The National Strategies
Secondary

Science subject leader development materials

Autumn 2009

department for
children, schools and families

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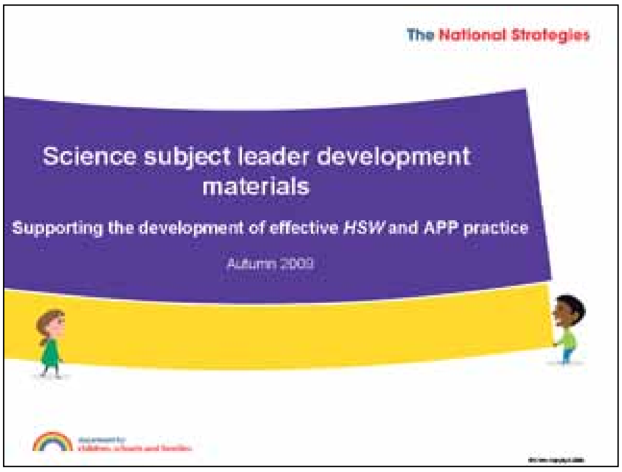

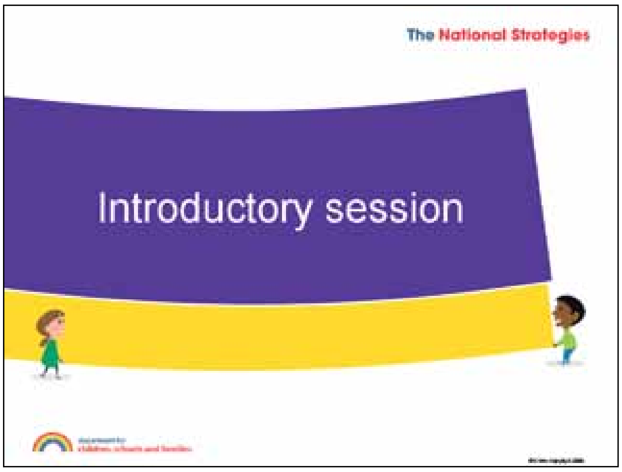

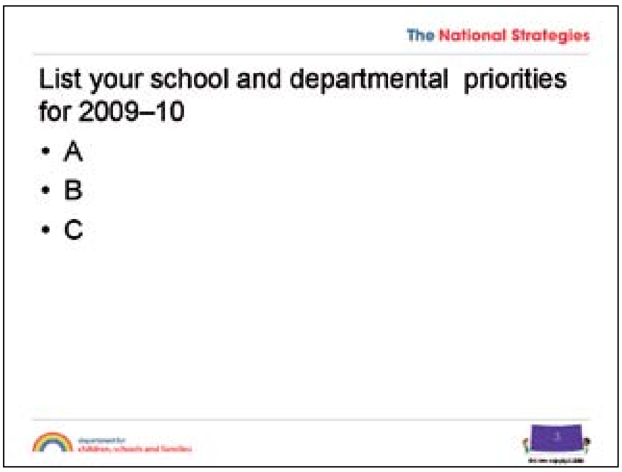

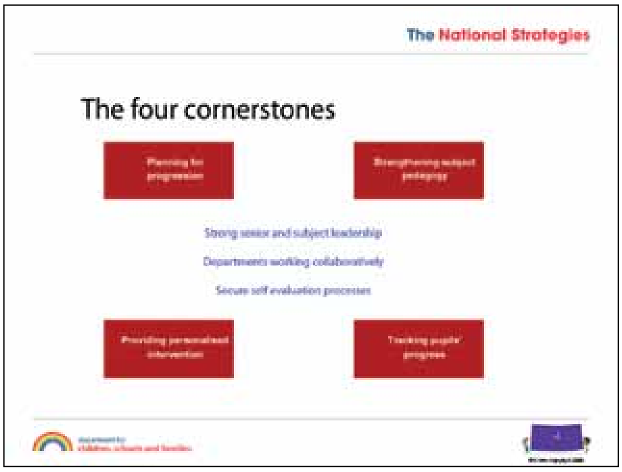
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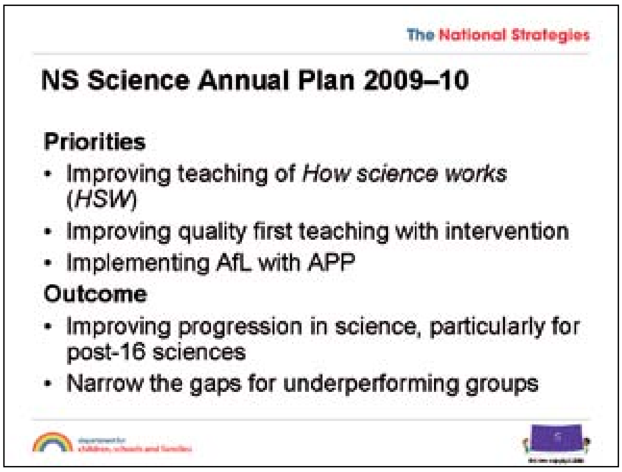
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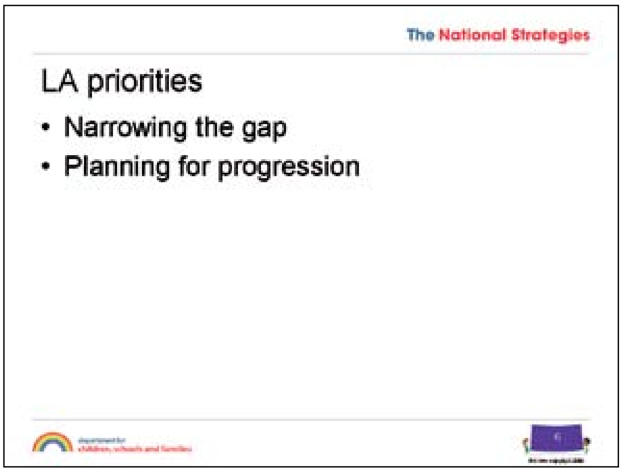
NS Science Annual Plan 2009–10
Priorities
• Improving teaching of How science works (HSW)
• Improving quality first teaching with intervention
• Implementing AfL with APP
Outcome
• Improving progression in science, particularly for post-16 sciences
• Narrow the gaps for underperforming groups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LA priorities
• Narrowing the gap
• Planning for progression

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Support available

- SLDM
- Consultant support
- ASE
- AST support
- Science Learning Centres
- SSAT
- Line manager support
- CPD opportunities for the department
- Department meeting time
- STEMNET
- ?

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Objectives

To:

- explore the links between the Framework, APP and the level descriptions
- experience how the Framework supports the planning and assessment of 'difficult to teach' areas
- identify the implications and next steps in developing department practice.

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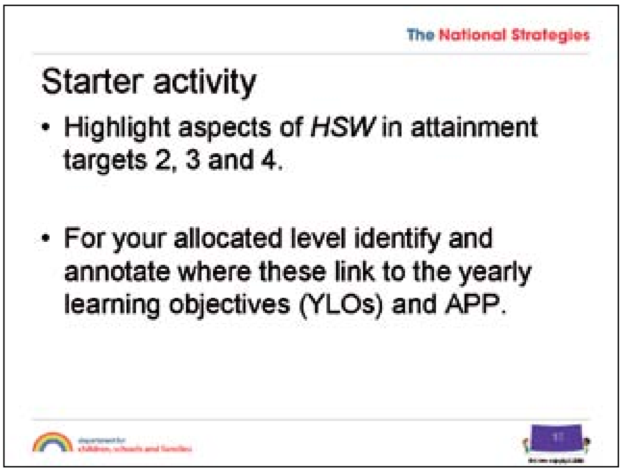
Outcomes

Participants will have:

- clarified how the Framework, APP and level descriptions are linked
- explored planning and assessment using the Framework resources
- identified the leadership actions that need to be taken.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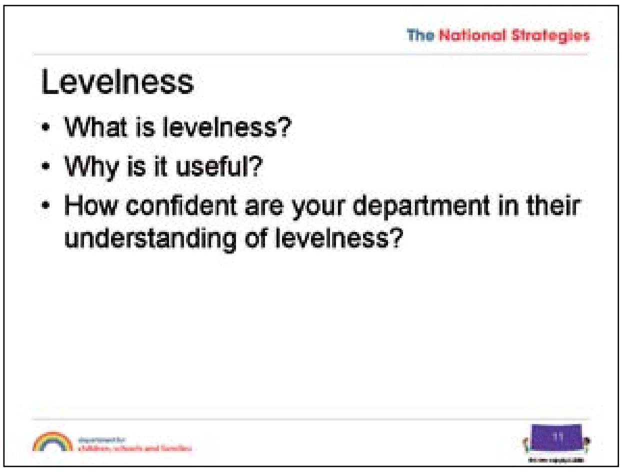
Starter activity
• Highlight aspects of *HSW* in attainment targets 2, 3 and 4.
• For your allocated level identify and annotate where these link to the yearly learning objectives (YLOs) and APP.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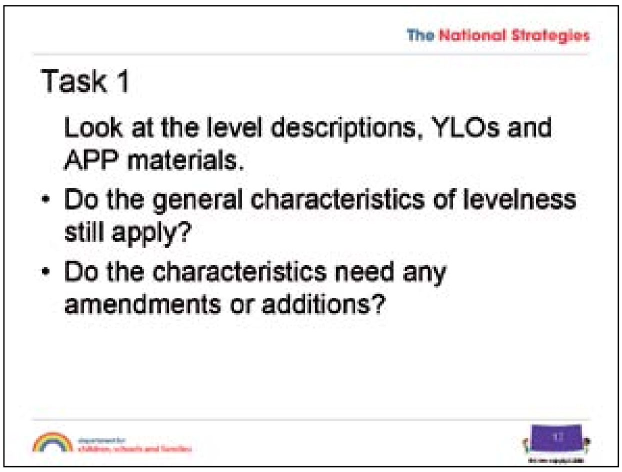
Levelness
• What is levelness?
• Why is it useful?
• How confident are your department in their understanding of levelness?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Task 1
Look at the level descriptions, YLOs and APP materials.
• Do the general characteristics of levelness still apply?
• Do the characteristics need any amendments or additions?

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11–16 progression

What are the

- positive points
- minus points
- interesting points

in thinking of Key Stages 3 and 4 in this way?

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Discussion

How well would these resources support a teacher for whom this is not an area of expertise, in:

- understanding progression in the area
- raising awareness of why pupils might struggle
- planning more effective lessons?

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Task 2

- Select one of the four areas in the context of one of your Key Stage 3 classes.
- Use APP to decide on a 'best fit' for each of the AFs and next steps.
- Complete planning sheet handout 1.7 for this class.

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Task 2 continued

- Use the amplification to write objectives and outcomes.
- Decide on the success criteria.
- Identify a suitable 'rich question' and any barriers pupils might have.
- Identify suitable activities to achieve the outcomes for the lesson.
- Complete the assessment box.

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Reflection

- Could your teachers plan in this way?
- What might be some of the barriers?
- What support would need to be in place to allow this to happen?
- What expertise do you have in your department that could be shared?

Managing the implementation of APP

Discuss your experiences so far

- What have been the barriers and enablers?
- Are these at whole-school or department level?

Eight steps of progression to develop *HSW* and APP practice side by side

- How successful have you been in moving to the next step?

OR

- Identify which step best describes your department and how you will move to the next step.

Reflection and planning time

- Plan a session for your department to help them move to the next step.

OR

- Identify the key actions that need to be taken by the department and how you will enable these to happen.

Handout 1.0 Science programme for subject leader development materials (SLDM) 2009–10

The science SLDM programme scheduled to run from summer 2009 to summer 2010 will have a core theme based on developing the teaching, learning and assessment of *How science works* (*HSW*) and the role of Assessing Pupils' Progress (APP) in this context. Additional materials will be available, focusing on key aspects of the STEM agenda and the commitment to improve progression to post-16 science. The underlying philosophy of all the sessions remains the dedication to strengthen science teaching and learning and to narrow the achievement gap.

Autumn 2009

Core session

- Supporting the effective development of *HSW* and APP in science practice.

Additional materials

- Progression to post-16 learning.
- Using repurposed key scientific ideas materials, with *HSW* and APP embedded.
- Supporting interactive teaching.

Spring 2010

Core session

- Supporting the effective development of *HSW* and Assessment for Learning (AfL) with APP practice.
- Narrowing the gap: supporting literacy in science particularly for bilingual learners.

Additional materials

- Narrowing the gap: gender guidance for science.
- Narrowing the gap: Key Stage 4 intervention strategies.
- 11–16 curriculum models to support progression.
- Using repurposed key scientific ideas materials, with *HSW* and APP embedded.

Summer 2010

Core session

- Enhancing the development of effective *HSW* and AfL with APP practice.
- Progression to post-16 in science.

Additional materials

- Making STEM enhancement and enrichment effective.
- Using repurposed key scientific ideas materials, with *HSW* and APP embedded.

