Intervention to support GCSE science

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Reported weaknesses in GCSE science (HSW and general aspects)

Scientific investigative skills

Absence of correct scientific terminology

Confusion and/or lack of precision in scientific terms and/or symbols

Mathematical ability

Not reading and/or answering a question precisely

Reported weaknesses in GCSE science (biology)

Absence of correct scientific terminology

Confusion and/or lack of precision in scientific terms and/or symbols

Mathematical ability

Not reading and/or answering a question precisely

Scientific concept – weaknesses from core science

Scientific concept – weaknesses from additional science or biology

Reported weaknesses in GCSE science (chemistry)

Absence of correct scientific terminology

Confusion and/or lack of precision in scientific terms and/or symbols

Mathematical ability

Not reading and/or answering a question precisely

Scientific concept – weaknesses from core science
Scientific concept – weaknesses from additional science or chemistry

Reported weaknesses in GCSE science (physics)

Absence of correct scientific terminology

Confusion and/or lack of precision in scientific terms and/or symbols

Mathematical ability

Not reading and/or answering a question precisely

Scientific concept – weaknesses from core science

Scientific concept – weaknesses from additional science or physics

Key questions on supporting pupil progress in science GCSEs

The new GCSE specifications due to be introduced in September 2011 have a number of implications for learning, teaching and subject leadership. To secure the best possible outcomes for pupils, teachers could consider how to respond to challenges and opportunities arising from the changes to the GCSE criteria including:

- extended questions
- controlled assessments
- number and nature of assessment units

The questions below link to examples of effective practice and support for pupils following both the new and existing science GCSE specifications:

How do I know how well my pupils are doing?

Tracking progress in GCSE science
Consideration of the effective and systematic use of reliable data to track pupils' progress, identify underperformance and inform intervention in GCSE science.
How well can my pupils write extended answers?

Developing extended writing in science
All new science GCSE assessments will require students to write extended answers. The resources in this section are designed to help teachers to improve pupil performance in their GCSE assessments:
• in the short term: by improving extended written answers in science examinations
• In the long term: by developing extended writing skills in science.

How can my pupils get better at explaining ideas, collaboration, modelling and justification of scientific decisions?

Developing explanations, argument and decisions in science
Using models, argument and explanation to understand science and justify decisions.

How well can my pupils generate and interrogate primary and secondary evidence?

Developing effective scientific practical and enquiry skills at GCSE
What is evidence? How do GCSE science pupils collect and work critically with evidence?

What concepts do my pupils struggle with?

Overcoming weaknesses in GCSE science
Common difficulties that pupils have when answering GCSE science papers have been identified with suggested resources that teachers might find useful in planning their schemes of work and lessons and for discussions in departmental meetings.

A summary table describing all of the steps tables supporting the development of writing, development of explanations, argument and decisions and developing effective scientific practical and enquiry skills can be used to identify the learning needs of individuals and groups of pupils. See Steps table summary – to support effective intervention during GCSE science courses.
Don't forget to study the appropriate specification and assessment materials for the awarding body you choose.

**File Attachments**

- [Steps table summary – to support effective intervention during GCSE science courses](xls 43 KB)

**Key changes to GCSE science specifications**

A number of changes to GCSE science courses are being implemented for first teaching from September 2011. These arise from:

- the generic criteria for GCSE specifications
- the specific criteria for science, additional science, additional applied science, biology, chemistry and physics
- the regulations for controlled assessments.

Remain aware of the role that these criteria and regulations play. The development of these for each of the courses is a new development; they are used to evaluate the submitted specifications by each of the awarding bodies.

The criteria also stipulate the assessment objectives for each course. For example, for GCSE science, they are:

- **AO1** Recall, select and communicate their knowledge and understanding of science, 30–40%
- **AO2** Apply skills, knowledge and understanding of science in practical and other contexts, 30–40%
- **AO3** Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence, 25–35%.

The significant changes for the courses are:

- restricted number of resits
- at least 40% of marks allocated at the end of the course, when the grade is awarded
- no more than four assessment units per GCSE
- specified level of control in controlled assessments
- twelve-month shelf life on controlled assessments

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• controlled assessments accounting for 25% of marks (60% in additional applied science)
• assessment modes, in all GCSE specifications, will include written responses of various lengths.

Ofqual criteria and regulations

GCSE generic and subject criteria: Ofqual - GCSE Criteria

Extracts available in these materials:

• Ofqual grade criteria – extended writing in GCSE science
• Ofqual grade criteria – EAD in GCSE science
• Ofqual grade criteria – Practical and enquiry skills in GCSE science

Regulations for GCSE controlled assessments: Ofqual - GCSE Controlled Assessments

Materials to support this process include:

• Checklist for departments prioritising developments to implement new GCSE science courses.

Related Links

• Ofqual - GCSE Criteria
• Ofqual - GCSE Controlled Assessments

File Attachments

• Checklist for departments (doc 52 KB)

Tracking progress in GCSE science

Effective tracking of pupils’ progress in Key Stage 4 science can provide pupils, parents, teachers and school leadership teams with an understanding of strengths and weaknesses in attainment to support progress. It also helps to support consistency in assessment procedures across the department, so that there is clarity of expectations for pupils and effective curricular target setting in science.

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Pupils make better progress in science when:

- approaches to planning and teaching are based on progress in the key concepts and processes;
- pupils' learning is tracked and assessed systematically, with timely use of intervention to improve attainment;
- pupils receive feedback that provides clear evaluation of strengths and weaknesses, prompts reflection, and identifies the next steps in their learning.

The tracking of progress informs intervention, so that the effective progress of all pupils is supported as well as the needs of groups at risk of underperforming being addressed. This will support the curriculum team in becoming more evaluative.

The challenges facing subject leaders to support better progress in GCSE science include the following:

- as there are no more than four assessment units per GCSE course, the frequency at which external assessment data is received is limited;
- furthermore, as at least 40 per cent of marks are allocated at the end of the course, this evidence is not available to inform tracking during the course;
- teachers apply grade criteria to evaluate the quality of pupils' work in terms of likely outcomes and recognise, for example, what a grade C response looks like;
- tracking data based on pupil performance across all three assessment objectives reflects the processes involved in science and is not entirely based on knowledge and understanding;
- tracking data limited to the outcomes of objective tests may conceal pupils' inability to generate extended answers.

Strategies to develop to support better progress:

- providing a range of internal assessment opportunities which require all pupils to respond in a variety of ways will help to provide regular feedback on their progress
- supporting departmental staff to develop their awareness of the assessment objectives and grade criteria will enable them to judge progress being made
- supporting departmental staff to be able to identify specific challenges and opportunities to enable pupils to make the next steps in learning.
Activities which might support effective tracking of progress include:

- Analysing pupil responses in assessments to identify the strengths and areas for development of individual students. It would be useful to explore whether issues are related to *How science works* (HSW) (either Developing effective scientific practical and enquiry skills at GCSE or Developing explanations, argument and decisions in science), exam technique including Extended written answers in science examinations, Overcoming weaknesses in GCSE science or Developing extended writing skills for GCSE science. Analysis could be used to identify pupil curricular targets, so that pupils know what they need to do to improve. Consider how these will be shared with pupils, so they know how to improve, and with parents and carers, so that they can offer support.
- Identified common areas for development can be used to modify existing teaching and learning sequences.
- Where classes are taught by more than one member of staff the relative progress of the pupil in each of the classes could be analysed. Systems to encourage shared intelligence and a collective accountability for pupils’ overall grades may inform joint planning to address areas of weakness.
- Effective assessment for learning, including diagnostic analysis of the evidence from day to day assessment, can inform specific interventions for individuals or groups of pupils at risk of underachievement. These might include guided learning or targeted revision support.
- Whole teaching sequences, topic areas and specific interventions in individual GCSE courses can be evaluated to measure the impact on pupils’ learning. If you carrying out this activity, consideration will need to be given to what data will be collected to evidence this.

Materials which might support effective tracking include:

- Question level analysis
- Core Plus science support materials
- Narrowing the gaps in science
- Key questions to consider regarding evidence to be collected

Related Links

- Core Plus science support materials
- Narrowing the gaps in science

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Key questions to consider regarding evidence to be collected

For effective tracking in KS4 science, you might like to consider the following questions:

What information is available to support pupil tracking?

- Is there sufficient prior learning data collected and included to inform target setting (for example, general pupil data – name, unique pupil number, gender, date of birth, teaching group/set, vulnerable groups such as free school meals, children looked after and Gifted and Talented)?
- What information do you have available to inform target setting? (for example, Key Stage 4 – Fischer Family Trust (FFT) model D estimate, three levels of progress target data)
- What are the best types of evidence to be used to track progress in both How science works and the range and content during the course?

When do you collect data?

- What is a suitable timeline for the frequency of science assessments throughout the year, and what are the best points in the term to fit in with whole-school tracking and reporting of progress and external assessments?
- Do you have agreed departmental operational guidelines for how and when pupils will be assessed – day-to-day, periodic? How are these reviewed?
- Do you have agreed departmental operational procedures for recording assessments to include deadlines for entering scores in a tracking system? Who is responsible for collecting and entering the data?
- How do you agree the process and frequency of identification of pupils at risk of underachievement, to trigger appropriate intervention strategies?
- How frequently do you discuss the timing of centre-assessed units with other departments within the school, to avoid overloading pupils?

Other issues you might like to consider:

- What are the current barriers to implementing assessment and recording of How science works through the range and content section of the programme of study for science, and addressing the needs of staff to make further progress?
- How confident are members of the department in their use of the GCSE grade criteria? Are they able to use the criteria to track pupil progress and set suitable curricular targets?
• How familiar are members of the department with the requirements and tracking of How science works and the range and content identified in the Key Stage 4 specification(s) delivered in the department?
• As a department, do you moderate standards across all science teaching groups to support accurate tracking of pupil progress using examples of pupils’ work from across the department?
• Do you display anonymised pupils’ work to illustrate the criteria for different grades? If so, how do you make use of it to support pupil progress?

Extended written answers in science examinations

Teachers can use these resources to improve pupil performance in extended writing of examination answers.

The two key elements are:

**Understanding the question – top tips**

Ask pupils to be clear about what the question is asking so that they can structure their written response.

- Annotate any observations or key points (e.g. use speech bubbles).
- Highlight any key vocabulary, facts or information.
- Identify the ‘command word’ and consider what this implies.
  You might also like to refer to your awarding body's specific resource on command words.
- Look at the number of marks allocated – how many key points will you need?

**Constructing an answer that meets the requirements of the marking scheme – top tips**

Ask pupils to:

- use key information from the question, including from graphs, tables and pictures
- include key scientific vocabulary
- use appropriate connectives to link statements
- construct a logical sequence.
Suggested teaching approaches

• Remind pupils of the 'Point, Evidence, Explanation' (PEE) strategy used in English to construct extended answers. This could be supported by the Thinking Frames approach.
• Model how you would answer a question, explaining your thinking out loud and annotating the question, to construct the full written answer jointly with pupils as a class activity.
• Model the thinking process with another question and ask the pupils to fill in the answers (individually or in pairs).
• Pupils answer a complete question independently, but annotate as the teacher has demonstrated.
• Pupils answer a complete question without any scaffolding.

Further suggestions

• Unpick pupils' answers by comparing to the awarding body marking scheme to reach agreement on what a good answer looks like.
• Use peer assessment, measured against specific success criteria.
• Provide a poor answer and ask pupils to suggest improvements.
• Provide several exemplar answers to a question and get pupils to discuss why one answer is better than another and develop criteria for a successful answer, which they can then apply to another question.
• Consult the examiners' reports from the awarding bodies for further advice. The section on 'Overcoming weaknesses in GCSE science' explores common weaknesses and provides links to materials to help address these.

Further resources are available to:

• support the writing of descriptions, explanations and argumentation
• show the relevant statements within the grade criteria for 2011 GCSE science specifications
• support the development of graphical skills if these are limiting pupils' ability to write extended answers.

Command words in examination questions

Be clear about what the question is asking you to do.
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<th>Command words and their meanings</th>
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<td><strong>Account for</strong></td>
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Developing extended writing skills for GCSE science

Resources to help teachers improve performance in pupils’ extended writing for GCSE science assessments over the long term.

THINK – TALK – WRITE

This approach is based on the idea that pupils eventually write best if they are first helped to work together to think and talk in a structured way.
The resources are organised in steps tables which can help teachers guide pupils to move from writing simply to producing more complex extended writing.

