics); it is the second law that determines the direction of time and limits the usefulness and lifetime of any resource;

    f. maths, relationships and calculations – ideas are often expressed in the language of mathematics and this has been extremely successful in describing the physical universe; using (and giving meaning to) formal relationships, proportion and ratios; for example:

        - in some sense, drift = push ÷ difficulty; $I = V/R$;
          fluid flow = pressure difference/resistance;

- some derived quantities are a measure of how much something is shared out: stress is force/area; intensity is power/area; and
- Some derived quantities are rates (how much something is spread out over time): speed is distance/time; acceleration is change in speed/time; power is energy/time.

g. they should be aware of some of the wonder of the physical Universe – often beyond the observable (the very large and the very small);

h. that physics addresses and provides answers to some of the awe-inspiring big questions, including (but not restricted to):

- what was the origin of the Universe?
- what are we made of?
- why does the physical world behave as it does?

i. using laws and ideas that work everywhere – they are universal.

9.5. Thinking like a physicist

108. In this document, we have referred to the idea of thinking like a physicist, which includes:

a. using a systematic method for going beyond what is known;

b. being able to step outside immediate experience and take a holistic view;

c. solving problems using a range of techniques, such as: using mathematics, approximations, reversing time, considering the extremes;

d. isolating physical phenomena to test ideas experimentally;

e. simplifying physical situations to explain or predict phenomena using models;

f. connecting physical phenomena with explanations and models;

g. looking for explanations rather than descriptions;

h. delving for an answer – not being satisfied with a superficial description; puzzling away at something to find an explanation that works;

i. looking for the fundamental answer that has predictive power across many domains;

j. testing that answers are consistent with themselves and other areas of physics;

k. being able to spot inconsistencies and incongruities in arguments.

10. Mapping and sequencing

10.1. Overview

109. The next stage of review will require content to be selected and sequenced. SCORE member organisations envisage that there will be a four stage process to this:

a) the desired outcomes from the National Curriculum for each of the sciences should be agreed;

b) then a complete list of all the content statements and processes that have been studied at 5-16 in the UK and overseas should be compiled;

c) the content statements in the list should be considered against the desired outcomes for the curriculum, and accepted or rejected; and

d) the content statements should then be sequenced, based on existing evidence.

110. The SCORE member organisations are working at various stages of this process, and expect that their work will inform the review of the National Curriculum during the coming months.

111. Below we describe where the subjects are in the process, the issues they each think need to be taken in to consideration, and their planned next steps.

10.2. Biology

112. The Society of Biology believes that is important that biological content is mapped and sequenced alongside the mathematics, chemistry and physics content.

113. The Society, as has been described in Section 7, has identified the areas of biology it believes are central to the National Curriculum. The Society of Biology, representing its broad membership and member organisations is best placed to proceed with co-ordinating the mapping and sequencing of subject content related to biological content. We welcome the opportunity to work with the expert panel during this process.

10.3. Chemistry

114. The Royal Society of Chemistry believes that way that the curriculum content for the sciences is developed, worded and presented should enable the appreciation of the cross-cutting nature of ideas across the sciences and maths, as well as the identification of progression and the development of ideas through each educational stage.

115. The Royal Society of Chemistry (RSC) intends to continue to develop the fundamental ideas in chemistry described in section 8 to form the basis of a framework which provides coherently mapped and sequenced chemistry ideas. The RSC would very much welcome the opportunity to continue to work with the Department for Education to devise and deliver an effective, coherent and inspirational essential knowledge framework for chemistry within the National Curriculum Programme of Study for Science.

10.4. Physics

116. It is the intention of the Institute of Physics to develop a map for the terrain of physics; work has begun and should be completed by Autumn 2011. This activity will complement the development of the National Curriculum and we would welcome the opportunity to work with the Department on this project.

117. The purposes of this content map are:

a. to ensure that each learning outcome earns its place in the curriculum and to provide evidence that it has done so; how it can develop ideas about science, overarching ideas of physics and aspects of thinking like a physicist;

b. compare statements from international curricula;

c. select and sequence learning outcomes in a coherent and logical way;

d. make clear the links between learning outcomes and constructs;

e. to allow any learning outcome to be queried to show how it links with other learning outcomes (in the same or another domain);

f. provide links to learning tasks and practical activities that can be used to develop a given learning outcome;

g. provide links from practical activities to relevant aspects of procedural knowledge;

h. show links to learning outcomes in physics from those in maths and other subjects; and

i. show how learning outcomes fit into broader narratives.

118. The Institute will send the expert group details of its progress to date.