Handout 1.1 Level descriptions – arranged with all levels together

Level 4

AT1: Pupils decide on an appropriate approach, including using a fair test to answer a question, and select suitable equipment and information from that provided. They select and use methods that are adequate for the task. Following instructions, they take action to control obvious risks to themselves. They make a series of observations and measurements and vary one factor while keeping others the same. They record their observations, comparisons and measurements using tables and bar charts and begin to plot points to form simple graphs. They interpret data containing positive and negative numbers. They begin to relate their conclusions to patterns in data, including graphs, and to scientific knowledge and understanding. They communicate their conclusions using appropriate scientific language. They suggest improvements in their work, giving reasons.

AT2: Pupils describe some processes and phenomena related to organisms, their behaviour and the environment, drawing on scientific knowledge and understanding and using appropriate terminology, for example using food chains to describe feeding relationships between plants and animals in a habitat. They recognise that evidence can support or refute scientific ideas, such as in the identification and grouping of living things. They recognise some applications and implications of science, such as the use of predators to control pest populations.

AT3: Pupils describe some processes and phenomena related to materials, their properties and the Earth, drawing on scientific knowledge and understanding and using appropriate technology, for example separation methods. They recognise that evidence can support or refute scientific ideas, such as the classification of reactions as reversible or irreversible. They recognise some applications and implications of science, such as the safe use of acids and alkalis.

AT4: Pupils describe some processes and phenomena related to energy, forces and space, drawing on scientific knowledge and understanding and using appropriate terminology, for example the observed position of the Sun in the sky over the course of a day. They recognise that evidence can support or refute scientific ideas, such as sounds being heard through a variety of materials. They recognise some applications and implications of science, such as the use of electrical components to make electrical devices.

Level 5

AT1: Pupils decide on appropriate approaches to a range of tasks, including selecting sources of information and suitable apparatus. They select and use methods to obtain data systematically. They recognise hazard symbols and make, and act on, simple suggestions to control obvious risks to themselves and others. They use line graphs to present data, interpret numerical data and draw conclusions from them. They analyse findings to draw scientific conclusions that are consistent with the evidence. They communicate these using scientific and mathematical conventions and terminology. They evaluate their working methods to make practical suggestions for improvements.

AT2: Pupils describe processes and phenomena related to organisms, their behaviour and the environment, drawing on abstract ideas and using appropriate terminology, for example the main functions of plant and animal organs and how these functions are essential. They explain processes and phenomena, in more than one step or using a model, such as the main stages of the life cycles of humans and flowering plants. They apply and use knowledge and understanding in familiar contexts, such as different organisms being found in different habitats because of differences in environmental factors. They recognise that both evidence and creative thinking contribute to the development of scientific ideas, such as the classification of living things. They describe applications and implications of science, for example, solving some of the health problems that arise when organ damage occurs.

AT3: Pupils describe processes and phenomena related to materials, their properties and the Earth, drawing on abstract ideas and using appropriate terminology, for example the weathering of rocks. They explain processes and phenomena, in more than one step or using a model, such as the deposition of sediments and their formation into rocks. They apply and use knowledge and understanding in familiar contexts, such as identifying changes of state. They recognise that both evidence and creative thinking contribute to the development of scientific ideas, such as basing separation methods for mixtures on physical and chemical properties. They describe applications and implications of science, such as the uses of metals based on their specific properties or the benefits and drawbacks of the use of fossil fuels.

AT4: Pupils describe processes and phenomena related to energy, forces and space, drawing on abstract ideas and using appropriate terminology, for example 'balanced forces'. They explain processes and phenomena, in more than one step or using a model, such as the length of a day or a year. They apply and use knowledge and understanding in familiar contexts. They recognise that both evidence and creative thinking contribute to the development of scientific ideas, such as objects being seen when light from them enters the eye. They describe applications and implications of science, such as the ways sound can be produced and controlled, for example in musical instruments.

Level 6

AT1: Pupils identify an appropriate approach in investigatory work, selecting and using sources of information, scientific knowledge and understanding. They select and use methods to collect adequate data for the task, measuring with precision, using instruments with finescale divisions, and identify the need to repeat measurements and observations. They recognise a range of familiar risks and take action to control them. They record data and features effectively, choosing scales for graphs and diagrams. They analyse findings to draw conclusions that are consistent with the evidence and use scientific knowledge and understanding to explain them and account for any inconsistencies in the evidence. They manipulate numerical data to make valid comparisons and draw valid conclusions. They communicate qualitative and quantitative data effectively, using scientific conventions and terminology. They evaluate evidence, making reasoned suggestions about how their working methods could be improved.

AT2: Pupils describe processes and phenomena related to organisms, their behaviour and the environment, using abstract ideas and appropriate terminology, for example simple cell structure and function. They take account of a number of factors or use abstract ideas or models in their explanations of processes and phenomena, such as environmental factors affecting the distribution of organisms in habitats. They apply and use knowledge and understanding in unfamiliar contexts, such as a food web in a habitat. They describe some evidence for some accepted scientific ideas, such as the causes of variation between living things. They explain the importance of some applications and implications of science, such as the use of selective breeding.

AT3: Pupils describe processes and phenomena related to materials, their properties and the Earth, using abstract ideas and appropriate terminology, for example the particle model applied to solids, liquids and gases. They take account of a number of factors or use abstract ideas or models in their explanations of processes and phenomena, such as word equations. They apply and use knowledge and understanding in unfamiliar contexts, such as relating changes of state to energy transfers in a range of contexts such as the formation of igneous rocks. They describe some evidence for some accepted scientific ideas, such as the patterns in the reactions of acids with metals and the reactions of a variety of substances with oxygen. They explain the importance of some applications and implications of science, such as the production of new materials with specific desirable properties.

AT4: Pupils describe processes and phenomena related to energy, forces and space, using abstract ideas and appropriate terminology, for example electric current as a way of transferring energy. They take account of a number of factors in their explanations of processes and phenomena, for example in the relative brightness of stars and planets. They also use abstract ideas or models, for example sustainable energy sources and the refraction of light. They apply and use knowledge and understanding in unfamiliar contexts. They describe some evidence for some accepted scientific ideas, such as the transfer of energy by light, sound or electricity, and the refraction and dispersion of light. They explain the importance of some applications and implications of science, such as the responsible use of unsustainable sources of energy.

Level 7

AT1: Pupils plan appropriate approaches and procedures, by synthesising information from a range of sources and identifying key factors in complex contexts and in which variables cannot readily be controlled. They select and use methods to obtain reliable data, including making systematic observations and measurements with precision, using a range of apparatus. They recognise the need for a risk assessment and consult appropriate sources of information, which they follow. They record data in graphs, using lines of best fit. They analyse findings to draw conclusions that are consistent with the evidence and use scientific knowledge and understanding to explain these conclusions and identify possible limitations in primary and secondary data. They use quantitative relationships between variables. They communicate effectively, using a wide range of scientific and technical conventions and terminology, including symbols and flow diagrams. They begin to consider whether the data they have collected are sufficient for the conclusions they have drawn.

AT2: Pupils describe a wide range of processes and phenomena related to organisms, their behaviour and the environment, using abstract ideas and appropriate terminology and sequencing a number of points, for example respiration and photosynthesis, or pyramids of biomass. They make links between different areas of science in their explanations. They apply and use more abstract knowledge and understanding, in a range of contexts, such as inherited and environmental variation. They explain how evidence supports some accepted scientific ideas, such as the structure and function of cells. They explain, using abstract ideas where appropriate, the importance of some applications and implications of science, such as the uses of cells in stem cell research.

AT3: Pupils describe a wide range of processes and phenomena related to materials, their properties and the Earth, using abstract ideas and appropriate terminology and sequencing a number of points, for example the rock cycle. They make links between different areas of science in their explanations, such as between the nature and behaviour of materials and their particles. They apply and use more abstract knowledge and understanding, in a range of contexts, such as the particle model of matter, and symbols and formulae for elements and compounds. They explain how evidence supports some accepted scientific ideas, such as the reactivity series of metals. They explain, using abstract ideas where appropriate, the importance of some applications and implications of science, such as the need to consider the availability of resources, and environmental effects, in the production of energy and materials.

AT4: Pupils demonstrate extensive knowledge and understanding related to materials, their properties and the Earth. They use and apply this effectively in their descriptions and explanations, identifying links between topics, for example relating mode of formation of rocks to their texture and mineral content. They represent common compounds by chemical formulae and use these formulae to form balanced symbol equations for reactions. They interpret, evaluate and synthesise data from a range of sources and in a range of contexts, such as describing chemical reactions, classifying them and suggesting how new substances could be made. They show they understand the relationship between evidence and scientific ideas, and why scientific ideas may need to be changed. They describe and explain the importance of a wide range of applications and implications of science.

Level 8

AT1: Pupils recognise that different strategies are required to investigate different kinds of scientific questions, and use scientific knowledge and understanding to select an appropriate strategy. In consultation with their teacher they adapt their approach to practical work to control risk. They record data that are relevant and sufficiently detailed, and choose methods that will obtain these data with the precision and reliability needed. They analyse data and begin to explain, and allow for, anomalies. They carry out multi-step calculations and use compound measures, such as speed, appropriately. They communicate findings and arguments, showing awareness of a range of views. They evaluate evidence critically and suggest how inadequacies can be remedied.

AT2: Pupils demonstrate extensive knowledge and understanding related to organisms, their behaviour and the environment. They use and apply this effectively in their descriptions and explanations, identifying links between topics, for example relating cellular structure of organs to their associated life processes. They interpret, evaluate and synthesise data from a range of sources and in a range of contexts, for example environmental data from fieldwork. They show they understand the relationship between evidence and scientific ideas, and why scientific ideas may need to be changed, for example the short-term and long-term effects of environmental change on ecosystems. They describe and explain the importance of a wide range of applications and implications of science, such as relating photosynthesis and respiration to changes in the atmosphere and growth of crops.

AT3: Pupils demonstrate extensive knowledge and understanding related to materials, their properties and the Earth. They use and apply this effectively in their descriptions and explanations, identifying links between topics, for example relating mode of formation of rocks to their texture and mineral content. They represent common compounds by chemical formulae and use these formulae to form balanced symbol equations for reactions. They interpret, evaluate and synthesise data from a range of sources and in a range of contexts, such as describing chemical reactions, classifying them and suggesting how new substances could be made. They show they understand the relationship between evidence and scientific ideas, and why scientific ideas may need to be changed. They describe and explain the importance of a wide range of applications and implications of science.

AT4: Pupils demonstrate extensive knowledge and understanding related to energy, forces and space, for example the passage of sound waves through a medium. They use and apply this effectively in their descriptions and explanations, identifying links between topics. They interpret, evaluate and synthesise data from a range of sources and in a range of contexts. They show they understand the relationship between evidence and scientific ideas, and why scientific ideas may need to be changed, such as the developing understanding of the structure of the solar system. They describe and explain the importance of a wide range of applications and implications of science, such as relating the dissipation of energy during energy transfer to the need to conserve limited energy resources.

Handout 1.2 The Framework for secondary science: overview and learning objectives

Overview of strands

Strands	Substrands	Sub substrands
1 *How science works*		
	1.1a Explanations, argument and decisions	1.1a1 Scientific thinking: developing explanations using ideas and models 1.1a2 Scientific thinking: challenge and collaboration in the development of explanations 1.1a3 Scientific thinking: developing argument 1.11b Applications, implications and cultural understanding 1.1.1c Communication for audience and with purpose
	1.1 Practical and enquiry skills	1.1.2a Using investigative approaches: planning an approach 1.1.2b Using investigative approaches: selecting and managing variables 1.1.2c Using investigative approaches: assessing risk and working safely 1.1.2d Using investigative approaches: obtaining and presenting primary evidence 1.1.2e Working critically with primary evidence 1.1.2f Working critically with secondary evidence

Strands	Substrands	Sub substrands
2 Organisms, behaviour and health		
	2.1 Life processes 2.2 Variation and interdependence 2.3 Behaviour	
3 Chemical and material behaviour		
	3.1 Particle models 3.2 Chemical reactions 3.3 Patterns in chemical reactions	
4 Energy, electricity and forces		
	4.1 Energy transfer and electricity 4.2 Forces	
5 The environment, Earth and the universe		
	5.1 Changing environment and sustainability 5.2 Changing Earth 5.3 Earth, Space and beyond	

How science works learning objectives

1 *How science works*

1.1 Explanations, argument and decisions

1.1a1 Scientific thinking: developing explanations using ideas and models

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• use an existing model or analogy to explain a phenomenon	• describe more than one model to explain the same phenomenon and discuss the strengths and weaknesses of each model	• describe the strengths and weaknesses of a range of available models and select the most appropriate	• justify the selection of a particular model as the most appropriate	• evaluate the effectiveness of using models and analogies in their explanations	• recognise that it is possible to have and to use different, and sometimes conflicting, models in their explanation
• recognise and explain the value of using models and analogies to clarify explanations	• describe how the use of a particular model or analogy supports an explanation	• explain why the manipulation of a model or analogy might be needed to clarify an explanation	• devise own simple models or analogies to explain observations, data or scientific ideas	• evaluate the strengths and weaknesses of their own models and analogies	• explain how devising and using alternative models could help to make a 'creative leap' in an explanation