The steps tables include descriptions of what pupils can be expected to achieve when they improve their skills in:

- writing descriptions and explanations (see Writing descriptions and explanations steps table)
- framing arguments (see Framing arguments steps table).

The steps table includes:

- suggested strategies for moving pupils from one step to another;
- exemplification of what pupils can do at each step.

These tables are designed to support planning for learning, not planning for assessment, and can be used to support progression in learning and to encourage increased progression to post-16 science courses.

The steps are not levelled or graded, as securing progress to a particular step in an individual aspect would not lead to the attainment of a particular overall grade. You could use the tables to:

- judge a pupil’s starting point within each aspect to gain a holistic view of the learning needs of that pupil in GCSE science
- support progress as far as possible in the identified aspects by suggesting opportunities to take the next step in learning.

Some pupils will progress further than others in some aspects and will be more able to achieve higher overall outcomes in their science GCSE courses.

## Writing descriptions and explanations steps table

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.
Step 1: Pupils can work effectively in groups to share and organise their ideas. They write descriptions and simple explanations in which the ideas are clearly organised and have appropriate links within and between paragraphs, using scientific vocabulary reasonably accurately.

Strategies to support progress from step 1 to step 2

- Model a written description or explanation showing pupils how to use paragraphs or sections to order ideas, use connectives to link ideas within a paragraph and how to provide links between paragraphs.
- Plan opportunities for groups to work collaboratively to evaluate the features of good scientific descriptions and explanations and to learn how to use these to improve their writing.
- Discuss and explain complex scientific vocabulary and shades of meaning (possibility, probability and certainty) or relationships between ideas, for example distinguishing between opinion or hypothesis and fact in explanations.

Step 2: Pupils can work effectively in groups to explore and clarify ideas, make evaluations and form explanations using models. Pupils independently write extended descriptions and explanations that have a clear sequence and meaning by using cohesive devices, well-structured paragraphs and appropriate scientific terminology.

Strategies to support progress from step 2 to step 3

- Plan structured whole-class and small group discussions that allow pupils to identify in written descriptions and evaluations key ideas and linked evidence, opinions models and analogies. Follow up with opportunities to use these in structured collaborative and independent writing.
- Create opportunities for groups of pupils to identify and evaluate strategies to develop logical and coherent complex written explanations across a range of scientific contexts.
- Model how to write descriptions and explanations for different audiences, using cohesive devices such as connectives for emphasis and effect in a paragraph; model how to provide links between paragraphs. Follow up with opportunities for pupils to use these in structured collaborative and independent writing.
**Step 3:** Pupils can collaborate effectively in groups to explore, challenge and develop complex explanations and evaluations that link ideas from a range of scientific models and analogies across a variety of scientific contexts. They write independently logical and coherent descriptions and explanations for a range of audiences and purposes using scientific terminology appropriately and accurately.

**Strategies to support progress from step 3 to step 4**

- Plan substantial discussion or debate opportunities for pupils to identify and then evaluate the range of scientific models and ideas used in an explanation; model how to write explanations coherently.
- Create opportunities for groups of pupils to identify and evaluate strategies to develop logical and coherent complex written explanations across a range of scientific contexts; and provide opportunities for pupils to learn how to modify their explanations when presented with new evidence.
- Provide regular opportunities across a range of scientific contexts for pupils to write logical and complex descriptions or explanations collaboratively and independently, incorporating scientific models and analogies, and using scientific terminology accurately and precisely.

**Step 4:** Pupils can collaborate effectively in groups to develop and evaluate complex explanations that link ideas from a range of sometimes conflicting scientific models and analogies, in a variety of scientific contexts. They write independently logical and coherent descriptions and explanations which include an evaluation of the strengths and weaknesses of the models. Their writing for a range of purposes and audiences is well-constructed and coherent, with accurate and precise use of scientific terminology.
Writing descriptions and explanations steps table – pupil exemplification

This exemplification shows how pupils may work in groups in the context of the process of coordination and moving messages around the body – an example from GCSE biology.

**Step 1:** Pupils can work effectively in groups to share and organise their ideas. They write descriptions and simple explanations in which the ideas are clearly organised and have appropriate links within and between paragraphs, using scientific vocabulary reasonably accurately.

Pupils are asked to produce a written explanation of how an arm lifts a book from a table when provided with a list of the parts, functions and adaptations of a motor neuron on cards, and provided with a diagram of a motor neuron.

**Step 2:** Pupils can work effectively in groups to explore and clarify ideas, make evaluations and form explanations using models. Pupils independently write extended descriptions and explanations that have a clear sequence and meaning, by using cohesive devices, well-structured paragraphs and appropriate scientific terminology.

Pupils are given an unlabelled diagram of a reflex arc and asked to produce a poster which describes the process by which a nerve impulse moves, showing how this specialist response occurs when a hand touches a very hot object.

**Step 3:** Pupils can collaborate effectively in groups to explore, challenge and develop complex explanations and evaluations that link ideas from a range of scientific models and analogies across a variety of scientific contexts. They write independently logical and coherent descriptions and explanations for a range of audiences and purposes, using scientific terminology appropriately and accurately.

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Pupils are asked to collaborate to produce a leaflet for young sufferers of diabetes on how to manage body glucose levels while in school, based on information from the Diabetic Support Group.

**Step 4**: Pupils can collaborate effectively in groups to develop and evaluate complex explanations that link ideas from a range of sometimes conflicting scientific models and analogies, in a variety of scientific contexts. They write independently logical and coherent descriptions and explanations which include an evaluation of the strengths and weaknesses of the models. Their writing for a range of purposes and audience is well-constructed and coherent, with accurate and precise use of scientific terminology.

Pupils are asked to collaborate and provide a survival guide for menopausal women on the relative importance of the hormonal and nervous systems in long- and short-term control of body temperature.

You can find extracts from the GCSE grade criteria relevant to extended writing later in this section.

**Framing arguments steps table**

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance in the new GCSE science courses.

**Step 1**: Pupils can talk about and share points in an argument, separating fact from opinion and including this in written responses.

**Strategies to support progress from step 1 to step 2**

- Provide a range of written evidence from which pupils can work in groups to identify statements that support a claim, counter claim or neither.
Create opportunities for groups to work collaboratively to identify the features of good written scientific arguments and to evaluate and improve their own written arguments.

Model how to construct a written argument logically, showing pupils how to use paragraphs or sections to order ideas, how to use connectives to link ideas within a paragraph and how to provide links between paragraphs.

Provide opportunities for pupils to write arguments collaboratively and independently, using writing scaffolds to support the writing process.

**Step 2**: Pupils can work effectively in groups to give reasons why evidence supports the claim or counter claims. They write a simple coherent argument that identifies a claim or a counter claim.

**Strategies to support progress from step 2 to step 3**

- Challenge pupils to assemble and record the defence of a claim that is contrary to their own point of view.
- Create opportunities for pupils to learn how criteria can be used to evaluate strategies to develop logical and coherent written arguments with supporting evidence, and how to adapt these for particular audiences.
- Model how to write arguments for different audiences using cohesive devices such as connectives for emphasis and effect in a paragraph; model how to provide links between paragraphs. Follow up with opportunities for pupils to use these in structured collaborative and independent writing.

**Step 3**: Pupils can collaborate effectively in groups to evaluate evidence appropriately in order to develop claims and challenge counter claims. They develop and write complex arguments fluently, incorporating a range of evidence to persuade an audience using appropriate conventions.

**Strategies to support progress from step 3 to step 4**

- Plan substantial discussion and debate opportunities for pupils to list the pros and cons of an argument, to identify claims and counter claims and to learn how to link the supporting evidence in arguments.
- Create opportunities to model for pupils how to produce logical and coherent written arguments, linking the evidence with each claim for a range of audiences, particularly those with views opposed to their own.
- Create opportunities for groups of pupils to identify and evaluate strategies to develop logical and coherent balanced written arguments.
across a range of scientific contexts, and to learn how to modify them when presented with new evidence.

**Step 4:** Pupils can collaborate effectively to develop balanced arguments, evaluating whether evidence supports claims and challenges counter claims. They write complex arguments fluently, and draw balanced conclusions incorporating appropriate evidence to support their arguments.

### Framing arguments steps table – pupil exemplification

This exemplification shows how pupils may frame arguments in the context of the provision of alternative sources of energy – an example from GCSE physics.

**Step 1:** Pupils can talk about and share points in an argument, separating fact from opinion and including this in written responses.

Given the question 'Should we build a wind farm in the village?’, pupils can talk about facts relating to the installation and separate these from opinion and personal feelings in a simple piece of writing.

**Step 2:** Pupils can work effectively in groups to give reasons why evidence supports a claim or counter claim. They write a simple coherent argument that identifies a claim or a counter claim.

Given the question 'Should we build a wind farm in the village?’, pupils can work together to collect evidence to both support and oppose the installation of the wind farm. They can construct an argument which presents valid evidence for both cases in clear paragraphs that convey meaning.

**Step 3:** Pupils can collaborate effectively in groups to evaluate evidence appropriately to develop claims and challenge counter claims. They develop and
write complex arguments fluently, incorporating a range of evidence to persuade an audience using appropriate conventions.

Given the question 'Should we build a wind farm in the village?', pupils work collaboratively to gather a range of evidence about both the positive and negative environmental and social impacts of the installation. Collectively they evaluate the validity and reliability of their evidence in order to develop their argument and refute counter claims. They communicate their conclusions by writing a complex argument that is structured appropriately and endeavours to persuade the local planning committee.

**Step 4**: Pupils can collaborate effectively to develop balanced arguments, evaluating whether evidence supports claims and challenges counter claims. They write complex arguments fluently and draw balanced conclusions incorporating appropriate evidence to support their arguments.

Given the question 'Should we build a wind farm in the village?', pupils can work collaboratively to evaluate a range of quantitative and qualitative evidence which supports their claim and challenges counter claims. They present a fluent, balanced argument that deals with the potential environmental and social aspects of each potential issue identified. Their conclusion is structured in a format that will convince the planning committee that they have considered all appropriate evidence.

You can find extracts from the GCSE grade criteria relevant to extended writing later in this section.

**Ofqual grade criteria – extended writing in GCSE science**

The following extracts from the grade criteria for the new science GCSE relate to extended writing.

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Grade F

Pupils use **limited** scientific and technical knowledge, **terminology** and conventions.

Pupils can **explain straightforward** models of phenomena, events and processes.

Grade C

Pupils use scientific and technical knowledge, **terminology** and conventions **appropriately**.

Pupils use models to **explain** phenomena, events and processes.

Pupils understand the limitations of evidence and **develop arguments with supporting explanations**.

Grade A

Pupils use scientific and technical knowledge, **terminology** and conventions **appropriately and consistently**.

Pupils make **effective use** of models to **explain** phenomena, events and processes.

Pupils evaluate information **systematically** to **develop arguments and explanations** taking account of the limitations of the available evidence.

### Developing explanations, argument and decisions in science

Practical strategies to improve pupils' progress by developing their skills in explanations, argument and decisions (EAD).

This section supports the development of the use of models, arguments and explanations to understand science and justify decisions. You may find this section helpful to improve the scores your pupils gain in GCSE questions that assess their ability to:
• apply skills, knowledge and understanding of science in practical and other contexts (assessment objective 2)
• analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence (assessment objective 3).

To develop the written expression of an argument, see 'Developing extended writing skills for GCSE science'.

This resource develops understanding and application of skills addressed in the following GCSE criteria for science:

• the nature of science and its applications, and interrelationships between science and society
• the relationships between hypotheses, evidence, theories and explanations
• evaluate claims based on science through critical analysis of the methodology, evidence and conclusions
• communicate in scientific contexts
• science is an evidence-based discipline
• the collaborative nature of science as a subject discipline and the way new scientific knowledge is validated
• how scientific understanding and theories develop, and the limitations of science.

The following are supported:

• Developing explanations using ideas and models (see Developing explanations using ideas and models steps table)
• Reaching agreement on scientific explanations thorough collaboration and debate (see Reaching agreement on scientific explanations steps table)
• Developing argument (see Developing argument steps table)
• Applications, implications and cultural understanding (see Applications, implications and cultural understanding steps table)
• Communication for audience and purpose (see Communication for audience and purpose steps table)

These steps tables offer:

• a four-stage approach proven to support pupils in developing their skills in an aspect of practical enquiry skills
• criteria to support identification of pupils' current progress and identify next steps
• exemplification in a Key Stage 4 context.