1.1a2 Scientific thinking: challenge and collaboration in the development of explanations

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• recognise that scientists of all disciplines and nationalities often work together to develop explanations	• recognise that science is a communal, and therefore fallible, human activity and that different explanations can arise from individual bias	• describe how bias, a lack of evidence or misconceptions can give rise to inappropriate theories and the role of scientists in questioning these	• describe the process of validating the work of other scientists and explain how this influences the acceptance or rejection of a theory	• explain why it is important for the scientific community to have a process for validating the work of other scientists and how this has influenced the acceptance of current theories	• explain and justify why a 'scientific claim' should be accepted or rejected by the application of the key components of validation to the evidence
• recognise that science cannot yet explain everything	• recognise questions that the scientific process cannot yet answer	• identify some questions that the scientific process cannot yet completely answer but can contribute to	• identify some questions that the scientific process cannot yet completely answer but can contribute to, and explain the reasons for this	• explain why scientific proof is only ever provisional	• explore the implications of the provisional nature of scientific proof

1.1a3 Scientific thinking: developing argument

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• identify a range of scientific data and other evidence to back an argument and the counterclaim in less complex and/or familiar contexts, e.g. establishing a wind farm	• identify a range of scientific data and other evidence to back an argument and the counterclaim in more complex and/or less familiar contexts, e.g. use of antibiotics	• use criteria to select relevant scientific data and other sources of evidence to support or negate an argument	• explain how the use of criteria improves the effectiveness of selecting scientific data and other sources of evidence to support or negate an argument	• devise criteria to select relevant scientific data and other sources of evidence to support or negate an argument in familiar contexts	• devise criteria to select relevant scientific data and other sources of evidence to support or negate an argument in less familiar contexts
• recognise that scientific evidence can be used to support or disprove theories	• describe how scientific evidence from different sources carries different weight in supporting or disproving theories	• explain how scientific evidence from a range of sources can be used to support or disprove theories	• describe examples of where scientific theories, applications and models have been changed by new evidence or societal norms	• explain how scientific theories, applications and models have been changed or modified by scientists as a result of new evidence	• explain how scientific theories, applications and models have been changed by the strength of new evidence, changes in societal norms or values

1.1b Applications, implications and cultural understanding

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe some benefits and drawbacks of scientific developments with which they are familiar	• explain some issues, benefits and drawbacks of scientific developments with which they are familiar	• evaluate the issues, benefits and drawbacks of scientific developments with which they are familiar	• evaluate the relevant issues, benefits and drawbacks of scientific developments with which they are familiar and draw conclusions about which would be more appropriate	• describe and evaluate examples of perceived and actual risk arising from the application of scientific or technological developments	• evaluate and analyse the potential impact of the application of new scientific and technological developments
• recognise that decisions about the use and application of science and technology are influenced by society and individuals	• recognise that decisions about the use and application of science and technology are influenced by society and individuals, and how these could impact on people and the environment	• recognise that different decisions on the use and application of scientific and technological developments may be made in different economic, cultural and social contexts	• explain that scientific evidence could be shaped by a number of factors and used to influence decisions taken on the application of scientific and technological developments	• describe the power and limitations of science in addressing a range of moral or ethical issues, and how this could influence the impact of decisions taken on the application of scientific and technological developments	• explain how scientific evidence can be shaped by bias, scientific status, political or economic factors, and how this could influence the impact of decisions taken on the application of scientific and technological developments

1.1c Communication for audience and with purpose

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• use key scientific vocabulary and terminology in discussions and written work	• use a range of scientific vocabulary and terminology consistently in discussions and written work	• communicate effectively and use appropriate scientific terminology and conventions in discussion and written work	• communicate effectively using a wide range of scientific terminology and conventions in discussion and written work	• communicate qualitative and quantitative evidence effectively using scientific terminology and conventions, drawing on abstract ideas and models as appropriate to the audience and purpose	• use a wide range of technical vocabulary and techniques with fluency, demonstrating communication and numerical skills as appropriate for a range of audiences and purposes
• identify and use the conventions of various genres for different audiences and purposes in scientific writing	• adapt the stylistic conventions of a range of genres for different audiences and purposes in scientific writing	• adapt the stylistic conventions of a wider range of genres for different audiences and purposes in scientific writing	• use simple criteria to judge the appropriateness of a piece of scientific writing for a particular audience	• devise criteria to judge the appropriateness of a piece of scientific writing for a particular audience	• critically evaluate criteria used to judge the appropriateness of a piece of scientific writing for a particular audience

1.2 Practical and enquiry skills

1.2a Using investigative approaches: planning an approach

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe an appropriate approach to answer a scientific question using a limited range of information and making relevant observations or measurements	• describe an appropriate approach to answer a scientific question using sources of evidence and, where appropriate, making relevant observations or measurements using appropriate apparatus	• explain how the planned approach to answer a scientific question was informed by scientific knowledge, understanding or other sources of evidence	• explain how the planned approach was informed by a range of scientific knowledge, understanding and evidence and, where appropriate, how this influenced the method of data collection	• explain how to plan appropriate approaches to investigatory work by synthesising information from a range of sources in complex contexts and where variables are less easily controlled	• explain why different approaches are required to investigate different kinds of scientific questions and how scientific knowledge, understanding and sources of evidence are used in the different approaches

1.2b Using investigative approaches: selecting and managing variables

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• recognise the range of variables involved in an investigation and decide which to control	• describe and identify key variables in an investigation and assign appropriate values to these	• use and apply independent and dependent variables in an investigation by choosing an appropriate range, number and value for each one	• identify key factors in complex contexts where variables are less easily controlled	• use and apply key variables in complex contexts, including ones in which variables are less easily controlled	• identify and manage a range of variables in complex contexts including ones in which variables are less easily controlled

1.2c Using investigative approaches: assessing risk and working safely

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• explain how action has been taken to control obvious risk and how methods are adequate for the task	• explain how to take action to control the risks to themselves and others, and demonstrate competence in their practical techniques	• explain how approaches to practical work were adapted to control risk	• use and apply risk assessment in carrying out practical procedures	• explain why the chosen approach to practical work needed to be adapted to control risk	• explain how hazards are identified and risks managed to collect data in a safe and skilful manner

1.2d Using investigative approaches: obtaining and presenting primary evidence

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe and record observations and evidence systematically	• explain how the observation and recording methods are appropriate to the task	• use and apply qualitative and quantitative methods to obtain and record sufficient data systematically	• explain how inherent variation, e.g. from human error, sensitivity and accuracy of instrument, needs to be considered when collecting data	• use and apply systematic observation and precise measuring with a range of apparatus, whilst taking account of inherent variation, to obtain and record reliable data	• use and apply systematic observation and precise measuring with a range of apparatus, while taking account of inherent variation, to obtain and record reliable data in a more demanding context
• recognise that the presentation of experimental results through the routine use of tables, bar charts and simple graphs makes it easier to see patterns and trends	• describe ways in which the presentation of experimental results through the routine use of tables, charts and line graphs makes it easier to see patterns and trends	• explain how the presentation of experimental results through the routine use of tables, charts and line graphs makes it easier to see patterns and trends	• apply and use appropriate ways of recording relevant observations and comparisons, clearly identifying points of particular significance	• explain how the chosen presentation of data has been used to support a valid conclusion	• explain how the chosen presentation of data takes account of uncertainty or alternative conclusions

1.2e Working critically with primary evidence

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe patterns and trends in results and link this evidence to any prediction made	• describe how the patterns and trends in the results link to the conclusions drawn and whether the evidence is sufficient	• explain how patterns and trends in results can be manipulated to be consistent with the evidence gathered and the predictions made	• explain how the numerical data have been manipulated to make valid comparisons and conclusions linked to the original scientific question	• synthesise and manipulate data, analyse findings and draw valid and reliable conclusions consistent with the evidence and linked to the original scientific question • recognise that correlation does not always imply causation	• synthesise and manipulate data, analyse findings, draw valid and reliable conclusions consistent with the evidence, and explain how strongly the evidence relates to the original scientific question • explain why correlation does not always imply causation
• describe and suggest how planning and implementation could be improved	• describe and suggest, with reasons, how planning and implementation could be improved	• explain how improvements to the planning and implementation would have led to the collection of more valid and reliable evidence and a more secure conclusion	• evaluate the planning and implementation, and explain how this could account for errors and anomalies and how inadequacies could be remedied	• evaluate the planning and implementation, and explain how this could account for errors and anomalies and the subsequent impact on the conclusion in simple contexts	• evaluate the planning and implementation, and explain how this could account for errors and anomalies and the subsequent impact on the conclusion in more complex contexts

1.2f Working critically with secondary evidence

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe patterns and trends in secondary evidence and link these to the prediction or conclusion drawn	• describe what needs to be considered in the collection and manipulation of simple secondary evidence to evaluate the conclusion or interpretation made	• explain whether the collection and manipulation of secondary evidence is sufficient or insufficient to support the conclusion or interpretation made	• explain, using scientific knowledge and understanding, how some of the limitations in the collection and manipulation of secondary evidence can distort the conclusion drawn	• evaluate the conclusions drawn by others, including scientists, in familiar or less complex contexts and consider how strongly the evidence supports these conclusions or claims	• evaluate the conclusions drawn by others, including scientists, in less familiar or more complex contexts, and consider how strongly the evidence supports these conclusions or claims
• recognise that different conclusions may be drawn from secondary data	• recognise that the selection, ordering or rejection of secondary data could lead to different conclusions	• explain how secondary numerical data have been manipulated to support a particular conclusion or viewpoint	• recognise that scientific controversies can arise from different interpretations of the same evidence	• describe a range of issues that can affect the credibility of data	• explain how scientific controversies can arise from different ways of interpreting evidence

Range and content learning objectives

2 Organisms, behaviour and health

2.1 Life processes

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe the role of organ systems in plants and animals that can contribute to the seven life processes	• explain how the organs and tissues in plants and animals function to support the seven life processes in a healthy organism	• explain how the specialisation of cells in plants and animals support the seven life processes in a healthy organism • explain how chemical, physical and biological factors can disrupt the seven life processes	• explain how individual intracellular and extracellular processes and structures in plants and animals support the seven life processes • explain why certain chemical, physical and biological factors can disrupt the seven life processes	• explain how the different intracellular and extracellular processes work together to support life in familiar contexts • evaluate the impact of chemical, physical and biological factors and explain their effects on the life processes	• use and apply their understanding of how life processes in organisms work together in unfamiliar contexts • critically evaluate the relative impact of chemical, physical and biological factors and their effect on life processes in unfamiliar contexts

2.2 Variation and interdependence

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe how organisms can vary and how this may lead to their survival in changing environments • describe how the major taxonomic groups are classified • use a combination of food chains within a habitat to produce food webs	• explain how variation has benefits and limitations for the survival of organisms in specific habitats • describe some examples of variation arising from inherited and environmental factors • explain energy transfer in food chains and webs and relate this to the abundance of organisms	• explain how variation in organisms can be artificially induced and the effect of these organisms on the environment • explain how internal and external factors can affect energy transfer in food chains and webs	• explain how the combined effects of changes to genes and environmental change can lead to variation in a species • explain the fluctuations in distribution and population size using: • energy flow • pyramids of number and biomass • predator/prey relationships	• apply and use their knowledge of variation and interdependence to explain: • natural selection • the applications and implications of artificial selection • evolutionary and ecological relationships	• apply and use their extensive knowledge of variation and interdependence to explain and critically evaluate the impact of human activity on evolutionary and ecological relationships

2.3 Behaviour

Year 7	Year 8	Year 9	Year 11	Year 11	Extension
• describe simple learned and innate behaviours in response to internal and external stimuli and how these aid survival	• explain how changes in learned behaviour due to internal and external stimuli are of benefit to the organism	• make links between observed social behaviours and the benefit to the survival of the species	• explain how chemical and electrical signals enable body systems to respond to internal and external changes and the effect of this on behaviour	• explain the effects of natural and artificial substances on chemical and electrical signals within the body, and possible effects on behaviour	• evaluate evidence from different sources about the impact of natural and artificial substances on behaviour

3 Chemical and material behaviour

3.1 Particle models

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe matter using a simple model and use it to explain changes of state • recognise the link between heating and cooling and changes of state • use the simple particle model to explain the physical characteristics of solids, liquids and gases	• apply and use the particle model to describe a range of physical observations • apply and use the particle model to describe a range of separation techniques	• evaluate and refine the particle model to explain a range of physical observations • evaluate and refine the particle model to explain a range of separation techniques	• refine the particle model to explore the structure of atoms, including protons, neutrons and electrons • apply particle models in unfamiliar contexts, and begin to evaluate the strengths and weaknesses of the model	• use the particle model and ideas from science and across disciplines to explain phenomena and evaluate the use of the model	• use the particle model and ideas from science and across disciplines to explain complex phenomena and make critical evaluations to justify the use of a 'good enough' model