These tables are designed to support planning for learning, not planning for assessment, and can be used to support progression in learning and to encourage increased progression to post-16 science courses.
The steps are not levelled or graded, as securing progress to a particular step in an individual aspect would not lead to the attainment of a particular overall grade. You could use the tables to:

- judge a pupil’s starting point within each aspect to gain a holistic view of the learning needs of that pupil in GCSE science
- support progress as far as possible in the identified aspects by suggesting opportunities to take the next learning step.

Some pupils will progress further in some aspects than others and will be more able to achieve higher overall outcomes in their science GCSE courses.

Developing explanations using ideas and models steps table

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.

**Step 1**: Pupils can use an existing model to describe or explain a phenomenon.

**Strategies to support progress from step 1 to step 2**

- Use a range of models and ask pupils to improve these to explain a particular process or concept.
- Create opportunities for pupils to develop their own models and identify the strengths and weaknesses in them.
- Compare the strengths and weaknesses of diagrams in different textbooks that show the same concept or process.

**Step 2**: Pupils can explain the selection of a particular model as the most appropriate and devise their own simple models or analogies to explain observations, data or scientific ideas in familiar contexts.
Strategies to support progress from step 2 to step 3

- Plan opportunities for pupils to discuss the suitability of their own models. Pupils could generate questions to ask about their model to help decide if it is 'good enough' to explain the principle or process.
- Use models that children have not come across before, and ask the class to discuss why these might seem plausible and how they would challenge their ideas.

**Step 3:** Pupils can evaluate the strengths and weaknesses of their own models and analogies within familiar and unfamiliar contexts.

Strategies to support progress from step 3 to step 4

- Explore the historical development of models and those that are currently changing, for example, solar system development or the causes of stomach ulcers.
- Ask pupils to generate and apply success criteria to test the usefulness of conflicting models.
- Create opportunities for pupils to devise and act out a model for a process such as photosynthesis. Ask pupils to predict what will happen if conditions change and then to act out the changes. Evaluate how well the model responds and decide if the model needs to be refined.

**Step 4:** Pupils can justify the use of different, and sometimes conflicting, models in their explanations and evaluate the strengths and weaknesses of these models.

Developing explanations using ideas and models steps table – pupil exemplification

This exemplification shows how pupils may develop explanations using ideas and models in the context of energy transfer mechanisms – an example from GCSE physics.

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**Step 1:** Pupils can use an existing model to describe or explain a phenomenon.

Use a simple model to account for the transfer of heat via conduction along a solid bar of metal.

**Step 2:** Pupils can explain the selection of a particular model as the most appropriate and devise their own simple models or analogies to explain observations, data or scientific ideas in familiar contexts.

Use and justify how the simple model of conduction or convection can explain the transfer of heat through solids, liquids and gases.

**Step 3:** Pupils can evaluate the strengths and weaknesses of their own models and analogies within familiar and unfamiliar contexts.

Extend their models of conduction and convection in solids, liquids and gases to include an appropriate model of heat transfer via radiation (for example, through a vacuum).

**Step 4:** Pupils can justify the use of different, and sometimes conflicting, models in their explanations and evaluate the strengths and weaknesses of these models.

Use the strengths and drawbacks of the particle and wave models of radiation to account for the transfer of heat via these mechanisms.

You can find extracts from the GCSE grade criteria relevant to explanations, arguments and decisions later in this section.
Reaching agreement on scientific explanations steps table

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.

**Step 1:** Pupils can describe how bias or a lack of evidence can give rise to inappropriate theories. They can identify some questions that the scientific process cannot yet completely answer but can contribute to.

**Strategies to support progress from step 1 to step 2**

- Involve pupils in identifying the success criteria for the scientific process used to answer a question.
- Create opportunities for pupils to explore whether objectivity in science is a myth and to explore historical scenarios in which science could not answer the question until new evidence came to light.
- Create opportunities for pupils to identify some of the laws and conventions that govern scientific research.

**Step 2:** Pupils can describe the process of validating the work of other scientists and explain how this influences the acceptance or rejection of a theory. They can identify some questions that the scientific process cannot yet completely answer but can contribute to, and explain the reasons for this.

**Strategies to support progress from step 2 to step 3**

- Encourage pupils to identify and explain their viewpoints about a particular issue. Allocate these viewpoints to different groups to discuss in order to identify aspects they disagree with and find evidence to back their view.
- Involve pupils in identifying an idea that cannot be explained by the scientific process and identify any steps that science could/has taken to help answer it.
- Involve pupils in evaluating how ‘data’ has been used and presented to support manufacturers’ claims.

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• Explore with pupils how the peer-review process and the regulatory bodies are used to validate the work of the scientific community.

**Step 3:** Pupils can explain how the scientific community validates the work of other scientists and how this has influenced the acceptance of current theories. In addition, they can explain why scientific proof is only ever provisional.

**Strategies to support progress from step 3 to step 4**

• Explore how decisions taken about a controversial issue have been influenced by society, politics and the media.
• Explore some well-known scientific hoaxes and explain why they worked.
• Create opportunities for pupils to track a scientific development along a timeline and explain how new evidence changed the theory.
• Involve pupils in discussing whether it is possible for the public to know what is mere opinion and what is underpinned by good research without the process of peer review.

**Step 4:** Pupils can explain and justify why a 'scientific claim' should be accepted or rejected by the use of validated evidence. They can explore the implications of the provisional nature of scientific proof.

**Reaching agreement on scientific explanations steps table – pupil exemplification**

This exemplification shows how pupils may reach agreement on scientific explanations in the context of medical health interventions.

**Step 1:** Pupils can describe how bias or a lack of evidence can give rise to inappropriate theories. They can identify some questions that the scientific process cannot yet completely answer but can contribute to.
From watching a video or reading the story of Ignác Semmelweis, students can describe the misconceptions which led to a failure to correctly diagnose the cause of puerperal fever.

**Step 2:** Pupils can describe the process of validating the work of other scientists and explain how this influences the acceptance or rejection of a theory. They can identify some questions that the scientific process cannot yet completely answer but can contribute to, and explain the reasons for this.

Students can describe and explain the sequence of steps Ignác Semmelweis used to gather evidence in order to gain acceptance of his theory within the scientific and public communities.

**Step 3:** Pupils can explain how the scientific community validates the work of other scientists and how this has influenced the acceptance of current theories. In addition, they can explain why scientific proof is only ever provisional.

Students can explain how a lack of peer review led to confusion over the safety of the MMR vaccine and its potential causal link with autism – in both the medical and public communities.

**Step 4:** Pupils can explain and justify why a ‘scientific claim’ should be accepted or rejected by the use of validated evidence. They can explore the implications of the provisional nature of scientific proof.

Students can present a variety of evidence from a range of sources to explain why homeopathic treatments should or should not be funded by the NHS.

You can find extracts from the GCSE grade criteria relevant to explanations, arguments and decisions later in this section.
Developing argument steps table

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.

**Step 1**: Pupils can separate information from opinion. They can identify evidence that supports or refutes a claim.

<table>
<thead>
<tr>
<th>Strategies to support progress from step 1 to step 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use a continuum to identify the level of support different evidence gives to a claim and review this throughout the lesson as new evidence is discussed.</td>
</tr>
<tr>
<td>• Explore with pupils how to create criteria to judge evidence and why these are important.</td>
</tr>
<tr>
<td>• Create opportunities for pupils to identify how they make decisions about whether information is based on strong or weak evidence.</td>
</tr>
<tr>
<td>• Allow pupils to debate alternative viewpoints.</td>
</tr>
</tbody>
</table>

**Step 2**: Pupils can give reasons why evidence supports a claim. They can identify possible alternative viewpoints.

**Strategies to support progress from step 2 to step 3**

| • Create opportunities for pupils to prioritise and explain the evidence they believe supports an alternative viewpoint. |
| • Create opportunities for pupils to research examples of where new evidence or pressure from society has influenced scientific theory (e.g. Galileo), applications (e.g. mobile phones) or models (e.g. the atomic model). |
| • Create opportunities for pupils to identify possible bias in an argument. |

**Step 3**: Pupils can identify evidence to support an alternative viewpoint or claim, identify possible weaknesses and/or bias in the argument and prioritise evidence in support of the claim.

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Strategies to support progress from step 3 to step 4

- To provide pupils with open-ended questions to allow them to explore the alternative viewpoints and reach their own conclusion.
- Create opportunities for pupils to defend and evaluate each other's arguments.
- Explore a case study of a development in which the funding source or the cultural background have raised questions about bias and debate the implication for taking a viewpoint.

**Step 4:** Pupils can present a balanced argument or conclusion, identifying supporting evidence and any alternative viewpoints.

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Developing argument steps table – pupil exemplification

This exemplification shows how pupils may develop explanations using ideas and models in the context of nuclear physics – an example from GCSE physics.

**Step 1:** Pupils can separate information from opinion. They can identify evidence that supports or refutes a claim.

Pupils comment on news reports and data of incidences of cancer near to nuclear reactors, stating the factual evidence and the opinions.

**Step 2:** Pupils can give reasons why evidence supports a claim. They can identify possible alternative viewpoints.

Pupils comment on the relevance of evidence supporting the risk of cancer from nuclear reactors compared to the risk in regions which have high natural background radiation – for example, Cornwall.
Step 3: Pupils can identify evidence to support an alternative viewpoint or claim, identify possible weaknesses and/or bias in the argument and prioritise evidence in support of the claim.

Pupils present evidence in support of different claims. They identify distortion and bias in the presentation of selected data, and identify bias reflecting the agendas of interested parties.

Step 4: Pupils can present a balanced argument or conclusion, identifying supporting evidence and any alternative viewpoints.

Pupils write a scientific report to present to government in response to a debate about whether further nuclear reactors should be installed in Britain and where they should be located.

You can find extracts from the GCSE grade criteria relevant to explanations, arguments and decisions later in this section.

Applications, implications and cultural understanding steps table

You could use the following descriptions to assess your pupils' current progress and to identify strategies that could help them improve their performance.

Step 1: Pupils can describe the issues, benefits and drawbacks of scientific developments. They can recognise that decisions in science may be made in different economic, cultural and social contexts.
Strategies to support progress from step 1 to step 2

- Create opportunities for pupils to look at a series of questions and distinguish between those that can be answered on scientific evidence and those that are opinion or value-based.
- Discuss current issues to explore how decisions about a development have been influenced by social and political factors, for example, the cost of drugs to treat Alzheimer’s disease compared with the predicted benefits.

Step 2: Pupils can identify the relevant issues, benefits and drawbacks of scientific developments and explain how they influence decisions. They can explain how scientific evidence can be influenced by economic, cultural and social context and used to pose and answer further questions.

Strategies to support progress from step 2 to step 3

- Create opportunities for pupils to debate an issue where there are limitations in the scientific knowledge, for example, ‘When is a life a life in the termination of a pregnancy?’, and then to evaluate the impact of the motion on different groups of people.
- Create opportunities to discuss the difference between perceived and actual risk.
- Involve pupils in explaining the influence of a number of factors, including scientific and societal, on a particular scientific or technological development.

Step 3: Pupils can explain and evaluate perceived and actual risk arising from the application of scientific or technological developments. They can describe the power and limitations of science in addressing a range of moral or ethical issues.

Strategies to support progress from step 3 to step 4

- Explore a case study showing how perception of risk can influence decision-making, for example, attitudes towards nuclear power in Britain and in France.
- Examine contemporary issues to analyse the various influences upon them and how this may affect decision-making.
Step 4: Pupils can justify their selection of relevant scientific data and other sources of evidence to support or negate an argument. They can explain how scientific theories, applications and models have been influenced by the strength of new evidence, or by changes in societal norms or values.

Applications, implications and cultural understanding steps table – pupil exemplification

This exemplification shows how pupils may develop in the area of applications, implications and cultural understanding in the context of the effect of decisions about whether of not to immunise – an example from GCSE biology.

Step 1: Pupils can describe the issues, benefits and drawbacks of scientific developments. They can recognise that decisions in science may be made in different economic, cultural and social contexts.

Given the question about MMR, pupils distinguish between statements of fact and statements of opinions, considering whether they themselves would wish to have the vaccination. They provide extra evidence and review their decisions. They sort questions on a double axis comparing the strength of factual evidence with the strength of value judgement. They then justify their position.

Step 2: Pupils can identify the relevant issues, benefits and drawbacks of scientific developments and explain how they influence decisions. They can explain how scientific evidence can be influenced by economic, cultural and social context and used to pose and answer further questions.
Having considered MMR, pupils study population graphs relating to the percentage of people receiving immunisation and the spread of disease. They identify the risks of not receiving the vaccine against the risks of receiving it.

**Step 3:** Pupils can explain and evaluate perceived and actual risk arising from the application of scientific or technological developments. They can describe the power and limitations of science in addressing a range of moral or ethical issues.

Having considered the use of the MMR vaccine, pupils review case studies relating to different immunity issues; for example, smallpox, anthrax, AIDS, polio.

**Step 4:** Pupils can justify their selection of relevant scientific data and other sources of evidence to support or negate an argument. They can explain how scientific theories, applications and models have been influenced by the strength of new evidence, or by changes in societal norms or values.

Pupils make statements relating to the possible advantages and disadvantages of the processes used to bring about the eradication of MMR, explaining who might be affected and how they might be affected.

You can find extracts from the GCSE grade criteria relevant to explanations, arguments and decisions later in this section.

**Communication for audience and purpose steps table**

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.
**Step 1:** Pupils can communicate ideas, explanations and opinions using simple models and appropriate scientific terminology and conventions.

**Strategies to support progress from step 1 to step 2**

- Plan opportunities to challenge pupils to present a case with evidence that is designed to counter a perceived point of view.
- Involve pupils in devising criteria to judge the appropriateness of writing for particular audiences.
- Explore with pupils a range of scientific articles and reports and consider their intended audience and purpose.
- Explore with pupils the techniques used by the media to represent or misrepresent scientific ideas or developments.

**Step 2:** Pupils use evidence, knowledge, terminology and conventions to communicate scientific ideas. They present explanations and arguments and identify alternative viewpoints.

**Strategies to support progress from step 2 to step 3**

- Create opportunities for pupils to peer-assess the appropriateness of a piece of writing for a particular audience and purpose.
- Encourage pupils to evaluate and refine the criteria used to judge a piece of writing for a particular audience and purpose.
- Plan structured discussion where pupils have to present an argument with evidence from a viewpoint that is different from their own.

**Step 3:** Pupils use a range of evidence, terminology and conventions in familiar contexts to communicate scientific ideas using a range of models and analogies. They present explanations and arguments recognising any weakness and bias in the evidence.
Strategies to support progress from step 3 to step 4

- Involve pupils in peer-assessing the criteria developed by other pupils to judge the appropriateness of a piece of writing for the intended audience and purpose.
- Create opportunities for pupils to evaluate a range of scientific articles and reports as appropriate for the intended audience and purpose.

**Step 4**: Pupils use a range of scientific knowledge, terminology and conventions in unfamiliar contexts, communicating complex ideas using models. They present fluent explanations and balanced arguments reconciling a range of conflicting evidence.

Communication for audience and purpose steps table – pupil exemplification

This exemplification shows how pupils may develop communication for audience and purpose in the context of how human health is affected by a range of environmental and inherited factors, by the use and misuse of drugs and by medical treatment – an example from GCSE biology.

**Step 1**: Pupils can communicate ideas, explanations and opinions using simple models and appropriate scientific terminology and conventions.

Pupils could write a text to a teenager to persuade them that taking recreational illegal drugs might be harmful.

Pupils could examine articles about scientific issues from both a tabloid and a broadsheet newspaper. They could lift out the essential criteria that distinguish the two, in terms of audience, purpose and conventions.
Step 2: Pupils use evidence, knowledge, terminology and conventions to communicate scientific ideas. They present explanations and arguments and identify alternative viewpoints.

Pupils could draft an article for a tabloid newspaper arguing that illegal recreational drugs are harmful. They could use agreed criteria to peer assess its appropriateness for audience and purpose.

You might structure a discussion where some pupils use evidence to argue that recreational illegal drugs are less harmful than alcohol.

Step 3: Pupils use a range of evidence, terminology and conventions in familiar contexts to communicate scientific ideas using a range of models and analogies. They present explanations and arguments recognising any weakness and bias in the evidence.

You might use appropriate selections from textbooks to contrast how a balanced argument, representing all views, is constructed and then get pupils to develop relevant criteria.

Your pupils could write articles for a tabloid and a broadsheet newspaper arguing that illegal recreational drugs are no more harmful than alcohol. They could use the criteria to peer assess their appropriateness for audience and purpose.

Step 4: Pupils use a range of scientific knowledge, terminology and conventions in unfamiliar contexts, communicating complex ideas using models. They present fluent explanations and balanced arguments reconciling a range of conflicting evidence.

Your pupils could either produce a presentation aimed at parents, or a leaflet for a doctor’s surgery which uses facts and figures to give a balanced view about the effects on human health of recreational illegal drugs as well as alcohol.
You can find extracts from the GCSE grade criteria relevant to explanations, arguments and decisions later in this section.

**Ofqual grade criteria – EAD in GCSE science**

The following extracts from the grade criteria for the new science GCSE relate to explanation, argument and decisions.

**Grade F**

Candidates recall, select and communicate their limited knowledge and understanding of science. They recognise simple interrelationships between science and society. They have a limited understanding that advances in science may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space. They apply skills, including limited communication, mathematical and technological skills, knowledge and understanding in practical and some other contexts. They show limited understanding of the nature of science and its applications. They can explain straightforward models of phenomena, events and processes.

**Grade C**

Candidates recall, select and communicate secure knowledge and understanding of science. They demonstrate understanding of the nature of science, its laws, its applications and the influences of society on science and science on society. They understand how scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.

They recognise, understand and use straightforward links between hypotheses, evidence, theories, and explanations. They use models to explain phenomena, events and processes.
Grade A

Candidates recall, select and communicate precise knowledge and detailed understanding of science. They demonstrate a comprehensive understanding of the nature of science, its laws, its applications, and the influences of society on science and science on society. They understand the relationships between scientific advances, their ethical implications and the benefits and risks associated with them. They use scientific and technical knowledge, terminology and conventions appropriately and consistently, showing a detailed understanding of scale in terms of time, size and space.

They apply appropriate skills, including communication, mathematical and technological skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models to explain phenomena, events and processes.

Developing effective scientific practical and enquiry skills at GCSE

This section supports the use and development of effective practical enquiry skills. You can help pupils to engage with science in an active, practical way to deepen their understanding of their world and how it works. You may find this section helpful to improve the scores your pupils gain in controlled assessments.

The following GCSE criteria for science are supported:

- plan practical ways to answer scientific questions and test hypotheses (see Planning an approach steps table)
- devise appropriate methods for the collection of numerical and other data (see Selecting and managing variables steps table)
- assess and manage risks when carrying out practical work (see Assessing risk and working safely steps table)
- collect, process, analyse and interpret primary and secondary data, including the use of appropriate technology (see Obtaining and presenting primary evidence steps table)
- draw evidence-based conclusions (see Working critically with primary evidence steps table and Working critically with secondary evidence steps table)
• evaluate methods of data collection and the quality of the resulting data (see Working critically with primary evidence steps table and Working critically with secondary evidence steps table)

These steps tables offer:

• a four-stage approach proven to support pupils in developing their skills in an aspect of practical enquiry skills
• criteria to support identification of pupils' current progress and identify next steps
• exemplification in a Key Stage 4 context.

These tables are designed to support planning for learning, not planning for assessment, and can be used to support progression in learning and to encourage increased progression to post-16 science courses.

The steps are not levelled or graded, as securing progress to a particular step in an individual aspect would not lead to the attainment of a particular overall grade. You could use the tables to:

• judge the starting points of a pupil within each aspect to gain a holistic view of the learning needs of that pupil in GCSE science
• support progress as far as possible in the identified aspects by suggesting opportunities to take the next learning step.

Some pupils will progress further than others in some aspects and will be more able to achieve higher overall outcomes in their science GCSE courses.

You may find the following resources helpful in supporting pupils to make progress in all of the above areas:

• Mini booster 1 – accuracy and reliability
• Mini booster 2 – evaluating practical technique
• Mini booster 3 – what do we mean by evidence?
• Mini booster 4 – making sense of graphical data
• Mini booster 5 – describing patterns
• Mini booster 6 – understanding variables
• Mini booster 7 – evaluation

Planning an approach steps table

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them to improve their performance.
Step 1: Pupils can describe and start to explain how their planned approach to answering a scientific question was informed by scientific knowledge, understanding or other sources of evidence.

Strategies to support progress from step 1 to step 2

- Demonstrate the importance of preliminary work to refine planning, including opportunities for pupils to determine the limitations of the apparatus, with respect to reliability and accuracy.
- Model how to decide if evidence gathered is relevant to the planning of an investigation.

Step 2: Pupils can describe and 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 collected.

Strategies to support progress from step 2 to step 3

- Create opportunities for pupils to draw together ideas and evidence from various sources to inform the planning process.
- Plan investigations to determine the effect of not controlling some variables adequately in concrete everyday contexts, then apply the results to a complex situation, for example, the use of historical data on global temperatures to make predictions into the future.
- Create opportunities for pupils to evaluate examples of investigations that were not based on direct experimentation, for example, evidence for an expanding universe.

Step 3: Pupils can describe and explain how to plan appropriate approaches to investigatory work by synthesising information from a range of sources in complex contexts.
Strategies to support progress from step 3 to step 4

• Create opportunities for pupils to compare each other’s proposed data collection for the same investigation and justify how the collection has been directed by the way the investigation was planned.
• Plan opportunities for pupils to peer-assess how well ideas and evidence have been used to inform the planning process.

Step 4: Pupils can describe and 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.

Planning an approach steps table – pupil exemplification

This exemplification shows how pupils may plan an approach in the context of an example from GCSE chemistry – the energy changes that take place during chemical reactions.

Step 1: Pupils can describe and start to explain how the planned approach to answering a scientific question was informed by scientific knowledge, understanding or other sources of evidence.

Given the question about how much heat chemicals can produce, pupils can develop a simple plan to investigate how much heat the reaction between magnesium and acid produces, by applying their understanding that the metal/acid reaction produces heat.

Step 2: Pupils can describe and 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 collected.
Given the question about how much heat chemicals can produce, pupils plan an experiment to compare the heat produced by different chemical reactions.

**Step 3:** Pupils can describe and explain how to plan appropriate approaches to investigatory work by synthesising information from a range of sources in complex contexts.

Given the question about how much heat chemicals can produce, pupils investigate whether heat pads or burners are better at producing heat. Pupils use data from combustion of fuels and their experimental evidence from different chemical reactions to compare the heat generated.

**Step 4:** Pupils can describe and 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.

Given the question about how much heat chemicals can produce, pupils investigate different methods for heating and cooling muscles. Pupils plan a detailed investigation using a range of experimental evidence and secondary data to investigate the question fully.

You can find extracts from the GCSE grade criteria relevant to practical and enquiry skills later in this section.

**Selecting and managing variables**

**steps table**

You could use the following descriptions to assess your pupils' current progress and to identify strategies that could help them improve their performance.
Step 1: Pupils can use and begin to apply independent and dependent variables in an investigation by choosing an appropriate range, number and value for each one.

Strategies to support progress from step 1 to step 2

- Model for pupils how the choice and range of variable might affect the quality of the conclusion drawn, for example, whether the range of temperatures used in an enzyme investigation is appropriate.
- Model the effect of inappropriate numbers of measurements on the precision and shape of a graph.
- Explore with pupils the types of investigations where variables are less easily controlled and how to decide when a control sample is necessary.

Step 2: Pupils use independent and dependent variables in investigations of increasingly complex content where variables are less easily controlled.

Strategies to support progress from step 2 to step 3

- Model how to use quantitative relationships between variables in predictions and analysis of data and explain the advantages of this.
- Create experimental opportunities for pupils to explain how they have managed variables that are less easy to control.

Step 3: Pupils can use and apply key variables in complex contexts, including those in which variables are less easily controlled.

Strategies to support progress from step 3 to step 4

- Create opportunities for pupils to compare and evaluate investigations with more and less easily controlled variables.
- Create experimental opportunities for pupils to identify, control and manipulate more than one variable, for example, compare the effect of biological and non-biological washing powders at different temperatures on a range of fabrics.
- Explain what a randomised controlled trial is and allow pupils to justify its use.
Step 4: Pupils can identify and manipulate a range of variables in complex contexts including those in which variables are less easily controlled.