3.2 Chemical reactions

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• sort some reactions into reversible and irreversible • recognise that new materials are made during chemical reactions	• recognise that materials can be made up of one or more kinds of particles • describe the type and arrangement of atoms in elements, compounds and mixtures • describe and develop a particle model to explain the differences between the terms *atoms*, *elements*, *compounds* and *mixtures*	• use a particle model to construct predictions for simple chemical reactions and to produce word equations	• use a particle model to construct predictions for chemical reactions and to produce symbol equations • explain the evidence that a chemical reaction has taken place in terms of energy transfer and rearrangements of bonds between atoms	• use a particle model to predict the outcome of chemical reactions and to produce balanced symbol equations • explain the evidence that a chemical reaction has taken place in terms of rearrangements of bonds between atoms, using the model of the differences of electron structure between elements	• use a particle model to predict the outcome of complex chemical reactions and to produce balanced symbol equations and ionic half-equations when appropriate • explain the evidence that a chemical reaction has taken place (in a system at equilibrium) in terms of energy transfer and rearrangements of bonds between atoms

3.3 Patterns in chemical reactions

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe, record and group observations from chemical reactions	• describe patterns in a range of chemical reactions	• link experimental and numerical data to illustrate a range of patterns in chemical reactions	• explain properties and patterns in reactivity in terms of a particle model for atomic structure	• apply knowledge of patterns of reactivity in the periodic table to predict the outcomes of reactions from a range of familiar contexts	• apply knowledge of patterns of reactivity in the periodic table to evaluate critically a range of domestic and industrial processes including systems at equilibrium

4 Energy, electricity and forces

4.1 Energy transfer and electricity

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe how energy can be stored, e.g. food, fuels and electrical cells • describe how energy is transferred in simple contexts such as heating and cooling, food chains and simple circuits • recognise that quantitative measures of energy transfer are needed to inform decisions, e.g. about lifestyles • describe how energy stored in a range of energy resources, e.g. food, biomass, oil, gas, wind and waves, can be usefully transferred	• use a simple model of energy transfer to describe common observations • explain why quantitative measures of energy transfer should also be considered when making informed decisions, e.g. building wind farms • explain how electricity is generated using a variety of energy resources	• develop more complex models of energy transfer mechanisms (incorporating ideas about particles or waves) • use energy-accounting systems, including Sankey diagrams, to track energy transfers • use quantitative measures of energy transfer to support informed decision-making • apply the idea of energy conservation and dissipation to simple biological, chemical and physical systems	• apply the concept of conservation of energy to energy efficiency calculations in living and non-living systems • develop the idea of energy dissipation in a variety of contexts • evaluate the economic costs and environmental effects of energy use through the measurement of energy transfers and efficiency calculations • describe the effects of energy transfer to living systems by electromagnetic and nuclear radiation	• use quantitative measures and the concept of energy conservation to evaluate a range of strategies to conserve limited energy resources • use and apply complex models of energy transfer to a wide range of phenomena • explain a wide range of complex phenomena using the principle of conservation of energy and appropriate wave or particle models	• apply broader or deeper knowledge and understanding of energy in explanations of observations and phenomena • use valid and rational argument to offer solutions to problems arising from the applications and implications of energy

4.2 Forces

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• recognise the forces acting on an object in different situations • distinguish between situations involving balanced and unbalanced forces • recognise that forces can combine or wholly or partly cancel each other out and their size and direction can be represented using arrows • recognise that there are contact forces and forces that act at a distance	• apply ideas about balanced and unbalanced forces to explain the way objects move • investigate situations where forces are applied over large and small areas or have a turning effect • recognise that forces at a distance get weaker as the distance increases	• recognise how simple quantitative relationships can be applied to the way objects move (including balanced and unbalanced forces) • recognise how simple quantitative relationships can be applied to situations where forces are applied over large and small areas or have a turning effect	• use simple quantitative relationships to make predictions in more complex situations • use simple relationships involving more complex quantities to make quantitative predictions in familiar situations	• use relationships involving more complex quantities to make quantitative predictions in more complex and unfamiliar situations	• apply knowledge and understanding of forces in explanations of observations and phenomena to complex and unfamiliar contexts • use valid and rational argument to offer solutions to problems arising from the applications and implications of forces

5 The environment, Earth and the universe

5.1 Changing environment and sustainability

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe how natural and human processes have changed the atmosphere over time	• explain some of the changes that have led to the composition of the current atmosphere • recognise simple ideas of sustainable development	• use one or more models, such as the carbon cycle or food webs, to explain some of the consequences of changes in the environment	• use primary and secondary forms of evidence to describe and explain the impact of human actions at a local, regional and global level	• evaluate the accuracy and validity of primary and secondary evidence in relation to human impact on the biosphere • describe and analyse how complex data could be represented or misrepresented to justify decisions taken to manage sustainability	• link and synthesise data and evidence from a range of sources to explain human impact on the biosphere • describe how evidence and arguments from different political and economic perspectives have been used to justify decisions taken to manage sustainability

5.2 Changing Earth

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• recognise the processes involved in the formation of rocks	• describe the processes involved in the formation of sedimentary, metamorphic and igneous rocks and use the characteristics of the rocks to explain how they formed	• use the rock cycle as a model to explain the cyclical nature of rock-forming processes and the timescales over which they operate	• use the theory of plate tectonics to explain some of the major slow (long-term) changes and the distribution and nature of active zones on the surface of the Earth	• link plate tectonic theory to its supporting geological evidence	• apply and use the theory of plate tectonics to explain related geological phenomena

5.3 Earth, Space and beyond

Year 7	Year 8	Year 9	Year 10	Year 11	Extension
• describe the apparent movement of the Sun across the sky and the pattern in the changing appearance of the Moon	• describe the position of the Earth in relation to the position of other bodies in the Solar System and use this to explain some phenomena • recognise that astronomy and space science provide evidence about the Solar System	• apply models and use scientific data to explain the relative movement of the celestial bodies in the solar system • describe how astronomy and space science provide evidence of the solar system and galaxy	• explain some methods used to explore the solar system and galaxy (both from the Earth and from Space) • explain how the electromagnetic spectrum can inform the study the stars in our galaxy (and universe)	• evaluate the available evidence and explain why it favours an expanding universe as the current consensus model	• explain, using available evidence and models of the universe, why the ultimate fate of the universe is difficult to predict

Handout 1.3
APP science assessment guidelines

Level	AF1 Thinking scientifically	AF2 Understanding the applications and implications of science	AF3 Communicating and collaborating in science	AF4 Using investigative approaches	AF5 Working critically with evidence
8	**Across a range of contexts and practical situations pupils:** • Describe or explain processes or phenomena, logically and in detail, making use of abstract ideas and models from different areas of science • Select and justify an appropriate approach to evaluating the relative importance of a number of different factors in explanations or arguments • Analyse the development of scientific theories through the emergence of new, accepted ideas and evidence	**Across a range of contexts and practical situations pupils:** • Describe ways in which the values of a society influence the nature of the science developed in that society or period of history • Evaluate the effects of scientific or technological developments on society as a whole • Explain the unintended consequences that may arise from scientific and technological developments • Make balanced judgements about particular scientific or technological developments by evaluating the economic, ethical/ moral, social or cultural implications	**Across a range of contexts and practical situations pupils:** • Critically evaluate information and evidence from various sources, explaining limitations, misrepresentation or lack of balance • Present robust and well structured explanations, arguments or counter arguments in a variety of ways • Suggest the specialisms and skills that would be needed to solve particular scientific problems or to generate particular new scientific or technological developments	**Across a range of contexts and practical situations pupils:** • Justify their choice of strategies for investigating different kinds of scientific questions, using scientific knowledge and understanding • Choose and justify data collection methods that minimise error, and produce precise and reliable data • Adapt their approaches to practical work to control risk by consulting appropriate resources and expert advice	**Across a range of contexts and practical situations pupils:** • Propose scientific explanations for unexpected observations or measurements, making allowances for anomalies • Process data, including using multi-step calculations and compound measures, to identify complex relationships between variables • Critically interpret, evaluate and synthesise conflicting evidence • Suggest and justify improvements to experimental procedures using detailed scientific knowledge and understanding and suggest coherent strategies to take particular investigations further

Level	AF1 Thinking scientifically	AF2 Understanding the applications and implications of science	AF3 Communicating and collaborating in science	AF4 Using investigative approaches	AF5 Working critically with evidence
7	**Across a range of contexts and practical situations pupils:** • Make explicit connections between abstract ideas and/or models in explaining processes or phenomena • Employ a systematic approach in deciding the relative importance of a number of scientific factors when explaining processes or phenomena • Explain how different pieces of evidence support accepted scientific ideas or contribute to questions that science cannot fully answer • Explain the processes by which ideas and evidence are accepted or rejected by the scientific community	**Across a range of contexts and practical situations pupils** • Suggest ways in which scientific and technological developments may be influenced • Explain how scientific discoveries can change worldviews • Suggest economic, ethical/moral, social or cultural arguments for and against scientific or technological developments • Explain how creative thinking in science and technology generates ideas for future research and development	**Across a range of contexts and practical situations pupils:** • Explain how information or evidence from various sources may have been manipulated in order to influence interpretation • Effectively represent abstract ideas using appropriate symbols, flow diagrams and different kinds of graphs in presenting explanations and arguments • Explain how scientists with different specialisms and skills have contributed to particular scientific or technological developments	**Across a range of contexts and practical situations pupils:** • Formulate questions or ideas that can be investigated by synthesising information from a range of sources • Identify key variables in complex contexts, explaining why some cannot readily be controlled and planning appropriate approaches to investigations to take account of this • Explain how to take account of sources of error in order to collect reliable data • Recognise the need for risk assessments and consult, and act on, appropriate sources of information	**Across a range of contexts and practical situations pupils:** • Explain how data can be interpreted in different ways and how unexpected outcomes could be significant • Identify quantitative relationships between variables, using them to inform conclusions and make further predictions • Assess the strength of evidence, deciding whether it is sufficient to support a conclusion • Explain ways of modifying working methods to improve reliability

Level	AF1 Thinking scientifically	AF2 Understanding the applications and implications of science	AF3 Communicating and collaborating in science	AF4 Using investigative approaches	AF5 Working critically with evidence
6	**Across a range of contexts and practical situations pupils:** • Use abstract ideas or models or multiple factors when explaining processes or phenomena • Identify the strengths and weaknesses of particular models • Describe some scientific evidence that supports or refutes particular ideas or arguments, including those in development • Explain how new scientific evidence is discussed and interpreted by the scientific community and how this may lead to changes in scientific ideas	**Across a range of contexts and practical situations pupils:** • Describe how different decisions on the uses of scientific and technological developments may be made in different economic, social or cultural contexts • Explain how societies are affected by particular scientific applications or ideas • Describe how particular scientific or technological developments have provided evidence to help scientists pose and answer further questions • Describe how aspects of science are applied in particular jobs or roles	**Across a range of contexts and practical situations pupils:** • Identify lack of balance in the presentation of information or evidence • Choose forms to communicate qualitative or quantitative data appropriate to the data and the purpose of the communication • Distinguish between data and information from primary sources, secondary sources and simulations, and present them in the most appropriate form	**Across a range of contexts and practical situations pupils:** • Apply scientific knowledge and understanding in the planning of investigations, identifying significant variables and recognising which are independent and which are dependent • Justify their choices of data collection method and proposed number of observations and measurements • Collect data choosing appropriate ranges, numbers and values for measurements and observations • Independently recognise a range of familiar risks and take action to control them	**Across a range of contexts and practical situations pupils:** • Suggest reasons based on scientific knowledge and understanding for any limitations or inconsistencies in evidence collected • Select and manipulate data and information and use them to contribute to conclusions • Draw conclusions that are consistent with the evidence they have collected and explain them using scientific knowledge and understanding • Make valid comments on the quality of their data

Level	AF1 Thinking scientifically	AF2 Understanding the applications and implications of science	AF3 Communicating and collaborating in science	AF4 Using investigative approaches	AF5 Working critically with evidence
5	**Across a range of contexts and practical situations pupils:** • Use abstract ideas or models or more than one step when describing processes or phenomena • Explain processes or phenomena, suggest solutions to problems or answer questions by drawing on abstract ideas or models • Recognise scientific questions that do not yet have definitive answers • Identify the use of evidence and creative thinking by scientists in the development of scientific ideas	**Across a range of contexts and practical situations pupils:** • Describe different viewpoints a range of people may have about scientific or technological developments • Indicate how scientific or technological developments may affect different groups of people in different ways • Identify ethical or moral issues linked to scientific or technological developments • Link applications of science or technology to their underpinning scientific ideas	**Across a range of contexts and practical situations pupils:** • Distinguish between opinion and scientific evidence in contexts related to science, and use evidence rather than opinion to support or challenge scientific arguments • Decide on the most appropriate formats to present sets of scientific data, such as using line graphs for continuous variables • Use appropriate scientific and mathematical conventions and terminology to communicate abstract ideas • Suggest how collaborative approaches to specific experiments or investigations may improve the evidence collected	**Across a range of contexts and practical situations pupils:** • Recognise significant variables in investigations, selecting the most suitable to investigate • Explain why particular pieces of equipment or information sources are appropriate for the questions or ideas under investigation • Repeat sets of observations or measurements where appropriate, selecting suitable ranges and intervals • Make, and act on, suggestions to control obvious risks to themselves and others	**Across a range of contexts and practical situations pupils:** • Interpret data in a variety of formats, recognising obvious inconsistencies • Provide straightforward explanations for differences in repeated observations or measurements • Draw valid conclusions that utilise more than one piece of supporting evidence, including numerical data and line graphs • Evaluate the effectiveness of their working methods, making practical suggestions for improving them