Selecting and managing variables steps table – pupil exemplification

This exemplification shows how pupils may select and manage variables in the context of an example relating to GCSE chemistry (rates of reaction) and GCSE biology (enzyme action).

Step 1: Pupils can use and apply independent and dependent variables in an investigation by choosing an appropriate range, number and value for each one.

What is the optimum temperature for trypsin to work?

In this experiment pupils can easily identify independent (temperature) and dependent (time to break down starch) variables and consider the range (0–70°C) and value for each.

Step 2: Pupils use independent and dependent variables in investigations of increasingly complex content where variables are less easily controlled.

What are the ideal conditions for trypsin to work? (any protease)

Pupils could consider key factors, such as pH, temperature and concentration; however there are complex issues that are less easily controlled, for example, surface area and agitation.

Step 3: Pupils can use and apply key variables in complex contexts, including those in which variables are less easily controlled.

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To ensure there are variables that are less easy to control, the investigation could be extended to ask: do enzymes (e.g. trypsin) in biological washing powder make the powders more effective?

Some examples of the key variables in this complex context could be: quantity of powder, concentration of enzyme in the powder, concentration of other ingredients, biological or non-biological stains, temperature, hardness of water, type of fabric being washed. Pupils note that some of these are less easily controlled.

**Step 4:** Pupils can identify and manipulate a range of variables in complex contexts including those in which variables are less easily controlled.

How do washing powders achieve the cleanest clothes?

This could allow pupils to consider variables that are less easily controlled, and draws in a variety of contexts, for example, type of washing technique, whether a chemical is used or not, physical conditions.

You can find extracts from the GCSE grade criteria relevant to practical and enquiry skills later in this section.

### Asssessing risk and working safely steps table

You could use the following descriptions to assess your pupils' current progress and to identify strategies that could help them improve their performance.

**Step 1:** Pupils can describe and explain how approaches to practical work were adapted to control risk.
Strategies to support progress from step 1 to step 2

- Model how to adapt risk assessments for particular situations.
- Plan opportunities for pupils to discuss in small groups whether they think a demonstrated procedure is safe and, if not, how to improve it.
- Model a simple risk assessment based on rating both the hazard and the likelihood of it happening on a scale of 1–5. Multiplying these would give a top score of 25. Ask pupils to apply this to everyday scenarios and then to consider how to reduce the risk.

**Step 2:** Pupils can use and apply risk assessment in carrying out practical procedures.

Strategies to support progress from step 2 to step 3

- Model how to use hazards and require pupils to refer to these when planning an investigation.
- Create experimental opportunities for pupils explicitly to use and apply risk assessment in their planning.

**Step 3:** Pupils can explain why the chosen approach to practical work needed to be adapted to control risk.

Strategies to support progress from step 3 to step 4

- Involve pupils in comparing a good and a less satisfactory plan in respect of controlling risk.
- Explore the difference between perceived and actual risk.
- Create opportunities for pupils to research why particular substances are hazardous.

**Step 4:** Pupils can explain how hazards are identified and risks managed to collect data in a safe and skilful manner.
Assessing risk and working safely steps table – pupil exemplification

This exemplification shows how pupils may assess risk and work safely in the context of an example relating to GCSE chemistry.

**Step 1:** Pupils can describe and explain how approaches to practical work were adapted to control risk.

> In a practical using acid, pupils can explain why they are wearing goggles to protect their eyes.

**Step 2:** Pupils can use and apply risk assessment in carrying out practical procedures.

> Pupils identify risks from acids and practical equipment and can carry out a practical where they have stated how they wear goggles, control quantities and use the equipment safely.

**Step 3:** Pupils can explain why the chosen approach to practical work needed to be adapted to control risk.

> When using acids to investigate rates of reaction, pupils can discuss how to manipulate complex equipment like burettes and pipettes and select appropriate concentrations of acid to reduce risk to themselves and others.

**Step 4:** Pupils can explain how hazards are identified and risks managed to collect data in a safe and skilful manner.
Pupils explain how they identified risks to themselves and others by their use of hazards and considering how the equipment must be appropriate to purpose. They then state the control measures and severity of risk to themselves, others and the environment.

You can find extracts from the GCSE grade criteria relevant to practical and enquiry skills later in this section.

**Obtaining and presenting primary evidence steps table**

You could use the following descriptions to assess your pupils' current progress and to identify strategies that could help them improve their performance.

**Step 1:** Pupils can use basic qualitative and quantitative methods to obtain and record sufficient data. They can describe how the presentation of experimental results through the use of simple tables, charts and line graphs makes it easier to see patterns and trends.

**Strategies to support progress from step 1 to step 2**

- Discuss how to decide the number of decimal places to which results need to be measured (accuracy) and how this should influence the choice of apparatus.
- Create opportunities for pupils to explain why they decided to take a number of repeat readings and use a mean value, for example, by comparing graphs drawn from mean values with graphs drawn using all of the data.
- Explain the uncertainty surrounding points on a graph and model how to draw lines of best fit.
- Create opportunities for pupils to use a range of techniques to present their results, justifying their choices to their peers.
Step 2: Pupils can use and apply qualitative and quantitative methods to obtain, record and manipulate sufficient data systematically, taking account of inherent variation. They can 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.

Strategies to support progress from step 2 to step 3

- Create opportunities for pupils to explain how they used a trend or pattern in results to make numerical predictions.
- Model how inherent variation, for example, from human error, sensitivity and accuracy of instrument, needs to be considered when collecting and interpreting data.
- Structure discussions for pupils to explore the extent to which the conclusion is strongly based upon the primary evidence provided.

Step 3: Pupils can 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. They can explain how the chosen presentation of data has been used to support a valid conclusion.

Strategies to support progress from step 3 to step 4

- Discuss with pupils how to evaluate an investigation for unexplored variables and how this might raise uncertainty about conclusions drawn.
- Model the drawing of different conclusions from the same set of data or from the selective use of the data.

Step 4: Pupils can collect precise, valid data in a more demanding context and justify an appropriate method of presentation.
Obtaining and presenting primary evidence steps table – pupil exemplification

This exemplification shows how pupils may obtain and present primary evidence in the context of an example relating to GCSE chemistry.

**Step 1:** Pupils can use basic qualitative and quantitative methods to obtain and record sufficient data. They can describe how the presentation of experimental results through the use of simple tables, charts and line graphs makes it easier to see patterns and trends.

The pupils could draw a two-column table and record temperature and numbers of bubbles. They could then draw a graph with axes labelled and a correct scale, and explain why they had done this.

**Step 2:** Pupils can use and apply qualitative and quantitative methods to obtain, record and manipulate sufficient data systematically, taking account of inherent variation. They can 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.

The pupils draw a table which averages the results. They then plot a graph that identifies which averages fit the pattern and if there are any outliers.

**Step 3:** Pupils can 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. They can explain how the chosen presentation of data has been used to support a valid conclusion.
The pupils draw a more complex table, which compares the effects of two or more variables on the rate of reaction. The pupils plot each variable on a graph and use the graphs to explain which variable had the biggest impact on their investigation.

**Step 4:** Pupils can collect precise, valid data in a more demanding context and justify an appropriate method of presentation.

Pupils complete a complex table in which they calculate the rate of reaction for each variable. They could then plot each individual rate curve and collate these to a graph, comparing rates of reaction against each variable.

You can find extracts from the GCSE grade criteria relevant to practical and enquiry skills later in this section.

**Working critically with primary evidence steps table**

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.

**Step 1:** Pupils can identify patterns and trends in results and how the results can be manipulated to be consistent with the predictions and evidence. They can explain how improvements to the planning and implementation would have led to a more secure conclusion.

**Strategies to support progress from step 1 to step 2**

- Model how to describe and explain more complex and quantitative relationships shown by data, and use these to make predictions or develop hypotheses, for example, with data on an ecosystem.

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• Create opportunities for pupils to peer-assess how well scientific
knowledge, understanding or models have been used to structure a
conclusion.
• Discuss with pupils the dangers of simplistic analysis and application of
data, for example, by taking a small sample and generalising to a whole
population, or treating large variation by averaging.
• Demonstrate how limitations in the selected measuring instruments can
affect reliability and accuracy of evidence.

**Step 2:** Pupils can explain how the numerical data have been manipulated to
make valid comparisons and conclusions linked to the original scientific
question. They explain how improvements to the planning and implementation
would have led to the collection of more valid and reliable evidence. They
explain how this could account for errors and anomalies and how these could be
remedied.

**Strategies to support progress from step 2 to step 3**

• Create opportunities for pupils to discuss the manipulation and
interrogation of their experimental data.
• Challenge pupils to identify the benefits and drawbacks of the
manipulation of data.
• Discuss with pupils the importance of linking scientific knowledge and
understanding from more than one key idea, for example, particles and
energy, to explain their evidence.
• Discuss with pupils examples of where a cause could be erroneously
drawn from a correlation, for example, thinking that deafness is caused by
having white hair, instead of realising that both can be a result of old age.

**Step 3:** Pupils can synthesise and manipulate data, analyse findings and draw
valid and reliable conclusions consistent with the evidence and linked to the
original scientific question. They recognise that correlation does not always
imply causation. They 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**.
Strategies to support progress from step 3 to step 4

- Create opportunities for pupils to peer-assess how well data have been collated and analysed from a series of experiments, or sources, to produce a valid model or conclusion.
- Create opportunities for pupils to identify how, and to what extent, different aspects of planning could lead to systematic errors or anomalies and the impact of this on the conclusion drawn.

Step 4: Pupils can synthesise and manipulate data, analyse findings, and draw valid and reliable conclusions consistent with the evidence. They explain how strongly the evidence relates to the original scientific question and explain why correlation does not always imply causation. They 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.

Working critically with primary evidence steps table – pupil exemplification

This exemplification shows how pupils may work critically with primary evidence in the context of an example relating to GCSE Chemistry.

Step 1: Pupils can identify patterns and trends in results and how the results can be manipulated to be consistent with the predictions and evidence. They can explain how improvements to the planning and implementation would have led to a more secure conclusion.

In an experiment looking at the absorbency of paper towels, the pupils explain how their results show that different towels have different absorbency because the patterns in their data prove this. They identify that their data may not be particularly reliable because there were systematic errors in their procedure, so
that the experiment was not particularly valid as the water left after the towel was removed was measured.

**Step 2:** Pupils can explain how the numerical data have been manipulated to make valid comparisons and conclusions linked to the original scientific question. They explain how improvements to the planning and implementation would have led to the collection of more valid and reliable evidence. They explain how this could account for errors and anomalies and how these could be remedied.

In an experiment looking at the absorbency of paper towels, the pupils explain how their results have been gathered and mean values taken with a stated range to improve the reliability of their results. They identify that their data may not be particularly reliable because there were systematic errors in their procedure, and identify ways to improve the procedure to reduce these errors. They may also note any results lying outside the normal variance, or anomalous results.

**Step 3:** Pupils can synthesise and manipulate data, analyse findings and draw valid and reliable conclusions consistent with the evidence and linked to the original scientific question. They recognise that correlation does not always imply causation. They 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.

In an experiment looking at the absorbency of paper towels, the pupils explain how their results have been gathered, including mean values taken with a stated range. They discuss how their original idea about the correlation between the thickness of the towel and its absorbency may be invalid as they did not account for the other more complex variables, for example, surface area, temperature, etc. They identify that their data may not be particularly reliable because there were systematic errors in their procedure, and identify ways to improve the procedure to reduce these errors. They also may note any anomalous results and suggest amendments to the planning and implementation of the investigation.
Step 4: Pupils can synthesise and manipulate data, analyse findings and draw valid and reliable conclusions consistent with the evidence. They explain how strongly the evidence relates to the original scientific question and explain why correlation does not always imply causation. They 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.

In an experiment looking at the absorbency of paper towels, the pupils consider different liquids to be absorbed. They explain how their results have been gathered, including mean values taken with a stated range. They discuss how the complex range of variables was controlled and their strategies to ensure that the claim they make from the evidence is valid. They identify where their data may not be particularly reliable and why this was the case. They note how they could change their procedure to improve the reliability of their results and reduce errors. They also may note any anomalous results and suggest amendments to the planning and implementation of the investigation.

You can find extracts from the GCSE grade criteria relevant to practical and enquiry skills later in this section.

Working critically with secondary evidence steps table

You could use the following descriptions to assess your pupils’ current progress and to identify strategies that could help them improve their performance.

Step 1: Pupils can identify whether the collection and manipulation of secondary evidence is sufficient to support the conclusion made.

Strategies to support progress from step 1 to step 2

- Provide opportunities for discussion of the implications of insufficient evidence and the formulation of appropriate responses.
Create opportunities for pupils to evaluate secondary sources and identify if evidence has been misrepresented.
• Explore how and why scientists make inferences.

**Step 2:** Pupils can explain, using scientific knowledge and understanding, how some of the limitations in the collection and manipulation of secondary evidence can distort the conclusion drawn. They explain how secondary numerical data have been manipulated to support a conclusion or particular viewpoint.

**Strategies to support progress from step 2 to step 3**

• Discuss with pupils the difficulties in challenging the validity, reliability and accuracy of secondary data.
• Create opportunities for pupils to formulate and peer-assess questions to assist in assessing the quality of secondary data.
• Encourage pupils to identify the features of strong inferences from data and to identify good and less satisfactory examples of this in the media.
• Challenge pupils to research, present and discuss examples in which the credibility of data may be questioned.

**Step 3:** Pupils can 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. They recognise that scientific controversies can arise from different interpretations of the same evidence.

**Strategies to support progress from step 3 to step 4**

• Create opportunities for pupils to evaluate conclusions based on unfamiliar contexts and to explain their thinking.
• Provide opportunities for pupils to locate and explain how evidence has been used to perpetrate a hoax.
• Create opportunities for pupils to explain how different interpretations could be drawn from the same set of evidence.

**Step 4:** Pupils can 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. They describe a range of issues that can affect the credibility of explanations.

Working critically with secondary evidence steps table – pupil exemplification

This exemplification shows how pupils may work critically with secondary evidence in the context of an example relating to GCSE biology.

**Step 1**: Pupils can identify whether the collection and manipulation of secondary evidence is sufficient to support the conclusion made.

Given data on 'skinny water' and weight loss, the pupils identify that they need more information about the gathering of the data to form a valid conclusion. They say that if the data has come from the makers of skinny water, then they would have a vested interest in presenting the data to support their claim.

**Step 2**: Pupils can explain, using scientific knowledge and understanding, how some of the limitations in the collection and manipulation of secondary evidence can distort the conclusion drawn. They explain how secondary numerical data have been manipulated to support a conclusion or particular viewpoint.

Given data on 'skinny water' and weight loss, the pupils identify that they need more information about the gathering of the data to form a valid conclusion. They consider their knowledge about weight loss and identify the range of variables that would need to be controlled for this data to be valid. They consider why different groups may give different interpretations of the scientific data.
**Step 3:** Pupils can 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. They recognise that scientific controversies can arise from different interpretations of the same evidence.

Given data on 'skinny water' and weight loss, the pupils identify who has presented the data and their possible bias. They consider their knowledge about weight loss and identify the range of variables that would need to be controlled for this data to be valid. They evaluate the conclusions drawn and give reasons as to why these may not be valid and how strongly the evidence supports the claims. A judgement about the credibility of the data is made and pupils discuss how to address their concerns.

**Step 4:** Pupils can 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. They describe a range of issues that can affect the credibility of explanations.

Given data on 'skinny water' and weight loss, and people's perceptions from surveys, the pupils compare the findings from both data sets and discuss the implications. They identify possible bias in the data and the difficulty with perception data. They consider their knowledge and experience of data use to identify how they would decide if this data were valid. They justify how strongly the evidence supports the claims based on the credibility of the data, and discuss how they might address their concerns.

You can find extracts from the GCSE grade criteria relevant to practical and enquiry skills later in this section.

**Ofqual grade criteria – Practical and enquiry skills in GCSE science**

The following extracts from the grade criteria for the new science GCSE relate to practical and enquiry skills.
Grade F

Using a **limited** range of skills and techniques, candidates answer scientific questions, solve straightforward problems and test ideas.

They interpret and evaluate some qualitative and quantitative data and information from a limited range of sources. They can draw elementary conclusions having collected limited evidence.

Grade C

Using appropriate methods, sources of information and data, candidates **apply** their skills to answer scientific questions, solve problems and test hypotheses.

They analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and develop arguments with supporting explanations. They draw conclusions consistent with the available evidence.

Grade A

Candidates use a wide range of appropriate methods, sources of information and data consistently, **applying relevant skills** to address scientific questions, solve problems and test hypotheses.

They analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.

**Overcoming weaknesses in GCSE science**

Analysis of GCSE examiners’ reports from all of the science specifications indicates that there are common areas which pupils find difficult; these have been synthesised for you to use in planning in order to improve pupils’ learning.
The common difficulties are identified here for science (How science works (HSW) and general aspects) and biology, chemistry and physics.

Sections in the booklets describing the common difficulties

The following generic sections appear in each booklet:

- absence of correct scientific terminology
- confusion and/or lack of precision in scientific terms and/or symbols
- mathematical ability
- not reading and/or answering a question precisely.

There is a section on scientific investigative skills specific to HSW.

The section on scientific concepts is split into core science and additional/triple science in the Biology, Chemistry and Physics booklets.

Each sections includes resources that may assist you, in your planning or in departmental discussions, to find ways of helping your pupils avoid or overcome the common difficulties.

How you might use the booklets describing the common difficulties

The materials could be used in a variety of ways, for example:

- at the start of every module to inform short-term planning;
- to inform planning of intervention at opportunities before the examination;
- to inform intervention for particular individuals and groups of pupils in response to examination and other assessment outcomes.

Accessing the booklets describing the common difficulties

Copies of the individual examiners’ reports can be obtained from the awarding bodies.

Analysing pupils' responses in GCSE science provides support for analysing GCSE papers for your own pupils. The booklets are:

- HSW and general aspects
- Biology
- Chemistry

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Physics

The *Intervention to support GCSE science* materials can help you support your pupils so that they can write better answers in science.

Reported weaknesses in GCSE science (HSW and general aspects)

These materials describe common weaknesses in science (*How science works* and general aspects) demonstrated by pupils at different approximate grades. Drawn from GCSE examiners' reports, they may help you plan so as to support pupils to avoid or overcome those weaknesses.

Scientific investigative skills

**Grades G–E**

- Can extend patterns of lines without due regard to scientific principles (for example can predict that the number of predators will continue to increase at the same time that their prey is in marked decline).
- May not suggest rational scientific ideas to explain given tabulated data (for example why the thickness of a reindeer's fur is greater than that of a tropical deer).
- May not be able to describe appropriately the shape of a curved graph line (for example they may be able to state that the curve rises, but not that it rises steeply at the start and then less steeply, plateauing at the end).
- When asked about points on a graph line, they often fail to state the axis they used to give the coordinates.
- May suggest ideas that are outside the known simple boundaries of science (for example to account for bacteria found at the edge of the Earth's atmosphere – 40+ km above the Earth’s surface – they may suggest that birds carried them there).
- May not be able to describe simple patterns and simply describe numbers.

**Grades D–C**

- May not be aware that data should be reliable in order to draw a conclusion (for example given temperature changes in the last hundred years, the fluctuations over a few years can be as great as an overall perceived rise, so conclusions that there is increased global warming are not justified on this evidence alone).
• May not appreciate that they need more than one source to research scientific ideas.
• May not understand that they need to compare the reliability of sources.
• May not appreciate that to justify a conclusion they need to refer to their sources.
• May not be able to deduce how long a particular factor persisted by deductions from a graph (for example deducing from the graph line and the x-axis how long blood glucose levels took to return to normal following the onset of a short burst of exercise).
• May make simple errors (for example they may incorrectly plot points, use thick or multiple lines for a curve, join dots rather than a line of best fit and draw a straight line rather than a curve).
• May incorrectly calculate averages or use incorrect scales on graphs.
• May use an ink line rather than a pencil line, making it difficult to make corrections.
• May misinterpret a given investigation and conclude that the independent variable should be kept constant (for example when asked about one variable that should be kept constant in an ‘effective temperature on enzyme reaction’, they state temperature).
• May not realise why results are repeated (though they tend to know that they should be).

Grades B–A

• May find it difficult to criticise old scientific theories (for example the phlogiston theory) with regard to current knowledge and given data.
• May fail to recognise scientific features of a graph (for example in a velocity/time graph they may not realise that a horizontal line at one end can indicate the final velocity.)
• May have difficulty in designing an investigation comprehensively.
• May not clarify and explain which source is more significant in writing a conclusion.

Suggested resources

Key resource

• Framework advice – 1.1 How science works: Explanations, argumentation and decisions – Strategies for progression and rich questions – Strategies for progression and rich questions provides support for developing pupils' skills.

Other useful resources

• Framework advice – 1.2 How science works: Practical and enquiry skills – Strategies for progression and rich questions provides support for developing pupils' skills.
• **Science intervention materials** – ‘mini boosters’ are a series of resources to support teachers in developing pupils’ enquiry skills.
• **Interactive teaching in science** – e-learning containing a number of resources which will help to encourage pupils to explore and develop their own understanding of HSW in a variety of contexts.

Related Links

- [1.1 How science works: Explanations, argumentation and decisions – Strategies for progression and rich questions](#)
- [1.2 How science works: Practical and enquiry skills – Strategies for progression and rich questions](#)
- [Interactive teaching in science](#)
- [Science intervention materials](#)

Absence of correct scientific terminology

**Grades G–E**

- See documents describing weaknesses in biology, chemistry and physics aspects of science.

Suggested resources

**Interactive teaching in science** is an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the *Responsiveness to pupils’ understanding* sequence.

Related Links

- [Interactive teaching in science](#)
Confusion and/or lack of precision in scientific terms and/or symbols

Grades G–E

- See documents describing weaknesses in biology, chemistry and physics aspects of science.

Grades D–C

- May not distinguish terms such as reliability, accuracy and fair testing.
- May not be clear about the variables that they are investigating (e.g. state that they are investigating photosynthesis rather than the effect of increased temperature on the rate of oxygen production in photosynthesis).

Suggested resources

Key resource

- Science intervention materials – ‘mini boosters’ are a series of resources to support teachers in developing pupils' enquiry skills.

External resources

- Practical Physics offers resources to help with How science works (HSW) aspects of physics investigations.

Related Links

- Practical Physics
- Science intervention materials
Mathematical ability

Grades G–E

- May not understand how to deduce rates from the axis of a simple bar chart (for example when given a bar chart that relates the time to roll down a slope to different objects they will choose the highest bar when asked, 'Which rolls quickest?').
- May not calculate percentages, for example, when given two percentages and they have to calculate a third by addition and subtraction (for example given 0.4 and 6.0, they calculate 3.6 rather than 93.6).

Grades D–C

- May not calculate percentages in energy transfer diagrams, for example when given two figures and they have to calculate the percentage by division or multiplication (for example given the energy in plants of 16,000 J, and the energy in the carnivores in the food chain as 1000 J, they cannot calculate the percentage of energy transferred as 6.25%).
- May have difficulty in calculating means.
- May have difficulty calculating the square of a number.
- May not be able to convert cm to m.
- May be imprecise in plotting lines and in placing lines of best fit (including curves).
- May not calculate range correctly in particular contexts, such as figures about solutions of different concentration.
- May not recognise the term 'outlier'.
- May always put their line through the origin even when not appropriate.
- May join dot to dot graphs when not appropriate.
- May plot categorical variables on a line graph or continuous variables on a bar chart.

Grades B–A

- May not be able to calculate average rates of fall or rise between two points on a graph line or from tabulated data.
- May believe that a probability of 3/4 is the same as 3:4 or 1:3.
- May be less able to relate a cause to an outcome, though may be better at recognising correlations.
- May not be able to recognise an outlier.
Suggested resources

Key resource

- Science intervention materials – ‘mini boosters’ are a series of resources to support teachers in developing pupils’ enquiry skills.

Other useful resources

- Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added ‘How science works’ ) – may help you to support pupils in developing clear understanding of the mathematical techniques used in science.

External resources

- The Association for Science Education's schoolscience resources cover a range of science disciplines.
- Awarding body-specific advice can support mathematical development. Search using these links:
  - AQA
  - edexcel
  - OCR
  - WJEC

Related Links

- Science intervention materials
- Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added ‘How science works’ )
- schoolscience
- AQA
- edexcel
- OCR
- WJEC
Not reading and/or answering a question precisely

Grades G–E

- Will tend to be vague, general and verbose rather than short and precise.
- May not read information sufficiently carefully to provide a precise response.