Level	AF1 Thinking scientifically	AF2 Understanding the applications and implications of science	AF3 Communicating and collaborating in science	AF4 Using investigative approaches	AF5 Working critically with evidence
4	**Across a range of contexts and practical situations pupils:** • Use scientific ideas when describing simple processes or phenomena • Use simple models to describe scientific ideas • Identify scientific evidence that is being used to support or refute ideas or arguments	**Across a range of contexts and practical situations pupils:** • Describe some simple positive and negative consequences of scientific and technological developments • Recognise applications of specific scientific ideas • Identify aspects of science used within particular jobs or roles	**Across a range of contexts and practical situations pupils:** • Select appropriate ways of presenting scientific data • Use appropriate scientific forms of language to communicate scientific ideas, processes or phenomena • Use scientific and mathematical conventions when communicating information or ideas	**Across a range of contexts and practical situations pupils:** • Decide when it is appropriate to carry out fair tests in investigations • Select appropriate equipment or information sources to address specific questions or ideas under investigation • Make sets of observations or measurements, identifying the ranges and intervals used • Identify possible risks to themselves and others	**Across a range of contexts and practical situations pupils:** • Identify patterns in data presented in various formats, including line graphs • Draw straightforward conclusions from data presented in various formats • Identify scientific evidence they have used in drawing conclusions • Suggest improvements to their working methods, giving reasons

Level	AF1 Thinking scientifically	AF2 Understanding the applications and implications of science	AF3 Communicating and collaborating in science	AF4 Using investigative approaches	AF5 Working critically with evidence
3	**Across a range of contexts and practical situations pupils:** • Identify differences, similarities or changes related to simple scientific ideas, processes or phenomena • Respond to ideas given to them to answer questions or suggest solutions to problems • Represent things in the real world using simple physical models • Use straightforward scientific evidence to answer questions, or to support their findings	**Across a range of contexts and practical situations pupils:** • Explain the purposes of a variety of scientific or technological developments • Link applications to specific characteristics or properties • Identify aspects of our lives, or of the work that people do, which are based on scientific ideas	**Across a range of contexts and practical situations pupils:** • Present simple scientific data in more than one way, including tables and bar charts • Use scientific forms of language when communicating simple scientific ideas, processes or phenomena • Identify simple advantages of working together on experiments or investigations	**Across a range of contexts and practical situations pupils:** • Identify one or more control variables in investigations from those provided • Select equipment or information sources from those provided to address a question or idea under investigation • Make some accurate observations or whole number measurements relevant to questions or ideas under investigation • Recognise obvious risks when prompted	**Across a range of contexts and practical situations pupils:** • Identify straightforward patterns in observations or in data presented in various formats, including tables, pie and bar charts • Describe what they have found out in experiments or investigations, linking cause and effect • Suggest improvements to their working methods

Handout 1.4 APP threads

Assessment Focus 1: Thinking Scientifically

Threads	
1	**Using models for and in explanations**
2	**Weighing up evidence to construct arguments and explanations**
3	**The process of development of scientific ideas including the role of the scientific community in their development**
4	**Provisional nature of scientific evidence**

Thread 1: Using models for and in explanations			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Describe or explain processes or phenomena, logically and in detail, making use of abstract ideas and models from different areas of science		
7	Make explicit connections between abstract ideas and/or models in explaining processes or phenomena		
6	Use abstract ideas or models or multiple factors when explaining processes or phenomena		
	Identify the strengths and weaknesses of particular models		
5	Use abstract ideas or models or more than one step when describing processes or phenomena		
	Explain processes or phenomena, suggest solutions to problems or answer questions by drawing on abstract ideas or models		
4	Use simple models to describe scientific ideas		
3	Represent things in the real world using simple physical models		

Thread 2: Weighing up evidence to construct arguments and explanations			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Select and justify an appropriate approach to evaluating the relative importance of a number of different factors in explanations or arguments		
7	Employ a systematic approach in deciding the relative importance of a number of scientific factors when explaining processes or phenomena		
6	Describe some scientific evidence that supports or refutes particular ideas or arguments, including those in development		
5	Identify the use of evidence and creative thinking by scientists in the development of scientific ideas		
4	Identify scientific evidence that is being used to support or refute ideas or arguments		
3	Identify differences, similarities or changes related to simple scientific ideas, processes or phenomena		
	Use straightforward scientific evidence to answer questions, or to support their findings		

Thread 3: The process of development of scientific ideas including the role of the scientific community in their development			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Analyse the development of scientific theories through the emergence of new, accepted ideas and evidence		
7	Explain the processes by which ideas and evidence are accepted or rejected by the scientific community		
6	Explain how new scientific evidence is discussed and interpreted by the scientific community and how this may lead to changes in scientific ideas		
5	Identify the use of evidence and creative thinking by scientists in the development of scientific ideas		
4	Use scientific ideas when describing simple processes or phenomena		
3	Respond to ideas given to them to answer questions or suggest solutions to problems		

Thread 4: Provisional nature of scientific evidence			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Analyse the development of scientific theories through the emergence of new, accepted ideas and evidence		
7	Explain how different pieces of evidence support accepted scientific ideas or contribute to questions that science cannot fully answer		
6	Describe some scientific evidence that supports or refutes particular ideas or arguments, including those in development		
5	Recognise scientific questions that do not yet have definitive answers		
4	Identify scientific evidence that is being used to support or refute ideas or arguments		

Assessment focus 2: Understanding the applications and implications of science

Threads	
1	Effect of societal norms (political, social, cultural, economic) on science
2	Creative use of scientific ideas to bring about technological developments
3	Implications, benefits and drawback of scientific and technological development of society and the environment
4	How science relates to jobs and roles

Thread 1: Effect of societal norms (political, social, cultural, economic) on science			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Describe ways in which the values of a society influence the nature of the science developed in that society or period of history		
7	Suggest ways in which scientific and technological developments may be influenced		
	Suggest economic, ethical/moral, social or cultural arguments for and against scientific or technological developments		
6	Describe how different decisions on the uses of scientific and technological developments may be made in different economic, social or cultural contexts		
5	Describe different viewpoints a range of people may have about scientific or technological developments		
	Identify ethical or moral issues linked to scientific or technological developments		

Thread 2: Creative use of scientific ideas to bring about technological developments			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Explain the unintended consequences that may arise from scientific and technological developments		
7	Explain how creative thinking in science and technology generates ideas for future research and development		
6	Describe how particular scientific or technological developments have provided evidence to help scientists pose and answer further questions		

Thread 3: Implications, benefits and drawbacks of scientific technological development of society and the environment			
Level	**Assessment criteria**	**Addressed with KS3 SOL**	**Implications for departmental training and development**
8	Evaluate the effects of scientific or technological developments on society as a whole		
	Make balanced judgements about particular scientific or technological developments by evaluating the economic ethical/moral, social or cultural implications		
7	Explain how scientific discoveries can change world views		
6	Explain how societies are affected by particular scientific applications or ideas		
5	Indicate how scientific or technological developments may affect different groups of people in different ways		
	Link applications of science or technology to their underpinning scientific ideas		

4	Describe some simple positive and negative consequences of scientific and technological developments		
	Recognise applications of specific scientific ideas		
3	Explain the purposes of a variety of scientific or technological developments		
	Link applications to specific characteristics or properties		

Thread 4: How science relates to jobs and roles			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
6	Describe how aspects of science are applied in particular jobs or roles		
4	Identify aspects of science used within particular jobs or roles		
3	Identify aspects of our lives, or of the work that people do, that are based on scientific ideas		

Assessment focus 3: Communicating and collaborating in science

Threads	
1	**Using appropriate presentation skills to enhance communication of scientific findings and arguments**
2	**Explaining ideas and evidence using appropriate conventions, terminology and symbols**
3	**Presenting a range of views judging any possible misrepresentation**
4	**Scientists communicating worldwide using conventions**

Thread 1: Using appropriate presentation skills to enhance communication of scientific findings and arguments

Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Present robust and well-structured explanations, arguments or counter arguments in a variety of ways		
7	Effectively represent abstract ideas using appropriate symbols, flow diagrams and different kinds of graphs in presenting explanations and arguments		
6	Choose forms to communicate qualitative or quantitative data appropriate to the data and the purpose of the communication		
5	Decide on the most appropriate formats to present sets of scientific data, such as using line graphs for continuous variables		
4	Select appropriate ways of presenting scientific data		
3	Use scientific forms of language when communicating simple scientific ideas, processes or phenomena		

Thread 2: Explaining ideas and evidence using appropriate conventions, terminology and symbols			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Present robust and well-structured explanations, arguments or counter arguments in a variety of ways		
7	Effectively represent abstract ideas using appropriate symbols, flow diagrams and different kinds of graphs in presenting explanations and arguments		
6	Distinguish between data and information from primary sources, secondary sources and simulations, and present them in the most appropriate form		
5	Use appropriate scientific and mathematical conventions and terminology to communicate abstract ideas		
4	Use appropriate scientific forms of language to communicate scientific ideas, processes or phenomena		
	Use scientific and mathematical conventions when communicating information or ideas		
3	Present simple scientific data in more than one way, including tables and bar charts		

Thread 3: Presenting a range of views judging any possible misrepresentation			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Critically evaluate information and evidence from various sources, explaining limitations, misrepresentation or lack of balance		
7	Explain how information or evidence from various sources may have been manipulated in order to influence interpretation		
6	Identify lack of balance in the presentation of information or evidence		
5	Distinguish between opinion and scientific evidence in contexts related to science, and use evidence rather than opinion to support or challenge scientific arguments		

Thread 4: Scientists communicating worldwide using conventions			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Suggest the specialisms and skills that would be needed to solve particular scientific problems or to generate particular new scientific or technological developments		
7	Explain how scientists with different specialisms and skills have contributed to particular scientific or technological developments		
5	Suggest how collaborative approaches to specific experiments or investigations may improve the evidence collected		
3	Identify simple advantages of working together on experiments or investigations		

Assessment focus 4: Using investigative approaches

Threads	
1	**To effectively plan appropriate scientific investigations**
2	**To identify and manipulate variables within the context of an investigation**
3	**To support the gathering of evidence through collection of precise and reliable data**
4	**To be aware of the risks associated with the investigative process**

Thread 1: To effectively plan appropriate scientific investigations			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Justify their choice of strategies for investigating different kinds of scientific questions, using scientific knowledge and understanding		
7	Formulate questions or ideas that can be investigated by synthesising information from a range of sources		
6	Collect data choosing appropriate ranges, numbers and values for measurements and observations		
5	Explain why particular pieces of equipment or information sources are appropriate for the questions or ideas under investigation		
4	Select appropriate equipment or information sources to address specific questions or ideas under investigation		
3	Select equipment or information sources from those provided to address a question or idea under investigation		

Thread 2: To identify and manipulate variables within the context of an investigation			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Justify their choice of strategies for investigating different kinds of scientific questions, using scientific knowledge and understanding		
7	Identify key variables in complex contexts, explaining why some cannot readily be controlled and planning appropriate approaches to investigations to take account of this		
6	Apply scientific knowledge and understanding in the planning of investigations, identifying significant variables and recognising which are independent and which are dependent		
	Justify their choices of data collection method and proposed number of observations and measurements		
5	Recognise significant variables in investigations, selecting the most suitable to investigate		
4	Decide when it is appropriate to carry out fair tests in investigations		
3	Identify one or more control variables in investigations from those provided		

Thread 3: To support the gathering of evidence through collection of precise and reliable data			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Choose and justify data collection methods that minimise error, and produce precise and reliable data		
7	Explain how to take account of sources of error in order to collect reliable data		
5	Repeat sets of observations or measurements where appropriate, selecting suitable ranges and intervals		
4	Make sets of observations or measurements, identifying the ranges and intervals used		
3	Make some accurate observations or whole number measurements relevant to questions or ideas under investigation		

Thread 4: To be aware of the risks associated with the investigative process			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Adapt their approaches to practical work to control risk by consulting appropriate resources and expert advice		
7	Recognise the need for risk assessments and consult, and act on, appropriate sources of information		
6	Independently recognise a range of familiar risks and take action to control them		
5	Make, and act on, suggestions to control obvious risks to themselves and others		
4	Identify possible risks to themselves and others		
3	Recognise obvious risks when prompted		

Assessment focus 5: Working critically with evidence

Threads	
1	**Evaluation of the planning and implementation of scientific investigations**
2	**Consideration of errors and anomalies**
3	**Processing and analysing data to support the evaluation process and draw conclusions**
4	**Explanation and evaluation of evidence to support the scientific process**

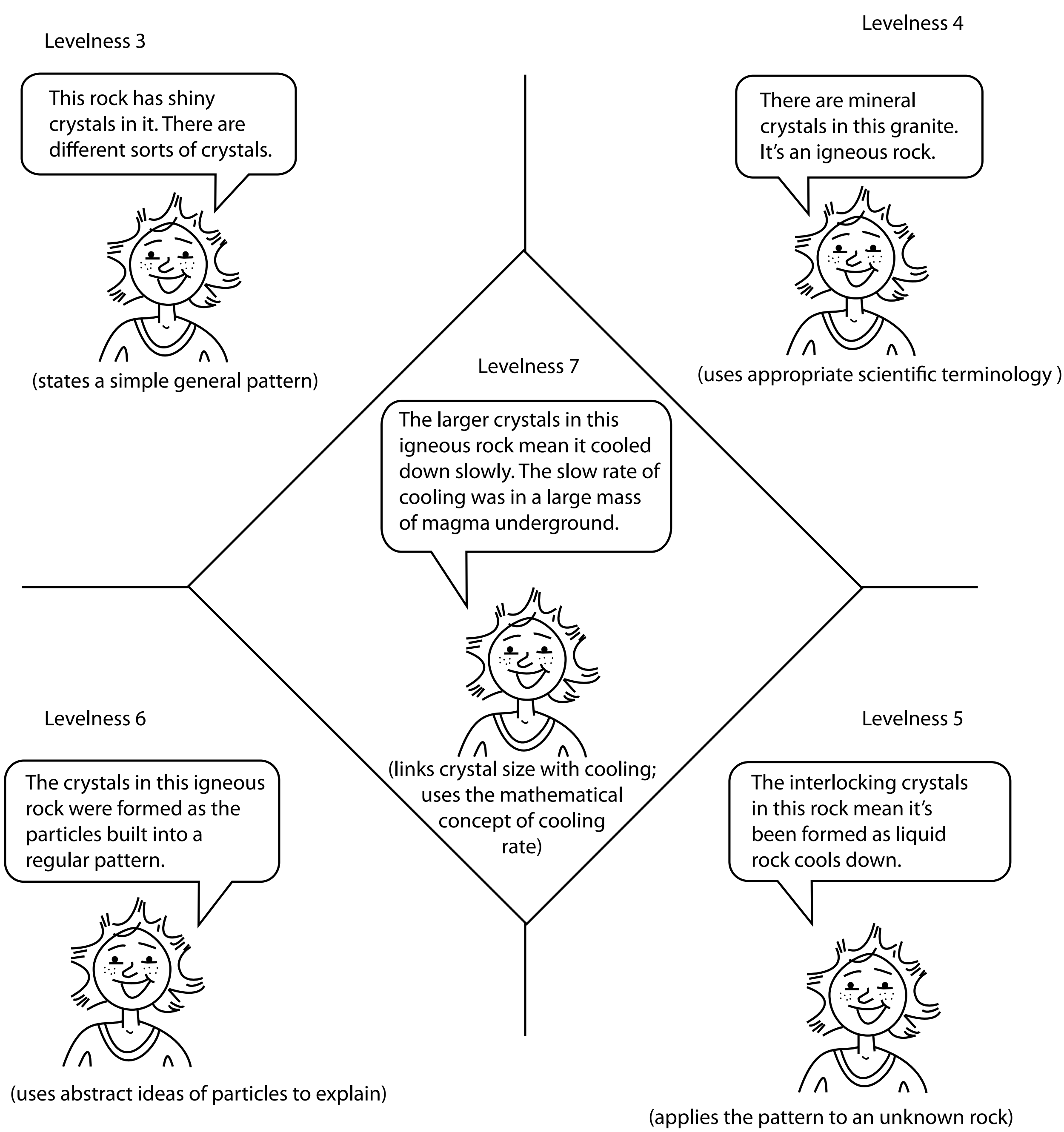
Thread 1: Evaluation of the planning and implementation of scientific investigations			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Suggest and justify improvements to experimental procedures using detailed scientific knowledge and understanding and suggest coherent strategies to take particular investigations further		
7	Explain ways of modifying working methods to improve reliability		
6	Make valid comments on the quality of their data		
5	Evaluate the effectiveness of their working methods, making practical suggestions for improving them		
4	Suggest improvements to their working methods, giving reasons		
3	Suggest improvements to their working methods		

Thread 2: Consideration of errors and anomalies			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Propose scientific explanations for unexpected observations or measurements, making allowances for anomalies		
7	Assess the strength of evidence, deciding whether it is sufficient to support a conclusion		
	Explain ways of modifying working methods to improve reliability		
6	Make valid comments on the quality of their data		
5	Provide straightforward explanations for differences in repeated observations or measurements		

Thread 3: Processing and analysing data to support the evaluation process and draw conclusions			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Process data, including using multi-step calculations and compound measures, to identify complex relationships between variables		
7	Assess the strength of evidence, deciding whether it is sufficient to support a conclusion		
6	Select and manipulate data and information and use them to contribute to conclusions		
	Draw conclusions that are consistent with the evidence they have collected and explain them using scientific knowledge and understanding		
	Make valid comments on the quality of their data		
5	Draw valid conclusions that utilise more than one piece of supporting evidence, including numerical data and line graphs		
	Interpret data in a variety of formats, recognising obvious inconsistencies		
4	Identify patterns in data presented in various formats, including line graphs		
	Draw straightforward conclusions from data presented in various formats		
3	Identify straightforward patterns in observations or in data presented in various formats, including tables, pie and bar charts		
	Describe what they have found out in experiments or investigations, linking cause and effect		

Thread 4: Explanation and evaluation of evidence to support the scientific process			
Level	**Assessment criteria**	**Addressed within KS3 SOL**	**Implications for departmental training and development**
8	Critically interpret, evaluate and synthesise conflicting evidence		
7	Explain how data can be interpreted in different ways and how unexpected outcomes could be significant		
	Identify quantitative relationships between variables, using them to inform conclusions and make further predictions		
6	Suggest reasons based on scientific knowledge and understanding for any limitations or inconsistencies in evidence collected		
4	Identify scientific evidence they have used in drawing conclusions		

Handout 1.5
Rough guide to levelness



Handout 1.6 Rich questions, strategies for progression, amplification and yearly learning objectives (YLOs) in four difficult areas

Behaviour

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
7	Describe simple learned and innate behaviours in response to internal and external stimuli and how these aid survival	Pupils could learn to: • describe some simple behaviours displayed by organisms in response to their external environment, e.g. innate responses to include movement of a sunflower to sunlight, dilating of the pupil in response to light, chicks following the first thing they see, the suckling instinct, learned responses to include salivation to smells, answering a door bell when it rings, child saying 'I want' when the television (TV) ad comes on, gender choice of toys and clothes	Plan structured research for pupils to identify the stimuli for a range of simple behaviours, e.g. reflex, taxis Support pupils in exploring how some technological developments have changed or affected human behaviour, e.g. mobile phones and TV, and evaluate the impact of these Create opportunities for pupils to classify some familiar behaviours as innate or learned, and to compare the advantages and disadvantages of innate and learned responses Support pupils in recognising when they are interpreting animal responses in terms of human experience or emotion Explore with pupils aspects of human body language, e.g. watch adverts or soap operas with no sound Create opportunities for pupils to experience trial-and-error learning, e.g. drawing round star shapes using a mirror so that the image is reversed Model how to plan an approach to gathering data involving some aspect of animal behaviour	Are elephants scared of mice? Do animals think? Do animals have emotions? Does my body give me away? Can you teach an old dog new tricks? Do plants grow better if given a good talking to?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
8	Explain how changes in learned behaviour due to internal and external stimuli are of benefit to the organism	Pupils could learn to: • distinguish between innate behaviour, learned behaviour, internal and external stimuli • explain how behaviours displayed by animals in response to their external environment can be beneficial to the organism, e.g. babies crying in response to wet nappy or hunger, a baby bird calling for food, animal and bird warning noises to young when predator approaches	Create opportunities for pupils to research a range of social behaviours and explore the survival advantages of these Involve pupils in observing human body language in different situations, e.g. school canteen or supermarket, devising qualitative and quantitative methods to record this and explaining differences in behaviour Provide pupils with clear criteria to enable them to explore sources of evidence related to a controversial social behaviour issue, e.g. knife crime, underage drinking, bullying	Are some animals more important than others? Is aggression always a bad thing? Is smiling good for you? Is behaviour worse on windy days? Are eyebrows a tool for communication?
9	Make links between observed social behaviours and the benefit to the survival of the species	Pupils could learn to: • explain how identified social behaviours, observed first-hand or from secondary sources, are beneficial to the species, e.g. bird territorial and attraction/ mating behaviours, hierarchical structures in farm and zoo animals, wolves or lions	Create opportunities for pupils to use secondary evidence to compare how chemical and electrical systems respond to stimuli Plan for structured research and discussion to identify, compare and analyse different types of behavioural response to a particular stimulus and its role in survival Encourage pupils to develop and evaluate their own models and analogies to explain the pathways between a stimulus and a response Create opportunities for pupils to explore the issues around investigating aspects of animal behaviour, e.g. identifying the variables that are less easy to control, and explaining how they will account for this in their planning and evaluation of evidence	Is behaviour always linked to survival? Is adrenaline a drug? Is a reflex response the brain losing control? Is cowardice an aid to survival?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
10	Explain how chemical and electrical signals enable body systems to respond to internal and external changes and the effect of this on behaviour	Pupils could learn to: • describe the differences between innate and learned responses and explain the survival advantages of each • evaluate how the chemical and electrical body systems (endocrine and nervous systems) work together and individually in a range of behaviours, i.e. fight and flight reaction, premenstrual tension, reflex reaction	Create opportunities for pupils to evaluate critically the evidence used to support arguments about the effect of a variety of substances on animal behaviour Provide opportunities to explore the ethical issues related to the use of chemicals to control animal and human behaviours Provide pupils with the opportunity to research and explain the relationship between behaviour, animal communication and survival Encourage pupils to explore the strengths and weaknesses between the models or analogies that could be used to explain the effect of substances on behaviour	Should chemicals be used to affect behaviour? Is perfume a behaviour-modification drug? Are we all addicted to the drugs our own bodies make? Do emotions make us more successful organisms?
11	Explain the effects of natural and artificial substances on chemical and electrical signals within the body, and possible effects on behaviour	Pupils could learn to: • explain how natural and artificial substances can affect behaviour, e.g. drugs and alcohol, hormones, adrenaline rush • evaluate the evidence for the impact of natural and artificial substances on innate and learned behaviour, and addictive behaviour (e.g. adrenaline rush for gambling addicts)	Create opportunities for pupils to research and explain the link between instinctive behaviour, natural selection, adaptation and survival Create opportunities for pupils to explore and explain how an understanding of animal behaviour offers a range of opportunities for exploitation	Is TV a drug? How accurate a term is brainwashing? Does asymmetric behaviour offer a survival advantage?
Extension	Evaluate evidence from different sources about the impact of natural and artificial substances on behaviour	Pupils could learn to: • explain how the interdependence of chemical and electrical signals affects behaviour and helps animals to adapt to new situations		