Grades D–C

- May refer to 'it has more' rather than 'object A has more than object B'.
- May have difficulty in developing a structured argument or in engaging in discussion in longer answers.
- May repeat the stem of the question in their answers.

Grades B–A

- May ignore given data that conflicts with a misconception (e.g. they are given the concentrations of protein in the blood, but believe it does not belong there because protein is broken down in digestion).
- May fail to read precise questions in topics that cross scientific disciplines (e.g. when asked about a driver's reaction time, they refer to his or her stopping time).
- May confuse similar general and specific terms (e.g. they may confuse 'micro-organism' with 'virus').

Suggested resources

Key resource

- Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works') – The Guidance for teachers on writing descriptions, Guidance for teachers on writing explanations and Guidance for teachers on writing arguments within the section 'Developing the writing of science' may help you to support pupils in developing clear descriptions and explanations in their science writing.

Other useful resources

- Going for gold: Securing attainment makes suggestions on how to support pupils in preparation for examinations.
• Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works') – Resource library: scientific writing – could be used to support how terminology can be taught in science to strengthen pupils’ understanding.

Related Links

• Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works')
• Guidance for teachers on writing descriptions
• Guidance for teachers on writing explanations
• Guidance for teachers on writing arguments
• Going for gold: Securing attainment

Reported weaknesses in GCSE science (biology)

These materials describe common weaknesses in biology demonstrated by pupils at different approximate grades. Drawn from GCSE examiners' reports, they may help you plan so as to support pupils to avoid or overcome those weaknesses.

Absence of correct scientific terminology

Grades G–E

• May be vague about enzyme action (breakdown of food rather than specifics).
• May not know the complete definition of a predator.
• May not be able to name the life processes.
• May not use the correct terms for water transport in a plant (for example root hair, xylem).

Grades B–A

• May give inaccurate definitions of filtration and filtrate.
Suggested resources

Key resource

• Interactive teaching in science – an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the Responsiveness to pupils’ understanding sequence.

Other useful resources

• Science Framework study guides: Strengthening teaching and learning of organisms, systems, organs and cells – supports the teaching of aspects of organisms, organs, systems and cells.
• Framework materials – Barriers to learning for ‘Life processes’, Barriers to learning for ‘Variation and interdependence’ and Barriers to learning for ‘Behaviour’ – guides to common aspects which pupils have found difficult and which can block further learning.
• Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added ‘How science works’) – Resource library: scientific writing – could be used to support how terminology can be taught in science to strengthen pupils’ understanding.
• Interactive teaching in science – e-learning containing a number of resources, including several biological teaching sequences.

External resources

• Society of Biology offers guidance about teaching biological concepts and practical activities that best support pupils’ understanding.
• Practical Biology is a resource for practical activities in biology.

Related Links

• Interactive teaching in science
• Science Framework study guides: Strengthening teaching and learning of organisms, systems, organs and cells
• Society of Biology
• Practical Biology

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Confusion and/or lack of precision in scientific terms and/or symbols

Grades G–E

- May name respiration rather than diffusion for O\(_2\) entering blood.
- May have confusion between XY and XX in males versus females.
- May refer to alleles as strong or weak rather than dominant or recessive.
- May confuse cell membrane and cell wall.
- May confuse increased global warming with the reduction in the ozone layer.

Grades D–C

- May think high pH is acid.
- May confuse chlorophyll with chloroplast.
- May confuse antibodies with antibiotics.
- May confuse antibody with antigen.
- May refer to nerves carrying messages rather than impulses.
- May have difficulty defining terms such as ‘clones’ or ‘alleles’.
- May report incorrectly that humans use natural selection to breed domestic animals.
- May not be able to explain terms such as ‘parasite’, ‘anaerobic’, ‘homeostasis’ or ‘conservation’.
- May give vague answers such as ‘animals may die if not protected’ rather than that they may become extinct.
- May give vague unqualified answers such as ‘the bird has claws’, instead of ‘large sharp claws to catch fish’.

Grades B–A

- May confuse genotype and phenotype.
- May confuse haploid and diploid.
- May confuse meiosis and mitosis, which can produce a mixing of these words (for example ‘miteiosis’).
- Overall, may have a significant difficulty with understanding of words in genetics.
- May refer to organisms working best at a particular temperature rather than referring to the optimal temperature for enzyme activity.
- May suggest that hormones (e.g. adrenalin) cause heartbeat rather than speeding it up.
- May not be able to give a creditable definition of homeostasis.
- May confuse spine with spinal cord.

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Suggested resources

Key resource

- Science Framework study guides: *Strengthening teaching and learning of organisms, systems, organs and cells* – supports the teaching of aspects of organisms, organs, systems and cells.

Other useful resources

- Framework advice – [Barriers to learning for 'Life processes'], [Barriers to learning for 'Variation and interdependence'] and [Barriers to learning for 'Behaviour']: guides to common aspects which pupils have found difficult and which can block further learning.
- *Literacy in science: Notes for participants* explains how to develop pupils' recounting and then writing of scientific ideas.
- *Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works')* – see the 'Information for teachers on writing descriptions', 'Information for teachers on writing explanations' and 'Information for teachers on writing arguments' within the section 'Developing the writing of science' which will help you to support pupils in developing clear descriptions and explanations in their science writing.

External resources

- [Society of Biology] offers advice about teaching biological concepts and practical activities that best support pupils' understanding.
- [Practical Biology] is a resource for practical activities in biology.

Related Links

- [Practical Biology]
- [Society of Biology]

Mathematical ability

Grades G–E

- May have difficulty giving numbers to one decimal place.
Grades B–A

• May not be able to read graph axes precisely or describe line trends in sufficient detail.

Not reading and/or answering a question precisely

Grades G–E

• May, for example, respond to questions about how cigarette smoking damages the lungs by referring to the heart.

Grades D–C

• May have difficulty deducing information (for example on food chains) from a given paragraph.

Grades B–A

• May be distracted by near but incorrect answers (for example 8% rather than 7%) when deducing figures from a graph in multiple-choice questions.
• May be reluctant to suggest that no conclusion can be made from data given, preferring to suggest a ‘positive’ answer even if incorrect.
• May ignore a question’s request to use the data given and rely on their understanding and/or knowledge.

Suggested resources

Key resource

• *Going for gold: Securing attainment* gives advice on how to support pupils in preparation for examinations.

Other useful resources

• *Literacy in science* includes advice to help develop pupils’ reading in science so as to strengthen pupils’ understanding.
• *Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added ‘How science works’)* – Resource library:
scientific writing – could be used to support how terminology can be taught in science to strengthen pupils' understanding.

Scientific concept – weaknesses from core science

Grades G–E

- May not know the function of human organs.
- May not know the way food moves through the oesophagus.
- May draw semi-lunar valves with blood flowing the wrong way.
- May suggest that sugar is digested to starch, protein to fatty acids.
- May not know how the products of digestion are transported in the blood (may not know that it is in the plasma).
- May suggest that starch digestion starts in the stomach first rather than the mouth.
- May not know the function of the muscle in the artery wall.
- May believe that the function of digestion is the use of nutrients in the body in contrast to the need to absorb them from food.
- May not realise that water is lost through breathing.
- May incorrectly order the sequence of structures that air will travel through in the lungs.
- May not know where oxygen enters the blood.
- May not realise that roots hold topsoil.
- May not be able to name a second female hormone in addition to oestrogen.
- May not understand that a clone has the same genetic material as the original.
- May think that sweating ‘washes heat off’ the body.
- May incorrectly believe that antibiotics kill viruses.

Grades D–C

- May not understand the limiting factors in photosynthesis.
- May not realise that photosynthesis is a chemical reaction (and cannot specify which are the reactants and which are the products).
- May have difficulty explaining the role of plasma in the blood (for example to carry hormones).
- May have difficulty expressing why pulse rate increases during exercise. Suggests more oxygen needed for blood rather than, for example, for muscle cells.
- May have difficulty explaining how the body removes pathogens and specifically explaining the role of white blood cells.
- May have difficulty deducing the phenotype from a given genotype.

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• May generally have difficulty applying their terminology in a range of applications.
• May make simple errors in classification (for example conclude that as a bat has wings it must be a bird).
• May have difficulty in describing the reflex function in the eye (for example in accommodation and pupil dilation).
• May not be clear whether sexual or asexual reproduction produces variation.
• May think that animal cells can become plasmolysed or turgid.
• May have limited understanding of osmosis and cannot apply it to particular situations such as animal rather than plant cells.
• May think that osmosis involves the transport of substances such as glucose in addition to or rather than water (in some contexts this is also true for Grades B–A).
• May not be able to describe the function of mucus in the lungs.

Grades B–A

• May not know the effect of hormone on kidney tubule and urine output.
• May have confusion between ADH and insulin.
• May have difficulty recognising vector-borne diseases and the notion of vectors.
• May have difficulty in explaining how adaptation develops through evolution (for example in the beaks of 'Darwin's finches').
• May have difficulty in explaining why crops might be genetically modified.
• May not be able to explain how evaporation aids cooling.
• May have difficulties generally in explaining more complex science processes in genetic engineering (for example the process of genetic modification of organisms involving the role of plasmids).
• May not be able to explain the concept of homeostasis.
• May not realise the potential dangers of high blood pressure in, for example, eye damage, stroke or kidney failure.
• May not recognise that alcohol is a depressant.
• May not recognise that fatty acids are acids and therefore have low pH.
• May think that bile is an enzyme.
• May think that muscle cells will produce lactic acid and CO₂ in anaerobic respiration.
• May not link nutrients causing increased bacterial growth with high oxygen demand that makes respiration for fish difficult.
• May be confused between or not know the processes of filtration and selective reabsorption by the kidney.
• May not realise that blood protein molecules are too large to go through a filter.
• May not realise that the contraceptive pill prevents ovulation because oestrogen inhibits the release of follicle-stimulating hormone (FSH).
• May not realise that inhalation results from a reduced pressure in the lung.
• May not be able to describe the function of certain parts of the brain (for example the medulla) in breathing.
• May not be able to describe or deduce parts of the menstrual cycle (for example menstruation).
• May not realise that the male sex hormone promotes the growth of testes.
• May not be able to define an allele.
• May not be able to explain how ciliary muscles and suspensory ligaments can change the shape of the lens of the eye.

Suggested resources

Key resource

• Interactive teaching in science – an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the Responsiveness to pupils’ understanding sequence.

Other useful resources

• Science Framework study guides: Strengthening teaching and learning of organisms, systems, organs and cells – supports the teaching of aspects of organisms, organs, systems and cells.
• Framework advice – Barriers to learning for 'Life processes', Barriers to learning for 'Variation and interdependence' and Barriers to learning for 'Behaviour': guides to common aspects which pupils have found difficult and which can block further learning.

Example external links

• The Triple Science network provides a range of resources to develop concepts across the sciences.
• Society of Biology offers advice about teaching biological concepts and practical activities that best support pupils’ understanding.
• Practical Biology is a resource for practical activities in biology.
• The Association for Science Education’s schoolscience resources cover a range of science disciplines.

Related Links

• schoolscience
• Practical Biology
• Society of Biology
• Triple Science

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Scientific concept – weaknesses from additional science or biology

Grades D–C

- May think that enzymes are a living thing (for example a bacterium) even though they know that they are biological catalysts.
- May report that antibiotics can destroy viruses.
- May not realise that stem cells differentiate into any type of cell.
- May not realise that respiration occurs all the time in plants, with photosynthesis taking place only in the light.
- May confuse cytoplasm with chloroplast or membrane.
- May not realise that for animal populations to rise or fall significantly, there should be a change in a contributing factor.
- May not recognise the concept of a common ancestor or divergence.
- May not know the elements that make up proteins (particularly oxygen).
- May not realise that cellulose is made by plants from glucose.

Grades B–A

- May have difficulty understanding active transport and that nitrate is needed by plants to form proteins.
- May not be able to explain the process of protein synthesis involving DNA, mRNA and tRNA.
- May not realise that proteins are formed from amino acids or that the site of protein formation is the ribosome.
- May not be able to name a protein (for example insulin) in the human body.
- May not be able to explain that plant cells become larger by absorbing water.