Particle models

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
7	Describe matter using a simple model and use it to explain changes of state Recognise the link between heating and cooling and changes of state Use the simple particle model to explain the physical characteristics of solids, liquids and gases	Pupils could learn to: • recognise obvious examples and properties of solids, liquids and gases using a simple model or analogy • explain the grouping of everyday materials into solid/liquid/ gas categories with reference to their properties, recognising that changes of state are reversible changes and dependent on temperature • justify their own classification of some 'difficult' materials, e.g. toothpaste, soap powder	Explore with pupils how the particle model can start to explain changes in matter and some of the limitations of the model Explore with pupils how the use of the particle model can support an explanation of the behaviour of solids, liquids and gases Provide and support opportunities to explore and compare the strengths and weaknesses of the particle model, e.g. explaining what is between the particles Explore with pupils to what extent materials can be classified by identifying their particular properties Provide opportunities for pupils to start to form links between the energy-transfer model and the particle model to explain changes in state Provide opportunities for pupils to experience changes of state and the reverse, including the associated energy changes Provide opportunities for pupils to select an appropriate model to explain separation techniques	Why can't we walk on water? What is the most common state of matter? Is shaving foam a liquid? Are any chemical reactions reversible? Is dissolving underwater melting?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
8	Apply and use the particle model to describe a range of physical observations Apply and use the particle model to describe a range of separation techniques	Pupils could learn to: • explain the grouping of materials into solid/liquid/gas categories with reference to their properties, and use this to describe simple evidence for the existence of gases, e.g. smell • describe and carry out a range of separation techniques, such as filtration or distillation in familiar contexts. • describe changes of state in terms of a particle model	Provide opportunities for pupils to predict the outcomes of particular separation techniques on unknown mixtures given each mixture's properties Discuss with pupils how manipulating a model or using an analogy could clarify their explanation of a separating technique Create opportunities for pupils to use the energy-transfer model to explain particle behaviour	Is the sea getting saltier? Do the particles in a gas ever slow down and stop? Can you melt wood? Can diffusion occur in space?
9	Evaluate and refine the particle model to explain a range of physical observations Evaluate and refine the particle model to explain a range of separation techniques	Pupils could learn to: • provide an explanation of a variety of separation techniques using a particle model • apply their knowledge of separation techniques, such as filtering and distillation, to unfamiliar situations, e.g. lumps in gravy, drying paint	Explore with pupils how they might justify their selection of an appropriate particle model to explain different phenomena Provide pupils with the opportunity to explore reasons for developments in the model of the atom Challenge pupils to use the energy-transfer model and the particle model to explain the differences in the melting and boiling points of different substances Structure opportunities for pupils to discuss how they can develop their particle model to explain the effects of changing pressure and volume	Do particles melt? Can you change the boiling point of a liquid? Do all gas particles move at the same speed? What's the secret to being a gas? Can you have a solution without a liquid? Are we living at the bottom of an ocean of air?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
10	Refine the particle model to explore the structure of atoms, including protons, neutrons and electrons Apply particle models in unfamiliar contexts, and begin to evaluate the strengths and weaknesses of the model	Pupils could learn to: • evaluate the particle model to include an appreciation of size • recognise the role of energy in particle behaviour and movement and use this to explain changes of state • use a particle model to explain differences in: – density – compressibility between solids, liquids and gases – diffusion in solids, liquids and gases – osmosis	Explore with pupils how the kinetic theory can be used to develop the way the particle model explains the behaviour of substances Create opportunities for pupils to use the kinetic theory to explain the effect of various factors upon solubility Create opportunities to compare different models of the atom and how a particular model was developed in the light of new information	Is glass really a liquid? If atoms are mainly empty space, are we? When is a particle not a particle? What is the energy content of food at absolute zero?
11	Use the particle model and ideas from science and across disciplines to explain phenomena and evaluate the use of the model	Pupils could learn to: • link kinetic theory to the particle model to explain: – change of state – diffusion – gas pressure – osmosis	Involve pupils in discussions about how to decide which of the different particle models is 'good enough' to explain phenomena such as the relationship between transpiration rate and humidity Create opportunities for pupils to explore how the interrelationship between the three dependent variables of pressure, volume and temperature can be investigated	Is Brownian motion a figment of imagination? Does gravity affect particles? Are more viscous liquids denser?
Extension	Use the particle model and ideas from science and across disciplines to explain complex phenomena and make critical evaluations to justify the use of a 'good enough' model	Pupils could learn to: • evaluate the effectiveness of the particle model in explaining other scientific phenomena, e.g. light, photosynthesis • explain relationship between volume, temperature and pressure in gases and use this to predict the effects of varying one factor on the other two		

Light

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
7	Describe how energy can be stored Describe how energy is transferred in simple contexts Describe how energy stored in a range of energy resources can be usefully transferred	Pupils could learn to: • explain that light travels in a straight line, and use the convention of straight lines as a way of representing light rays • explore the way different materials absorb, transmit or reflect light and why non-luminous objects can only be seen when light from a luminous object shines on them	Introduce pupils to the model of energy transfer and explore how this can be used to explain how transparent, translucent and opaque materials behave when light falls on them Explore how well the ray-diagram model can represent observations of light phenomena Evaluate the rigour of the scientific explanations used in promotional material for road-safety products that use reflection Create opportunities for pupils to make and test their predictions, e.g. for reflection, to develop their understanding of the straight-line model of light	Can you bend a pencil without breaking it? Do things still shine when the lights go out? Can white walls save me money? Can you see around corners? Can you see further in space? Where are the reflectors in the night sky?
8	Use a simple model of energy transfer to describe common observations	Pupils could learn to: • explore how using straight lines as a model to represent light rays is often a simplification and could lead to misconceptions • explore how light of different colours is absorbed or reflected by different surfaces	Provide opportunities for pupils to use creative thinking to explain how the behaviour of light is affected by filters and prisms Explore with pupils how well the energy-transfer model can explain observations made when light interacts with transparent, translucent and opaque materials Create opportunities for pupils to use the simple ray model to explain how images are formed and to discuss whether the model can lead to misconceptions Encourage pupils to plan a procedure to take and record observations and measurements of the path of light through materials of different densities Explore with pupils how the straight-line model of light can be extended to explain the colours in the visible spectrum	Is the sea blue? Is there an end to a rainbow? Are all images the same? Why can't people swap glasses? How does the world look to an insect?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
			Create opportunities for pupils to study the way that evidence has been used in the past to produce alternative models to explain the behaviour of light	
9	Develop more complex models of energy-transfer mechanisms (incorporating ideas about particles or waves)	Pupils could learn to: • apply and use the model of energy transfer by light to explain what happens when light strikes or passes through different materials • use a model that white light is made up of different colours to explain dispersion and combine this with energy transfer to explain why coloured objects (red, green, blue) look coloured when white light is shone on them	Explore with pupils how the model of electromagnetic (EM) electromagnetic radiation can be used to explain observable characteristics of light phenomena and relate this to wavelength Plan structured class discussion in which pupils use models, such as energy transfer and wave behaviour, to explore and evaluate a range of strategies to solve communication problems Explore with pupils the advantages and disadvantages of the phenomenon of dissipation and identify the variety of effects it leads to	Is light white? Is black a colour? Why do might you be disappointed with the look of your clothes when you get them outside the shop? Is there an infrared rainbow? Do blue and yellow always make green? Was Pepper's Ghost all 'smoke and mirrors'? Do car lights work better at night-time? Where does all the light go?
10	Apply the concept of conservation of energy to energy efficiency calculations in living and non-living systems Develop the idea of energy dissipation in a variety of contexts	Pupils could learn to: • apply models of energy transfer, absorption and reflection and the make-up of white light to explain the appearance of different coloured objects in different coloured lights	Create opportunities for pupils to compare the strengths and weaknesses of different models to explain and account for more complex wave phenomena Provide opportunities for pupils to draw upon models and use graphical representations to explain unfamiliar light phenomena	Why do mirages in the desert always look like pools of water? Should a magnifying glass carry a health warning? Is light invisible?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
	Describe the effects of energy transfer to living systems by electromagnetic (EM) and nuclear radiation	• identify light as electromagnetic (EM) radiation that can transfer energy from a source to a receiver or detector through a vacuum	Create opportunities for pupils to evaluate and use evidence to construct an argument to support the model of light as a wave Structure opportunities to explore how creative uses of electromagnetic (EM) radiation have led to the development of a range of medical imaging applications, and consider the response to these from a range of economic, social or cultural perspectives Provide opportunities for pupils to use models, including tools such as speed, frequency and wavelength, and evidence to construct quantitative explanations for wave phenomena	Why can't we see light? Does light have a split personality?
11	Use and apply complex models of energy transfer to a wide range of phenomena Explain a wide range of complex phenomena using the principle of conservation of energy and appropriate wave or particle models	Pupils could learn to: • link ideas of energy transfer, energy dissipation, wave speed, frequency and wavelength to explain refraction, dispersion and dissipation of light, and how these are applied in the transmission of information • compare and contrast the properties of light and other waves in the electromagnetic (EM) spectrum in terms of wavelength, frequency and speed	Create opportunities for pupils to use a range of evidence to evaluate the risks and benefits associated with electromagnetic (EM) waves of different frequencies and intensities and their effects on body cells Create opportunities for pupils to select and apply appropriate models to explain the choice of the frequency in a variety of applications of electromagnetic (EM) waves Provide opportunities for pupils to explore the reasons for the development of the photon model and to evaluate it in comparison with the wave and particle models	Are shorter wavelengths hazardous? Is there scientific evidence for auras? Are ghosts' figments of the electromagnetic (EM) spectrum? Do all stars twinkle?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
Extension	Apply broader or deeper knowledge and understanding of energy in explanations of observations and phenomena Use valid and rational argument to offer solutions to problems arising from the applications and implications of energy	Pupils could learn to: • apply understanding of wave phenomena to explain issues relating to communications technology, e.g. positioning of mobile phone masts • apply understanding of the EM spectrum to explain choice of frequency for a variety of applications, e.g. TV remote control, intercontinental communication systems		

Earth, Space and beyond

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
7	Describe the apparent movement of the Sun across the sky and the pattern in the changing appearance of the Moon	Pupils could learn to: • describe, using a simple model, how the relative positions of the Sun and Earth change over the course of time • recognise that the phases of the Moon are due to its position in relation to the Sun and Earth	Use models to demonstrate and challenge misconceptions about the relative movement of the Earth and Sun Provide opportunities to develop a timeline of the phases of the Moon Explore the use of the tilted Earth model with pupils to explain seasonal change and address common misconceptions Encourage pupils to evaluate a range of models to explain the relative sizes of planets and of distances in the solar system Create opportunities to discuss how astronomers gather evidence Involve all pupils in modelling why the same side of the Moon always faces us Explore with pupils how Earth/ Moon diagrams can create misconceptions about the causes of the phases of the Moon	Where is the Earth? How do we know the Earth isn't flat? Where are we in the universe? Does the Moon have seasons? Do the Sun, Earth and Moon move in the same way?
8	Describe the position of the Earth in relation to the position of other bodies in the solar system and use this to explain some phenomena Recognise that astronomy and space science provide evidence about the solar system	Pupils could learn to: • explain, using simple models, the seasons and phases of the Moon • describe the relative positions of celestial bodies in the solar system • describe how the relative positions of celestial bodies in the solar system can result in observable phenomena, e.g. eclipses • recognise how data are gathered from space that provide an insight into the nature of the solar system, e.g. satellites, telescopes, interplanetary probes	Support pupils in evaluating models to explain the relative movement of the Earth and other celestial bodies Explore with pupils how Sun/ Earth/Moon diagrams can create misconceptions about the formation of eclipses Create opportunities for pupils to use secondary data as evidence to identify and describe patterns within the solar system Explore with pupils how scientists use data gathered by space probes to further our understanding	Are planets and stars always visible? Do mobile phones need satellites? What's in the solar system? What is a planet?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
9	Apply models and use scientific data to explain the relative movement of celestial bodies in the solar system Describe how astronomy and space science provide evidence of the solar system and galaxy	Pupils could learn to: • explain some of the strengths and weaknesses in the models used to explain the relative movement of celestial bodies in the solar system, e.g. the Earth and Moon in night and day, and seasons • use models, patterns or data to explain the relative motion of the Earth and other planets • recognise some of the consequences of space exploration and colonisation	Create opportunities for pupils to explore how models have developed from observations and, over time, influenced our understanding of the universe Explore with pupils how observations made using the electromagnetic (EM) spectrum have furthered our knowledge of the universe Plan structured whole-class discussion to compare different methods of space exploration and the nature of the evidence they produce Create opportunities for whole-class discussion on the political and ethical issues surrounding the future of space exploration	Why study the universe? Is space exploration good value? Is space the final frontier?
10	Explain some methods used to explore the solar system and galaxy (both from the Earth and from space) Explain how the EM spectrum can inform the study of the stars in our galaxy (and universe)	Pupils could learn to: • explain how the current model of the solar system developed • evaluate the benefits and drawbacks of space exploration and colonisation in relation to ethical. moral, cultural and political dimensions • link some of the types of radiation received to their various sources, e.g. Sun, stars, planets, background, and how this leads to further study of the universe	Support pupils in exploring how complete is the evidence for some celestial phenomena Provide and support opportunities for pupils in tracking the investigation of the universe along a time line and explaining how theories changed with new evidence and political, religious and cultural bias Create opportunities for pupils to compare the arguments presented for and against Galileo's model of the solar system in terms of evidence and inference Create opportunities for pupils to consider evidence for and against different models of the universe	What was there before the Big Bang? How do we know there was a Big Bang? Where did everything in the universe come from and where is it going? Will the universe end in tears?

Year	Yearly learning objectives	Amplification	Strategies for progression	Rich questions
11	Evaluate the available evidence and explain why it favours an expanding universe as the current consensus model	Pupils could learn to: • evaluate how the current model of the solar system and expanding universe was developed on the strength of new evidence, e.g. how this was influenced by the political, religious and cultural norms of the day • explain how the evidence, e.g. data from space telescopes, is acquired and how it is provisional in nature, e.g. about distant stars, black holes and galaxies	Explore with pupils how evidence has led most scientists to accept the Big Bang theory as the most convincing current model of the formation of the universe Use various accepted models to produce alternative predictions for the future of the universe	If the universe is expanding, is it getting heavier? Is matter finite? Is time travel feasible?
Extension	Evaluate, using available evidence, and models of the universe, why the ultimate fate of the universe is difficult to predict	Pupils could learn to: • explain the main idea of the 'Big Bang' theory, e.g. red shift • explain and justify the reliability of the current consensus models as a basis for predicting the fate of the universe		

Handout 1.7 Planning sheet

Year group:			**Title of unit:**	
Target range of levels based on APP:			Learning objectives:	
Learning outcomes	**Success criteria – what pupils will need to do to show that they have achieved the outcomes**			**Rich question to set context of lesson**
Common misconceptions or barriers to consider – how will I know if pupils have these barriers?				
Teaching strategies to address the objectives and achieve the outcomes				
Assessment criteria	**AF**	**Level**	**Evidence**	**Which pupils achieved this**

Handout 1.8 Rich questions

What is a rich question?

This is an open-ended, higher order question which requires learners to either link or apply ideas, give reasons, summarise or evaluate. Sometimes the questions encourage learners to ask further questions to qualify what the question is actually asking them to explain. These questions generally require extended answers.

Sometimes they are 'big' questions that can't be answered immediately. They may prompt a range of possible answers from a number of learners which in turn raise a list of smaller questions that need to be answered before the answer to the 'big' question can be formulated.

Rich questions can often be accessed by learners at different levels so the same rich question could be used at both Year 7 and Year 13.

How can rich questions support teaching and learning?

Rich questions can be used:

- as a starter activity to engage and motivate learners and make mundane lessons more interesting;
- as a vehicle to explore pupils' current levels of understanding and any barriers or misconceptions that might be present
- to structure a synoptic-type lesson where pupils are required to apply their skills, knowledge and understanding from a range of scientific ideas
- to enable pupils to develop higher order thinking
- to provide a different way to revisit a topic
- to broaden and deepen understanding
- to provide opportunities for learners to demonstrate their full potential
- to help learners understand that uncertainty is a key part of the scientific process
- to make learners aware that science cannot explain everything
- to prompt group work, discussion and argument
- to make the lesson more relevant.

Handout 1.9 Barriers to learning

Barriers to learning – behaviour

There are common barriers that could prevent learning in this area. They need to be identified in the scheme of work and addressed through teaching.

- It is hard for pupils not to interpret responses in terms of human experience, i.e. anthropomorphism.
- Pupils tend to put themselves in place of the animal when interpreting data, i.e. anthropocentric responses.
- Pupils do not easily make links between the brain, nervous system, hormones and behaviour; nor between behaviour and survival.
- Pupils will often interpret the cause of the observation in terms of its outcome by giving a predetermined purpose to a behaviour, such as seeing a dog eating and assuming it did so because it was hungry, i.e. teleology.
- It is important to make pupils aware that many studies on behaviour have taken place under controlled conditions and may not reflect the behaviour of organisms in their natural environment.

Barriers to learning – particle model

There are common barriers that could prevent learning in the Particle model substrand. They need to be identified in your scheme of work and addressed through your teaching.

Pupils often think that:

- substances contain particles rather than consist of particles, e.g. pupils think water has particles in it, with water or air between the particles; pupils think that air has oxygen particles in it and there is air between the particles;
- particles are comparable in size to cells, dust specks, etc., and they can be seen with an optical microscope;
- particles of the same substance have different properties in solid, liquid or gas state, e.g. some pupils think solid ice particles are cold and hard, liquid water particles have expanded and so they are larger and softer, while water vapour particles expand even more and are very large and squashy;
- all liquids contain water;
- air is good (breathing) and gas is bad (flammable or poisonous);
- gases have no weight, or even have negative weight, and that is why things filled with gas float;
- when water evaporates it splits up into atoms of hydrogen and oxygen;
- the bubbles in a boiling liquid are bubbles of air;
- melting and dissolving are the same;
- boiling points are not fixed and the temperature will continue to go up as more energy is transferred;
- condensation forms as a result of the 'cold' causing oxygen and hydrogen in the air to make water;
- atoms are a small bit of the parent material with all the same properties as that material;
- the proportions of combining elements in a compound are not fixed;

- metallic properties are due to properties of the atom rather than the atomic arrangement;
- non-metals are substances such as sugar or wood rather than non-metallic elements;
- chemical change is what is observed during the reaction, e.g. fizzing, not the production of a new substance.

Pupils are often confused or uncertain about:

- the function of the air, although they know that air is needed for burning;
- the use of scientific words, such as material, matter, substance and pure lead, where there is also a different everyday meaning, e.g. 'pure' means it doesn't contain anything harmful;
- conservation of mass if they still think gases are weightless or substances disappear, e.g. by evaporation or burning.

Barriers to learning – light

There are common barriers that could prevent learning in this area. They need to be identified in your scheme of work and addressed through your teaching.

Pupils often think that:

- light transfers energy from one place to another instantaneously
- an object is seen whenever light shines on it, with no recognition that light must move between the object and the observer's eye
- when objects are seen light (or 'rays') comes out of the eye and travels to the object
- lines drawn outward from a light bulb in a sketch represent the 'glow' surrounding the bulb; light from a bulb only extends outward a certain distance and then stops; how far it extends depends on the brightness of the bulb
- light is reflected by shiny surfaces, but light is not reflected at all from other surfaces
- light always passes straight through transparent material (without changing direction)
- blocking part of the lens surface would block the corresponding part of the image
- the purpose of the screen is to capture the image so that it can be seen; without a screen, there is not an image
- an image is formed at the focal point of a lens
- the size of an image depends on the size (diameter) of the lens used to formed the image
- gamma rays, X-rays, ultraviolet light, visible light, infrared light, microwaves and radio waves are all very different things
- when waves or pulses interfere (as in a spring, rope, water wave or light wave) they bounce off each other and go back in the opposite direction from which they came
- when a wave moves, particles move along with the wave from the point of transmission to the point of reception
- when light passes through a prism or a filter, colour is added to the light
- the rules for mixing coloured lights are the same as the rules for mixing coloured paints.

Barriers to learning – Earth, Space and beyond

There are common barriers that could prevent learning in this area. They need to be identified in the scheme of work and addressed through teaching.

Pupils often think that:

- the Sun orbits the Earth and this causes day and night
- the phases of the Moon are caused by cloud cover or the shadow of planets, the Earth or the Sun
- the seasons are caused by the distance of the Earth from the Sun, i.e. the Earth is nearer to the Sun in summer
- the planets and the Moon are light emitters
- there is not much difference in the size of the Sun and the planets, and that all stars are the same distance from the Earth; alternatively pupils may think that all stars are the same size and that their different distances from the Earth cause differences in brightness – this is because of the scales used in the solar system and universe diagrams
- the Sun rises exactly in the east and sets exactly in the west every day
- the Sun is always directly overhead or directly south at noon
- the surface of the Sun has no visible features
- light years refers to time rather than distance
- dwarf planets are ‘tiny planets’ rather than a celestial body rounded by its own gravity.

Handout 1.10 Progression in developing *How science works (HSW)*

Practical skills are alluded to in general terms in the scheme of learning (work)	Practical skills are expected to be taught but left to teacher's discretion with little monitoring of practice across the department	*HSW* activities are added to some units in the scheme of learning but in an ad hoc fashion	*HSW* activities are written into the scheme of learning for all units but not all the skills are well represented. Activities are not used by the whole department	*HSW* activities and objectives are planned into the scheme of learning so that all skills are represented but there is no clear progression	*HSW* activities have agreed objectives and outcomes that support better progression in the scheme of learning	*HSW* objectives and outcomes are plotted progressively across all schemes of learning in Key Stage 3 and 4	*HSW* objectives and outcomes are personalised for pupils in response to their progress
Teachers do not see the importance of teaching *HSW* and restrict it mainly to Years 7, 8 and 10. Objectives and outcomes are focused on content	Teachers consider *HSW* to be the same as practical work. This practical work is 'recipe driven' with the assumption that pupils will pick up skills with practice	Teachers are unclear about the different purposes of practical work, e.g. to illustrate a piece of science knowledge, to develop a practical skill or to develop non-practical skills such as argumentation	Teachers are unsure how to plan with a *HSW* focus and find it hard to deliver the activities in scheme of learning (work) with any confidence	Teachers are clear about the importance of teaching *HSW*. The purpose of practical work is made explicit to pupils	Teachers are comfortable with, and plan for, progression in *HSW*. Lessons are well designed to deliver the *HSW* outcomes	Teachers are confident in their understanding of progression in *HSW*	Teachers have integrated their understanding of *HSW* skills into their whole approach to teaching science

Pupils spend a lot of time on low-level tasks that occupy their time but add little to skill development	Pupils will say that they like the practical work but actually learn little from it	Pupils' investigations show little improvement and often rely on a planning frame	Pupils make haphazard or accidental gains in *HSW* skills of developing explanations or argumentation	Pupils are aware that *HSW* is more than just practical work and are supported in making decisions and using *HSW* skills in lessons	Pupils make appropriate decisions and use a range of *HSW* skills in lessons	Pupils use the skills of *HSW* to engage with content, e.g. by exploring the strengths and weaknesses of models	Pupils independently use a range of skills to explain, evaluate, develop explanations and arguments about scientific ideas and identify next steps in their learning

Strategies to move to the next step

The strategies listed below are suggested starting points that will need to be personalised to support your particular circumstances. For example, if the consultant is to run a department meeting you need to have a very clear focus. This must require follow-up work for all teachers before the next meeting, otherwise the practice will not change.

- Arrange for your science consultant to run a department meeting or in-service training day on *How science works* (*HSW*) for example on progression or learning objectives.
- Agree a programme with your science consultant to work with teachers in planning and delivering *HSW* in lessons.
- Use your science consultant to support peer coaching with members of the department in developing their own practice.
- Identify particular continuing professional development issues for individual teachers in the department and appropriate training.
- Build regular slots on *HSW* into department meetings.
- Share examples of good practice at department meetings.
- Approach the senior leadership team (SLT) for additional time and resources to develop *HSW* practice.
- Establish a baseline current practice through lesson observation, book scrutiny or pupil and staff interview to be able to identify success clearly.
- Review your scheme of learning.
- Use the yearly learning objectives (YLOs), amplification and teaching strategies from the science Framework to plan for the progressive development of skills across Key Stage 3 and/or Key Stage 4.
- Visit another department that is further along the progression.
- Use the *HSW* 'steps and layers' approach from this resource.
- Use other strategies and materials from this resource.
- Liaise with other departments to improve practice in constructing arguments or analysing secondary evidence.

Progression in developing *How science works* (*HSW*) and links to Assessing Pupils' Progress (APP)

Department	Practical skills are alluded to in general terms in the scheme of learning	Practical skills are expected to be taught but left to the teachers' discretion with little monitoring of practice across the department	*HSW* activities added to some units in the scheme of learning but in an ad hoc fashion	*HSW* activities are written into the scheme of learning for all units but not all the skills are well represented. Activities are not used by the whole department	*HSW* activities and objectives are planned into the scheme of learning so that all skills are represented but no clear progression	*HSW* activities have agreed objectives and outcomes that support better progression in the scheme of learning	*HSW* objectives and outcomes are plotted progressively across all schemes of learning in Key Stages 3 and 4	*HSW* objectives and outcomes are personalised for pupils in response to their progress
What assessment might look like or typical activities								
Steps for implementing APP								

Teachers	Teachers do not see the importance of teaching *HSW* and restrict it mainly to Years 7, 8 and 10. Objectives and outcomes are focused on content	Teachers consider *HSW* to be the same as practical work. This practical work is 'recipe driven' with the assumption that pupils will pick up skills with practice	Teachers are unclear about the different purposes of practical work, e.g. to illustrate a piece of science knowledge or to develop a practical skill or to develop non-practical skills such as argumentation	Teachers are unsure how to plan with a skills focus and find it hard to deliver the activities in the scheme of learning with any confidence	Teachers are clear about the importance of teaching *HSW*. The purpose of practical work is made explicit to pupils	Teachers are comfortable with, and plan for, progression in *HSW*. Lessons are well designed to deliver the *HSW* outcome	Teachers are confident in their understanding of progression in *HSW*	Teachers have integrated their understanding of *HSW* skills into their whole approach to teaching science
What assessment might look like or typical activities								
Steps for implementing APP								

Pupils	Pupils spend a lot of time on low-level tasks that occupy their time but add little to skill development	Pupils will say that they like the practical work but actually learn little from it	Pupils' investigations show little improvement and often rely on a planning frame	Pupils make haphazard or accidental gains in *HSW* skills of developing explanations or argumentation	Pupils are aware that *HSW* is more than just practical work	Pupils make appropriate decisions and use a range of *HSW* skills in lessons	Pupils use the skills of *HSW* to engage with content, e.g. by exploring the strengths and weaknesses of models	Pupils independently use a range of skills to explain, evaluate, develop explanations and arguments about scientific ideas and identify next steps in their learning
What assessment might look like or typical activities								
Steps for implementing APP								

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