Suggested resources

Key resource

- Interactive teaching in science – an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the Responsiveness to pupils’ understanding sequence.
Other useful resources

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Related Links

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- Society of Biology
- Triple Science

Reported weaknesses in GCSE science (chemistry)

These materials describe common weaknesses in chemistry demonstrated by pupils at different approximate grades. Drawn from GCSE examiners' reports, they may help you plan so as to support pupils to avoid or overcome those weaknesses.
Absence of correct scientific terminology

Grades D–C

Weaknesses identified in 2008–09 responses

- May give incorrect symbols for familiar elements (for example Po for potassium, CO₂ for carbon dioxide or HCL for hydrogen chloride)
- May not know the term 'exothermic'
- May not know what some commonly used terms mean (for example 'thermal', 'decomposition' or 'alloy')

Grades B–A

- May not know the term 'addition polymerisation'
- May not know the term 'subduction'

Suggested resources

Key resource

- Interactive teaching in science – an e-learning resource which could be used to help to develop strategies to identify pupils' lack of understanding in the Responsiveness to pupils' understanding sequence.

Other useful resources

- Science framework study guides: Strengthening teaching and learning of particle theory – supports the teaching of aspects of particles.
- Framework advice – Barriers to learning for 'Particle models', Barriers to learning for 'Chemical reactions' and Barriers to learning for 'Patterns in chemical reactions': guides to common aspects which pupils have found difficult and which can block further learning.
- Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works') – Resource library: scientific writing – could be used to support how terminology can be taught in science to strengthen pupils' understanding.
- Interactive teaching in science – an e-learning package containing a number of resources including several chemical teaching sequences.
External resources

- Practical Chemistry and Royal Society of Chemistry offer resources and advice about teaching chemistry concepts and practical activities that best support pupils' understanding.

Related Links

- Practical Chemistry
- Royal Society of Chemistry

Confusion and/or lack of precision in scientific terms and/or symbols

Grades G–E

- May not realise that methane is the major component of natural gas.
- May give imprecise answers (for example 'plastics will give off fumes' rather than 'plastics will give off fumes when they are burnt').
- May, for example, state that a gas is heavy rather than that it is heavier than air.
- May, for example, state that a noble gas is less reactive rather than that it is inert.

Grades D–C

- May state that high pH is acid.
- May incorrectly describe hydrocarbons as a mixture of hydrogen and carbon.
- May describe collision theory in terms of particles that move more and collide rather than move faster and collide more often.
- When comparing may refer to 'it' rather than the object or material (for example 'it has more oxygen' rather than 'the Earth has more atmospheric oxygen than Venus').
- May give symbols when names of elements are required.
- May not be able to define the terms 'atom', 'molecule', 'element', 'mixture' or 'compound'.
- May report that electrons are found in the outer shell rather than in shells outside the nucleus. May confuse 'inner shell' with 'nucleus'.
- May refer to vague descriptions (for example 'bad gases' rather than 'toxic from combustion', 'strong' rather than 'shatterproof' for a property of plastic).
• May confuse the notion that plastics do not degrade with notions of whether plastics corrode or erode.
• May suggest that non-ferrous metals can rust rather than corrode.
• May not be able to explain the term 'electrolysis'.
• May confuse alkanes with alkenes.
• May not recognise that lava is liquid rock, not just a liquid.

Grades B–A

• May not understand and hence may confuse the terms 'polymerisation' and 'cracking'.
• May have difficulty naming unfamiliar compounds (e.g. 'sodium selenium oxide' rather than 'sodium selenate').
• May confuse sodium carbonate with sodium hydrogen carbonate.
• May not know the formula for ammonium in compounds.
• May give too general an answer (e.g. that graphite has three carbon bonds rather than each atom has three bonds).
• May not understand how changing a material can affect its life cycle assessment.

Suggested resources

Key resource

• Science Framework study guides: *Strengthening teaching and learning of particle theory* – supports the teaching of aspects of particles.

Other useful resources

• Framework advice – *Barriers to learning for 'Particle models', Barriers to learning for 'Chemical reactions' and Barriers to learning for 'Patterns in chemical reactions'*: guides to common aspects which pupils have found difficult and which can block further learning.
• *Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works')* – 'Information for teachers on writing descriptions', 'Information for teachers writing explanations' and 'Information for teachers on writing arguments' within the section 'Developing the writing of science' which may help you to support pupils in developing clear descriptions and explanations in their science writing.
• *Literacy in science: Notes for participants* – a guide on to how to develop pupils' recounting and then writing of scientific ideas.

External resources

• *Practical Chemistry* and *Royal Society of Chemistry* offer resources and advice about teaching chemistry concepts and practical activities that best support pupils' understanding.
Related Links

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- Royal Society of Chemistry

Mathematical ability

Grades G–E

- May not read intermediate numbers off graph scales correctly.

Grades D–C

- May not be able to use percentages to calculate the amount of a metal element in a given mass of an alloy.
- May refer to a powdered material as having less surface area than, for example, a ribbon of metal.

Grades B–A

- May incorrectly round down decimals (for example giving 1.36 as 1.3 rather than 1.4).

Suggested resources

Practical Chemistry and Royal Society of Chemistry offer resources and advice about teaching chemistry concepts and practical activities that best support pupils' understanding.

Related Links

- Practical Chemistry
- Royal Society of Chemistry
Not reading and/or answering a question precisely

Grades D–C

• May think that petrol is a fossil fuel.
• May give unqualified answers without specifying (for example stating that pollution rather than release of sulphur dioxide causes air pollution).

Suggested resources

Key resource

• Going for gold: Securing attainment makes suggestions on how to support pupils in preparation for examinations.

Other useful resources

• Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works') – Resource library: scientific writing – could be used to support how terminology can be taught in science to strengthen pupils’ understanding.

Scientific concept – weaknesses from core science

Grades G–E

• May not realise that, as well as CO₂, water is also produced in combustion.
• May think that copper does not corrode.
• May use the term 'stronger acid' when they mean more concentrated acid.
• May think that copper is used in wires because it does not conduct electricity and is therefore safe.
• May not know the lime water test for CO₂.
• May not recognise periods in the periodic table.
• May not recognise metal catalysts.
• May not recognise that water is a product of neutralisation.
• May not know that H⁺ is the ion that makes solutions acidic.
• May confuse biodegradable with non-biodegradable.
• May not be able to write a word equation for the reaction of Group 1 metals with water.
• May invert the reactivity of groups (also true for grades D–C and B–A).
• May not explain why an endothermic reaction needs an external source of heat.
• May believe that monosodium glutamate (MSG) produces flavours rather than enhances them.

Grades D–C

• May give the formula of oxygen as O rather than O₂ (also a higher-level candidate issue).
• May not know the gaseous composition of air (previously an issue in Key Stage 3 tests).
• May not know the composition of water (for example they may draw a structure of two oxygen atoms and one hydrogen).
• May believe that methane burning in oxygen produces methoxide.
• May confuse mixtures with compounds.
• May think that high pH is acid.
• May think that the removal of oxygen is oxidation.
• May not recognise that dehydration is the removal of elements of water from a compound.
• May report that fermentation takes place at 70°C or at a higher temperature.
• May report that distillation is involved in winemaking.
• May report that only carbon or carbon dioxide is a product of combustion of hydrocarbons.
• May have difficulty in explaining how nitrogen is produced from air (may tend to suggest reaction) or why it is used in food packaging.
• May not be able to explain how a sunblock cream could work.
• May not know the term ‘fractionating column’.
• May not recognise what compound is being reduced in a reaction.
• May not write simple balanced equations requiring a recognition that gases such as H, Cl and O exist as H₂, Cl₂ and O₂.
• May not relate higher melting points in compounds with an ionic structure.
• May have difficulty recognising from given data on a variety of elements that potassium differs from other metals by having a lower melting point.
• May not be able to deduce that a substance is, for example, sodium from a given simple atomic structure.
• May not recognise that the colour of precipitates indicates a particular metal (for example copper from chemical reactions of metal salt solutions with sodium hydroxide).
• May not be able to explain how to prepare salts including insoluble salts (for example that an excess of a metal oxide is needed to ensure all of an acid has reacted).
• May think that cracking produces ‘smaller molecules in order to store them more easily’.
Grades B–A

- May not realise that polymers are formed by many monomers.
- May give explanations of oxidation only in terms of a gain of oxygen rather than a loss of electrons.
- May not recognise that a halogen atom will have seven outer electrons rather than one.
- May incorrectly report that chlorine turns litmus paper blue.
- May report that soot produced in combustion indicates carbon monoxide.
- May not realise that CO₂ is produced when ethanol burns.
- May have difficulty in explaining the fractionating of crude oil including the state of the oil in the tower (e.g. state liquid rather than gas).
- May not write ionic equations for neutralisation reactions.
- May have difficulty balancing chemical equations.
- May not be able to name the solutions needed to make ammonium nitrate.
- May not recognise that the number of electrons in the outer shell will give the group in the periodic table.
- May not know that transition metals are catalysts.
- May not recognise how to calculate mass given an equation where a number greater than 1 is at the front of a compound, or the volume of gas produced given relative formula mass.

Suggested resources

Key resource

- *Interactive teaching in science* – an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the Responsiveness to pupils’ understanding sequence.

Other useful resources

- Science Framework study guides: *Strengthening teaching and learning of particle theory* – supports the teaching of aspects of particles.
- Framework advice – *Barriers to learning for ‘Particle models’, Barriers to learning for ‘Chemical reactions’* and *Barriers to learning for ‘Patterns in chemical reactions’*: guides to common aspects which pupils have found difficult and which can block further learning.

External resources

- The *Triple Science* network provides a range of resources to develop concepts across the sciences.
- *Practical Chemistry* and *Royal Society of Chemistry* offer resources and advice about teaching chemistry concepts and practical activities that best support pupils' understanding.
- The Association for Science Education's *schoolsscience* resources cover a range of science disciplines.
Scientific concept – weaknesses from additional science or chemistry

Grades D–C

• May not realise that polyunsaturated fats have more than one double bond.
• May not know the symbol for double bond.
• May not realise that the mass of a catalyst remains unchanged at the end of a reaction.
• May think that ethene is a large molecule (despite knowing that it is a monomer) and may consider that it can be made from methane.
• May not realise that covalent bonds contain electrons (may give answers such as ions or atoms).
• May not realise how ions are formed or even what they are (for example they may think that a chlorine ion has lost an electron or is Cl$^2$).
• May have little understanding about intermolecular forces.
• May not be able to describe correctly the position or the relative numbers of electrons, neutrons and protons in an atom.
• May report that fossil fuels are renewable.

Grades B–A

• May not recognise exothermic or endothermic reactions based on energy released or needed in bond breaking or formation.
• May not understand metallic bonding and the role of the outermost electrons in electrical conduction.
• May not know how the relation of atoms in metallic structure can explain ductility or malleability.
• May have difficulty in explaining the roles of oxidation and reduction in separating metals from their ores.
• May not realise that ethane is a saturated compound.
• May think that ethane can turn bromine water colourless (even when given the structure of ethane).
• May have poor understanding of ionic equations.
• May have poor understanding of balanced equations.
• May not be able to explain the strength of bonds and forces in simple covalent compounds.
• May not recognise that the following will increase yield of product:
  ◦ high temperatures (in an endothermic forward reaction);
  ◦ low pressures (where the forward reaction results in an increase of molecules).

• May think that the amount of products and reactants are equal in an equilibrium reaction.
• May show a poor understanding of atom economy and temperature on yield in an equilibrium reaction.
• May have difficulty designing an investigation (for example relating oxygen production to increased temperature of H₂O₂ solution) – this includes issues with changing and measuring temperature or time and understanding the products.
• May not realise that plasticisers make polymers more flexible.

Suggested resources

Key resource

• *Interactive teaching in science* – an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the *Responsiveness to pupils’ understanding* sequence.

Other useful resources

• Science Framework study guides: *Strengthening teaching and learning of particle theory* – supports the teaching of aspects of particles.
• Framework advice – *Barriers to learning for ‘Particle models’*, *Barriers to learning for ‘Chemical reactions’* and *Barriers to learning for ‘Patterns in chemical reactions’*: guides to common aspects which pupils have found difficult and which can block further learning.

External resources

• The *Triple Science* network provides a range of resources to develop concepts across the sciences.
• *Practical Chemistry* and *Royal Society of Chemistry* offer resources and advice about teaching chemistry concepts and practical activities that best support pupils' understanding.
• The Association for Science Education’s *schoolscience* resources cover a range of science disciplines.
Reported weaknesses in GCSE science (physics)

These materials describe common weaknesses in physics demonstrated by pupils at different approximate grades. Drawn from GCSE examiners' reports, they may help you plan so as to support pupils to avoid or overcome those weaknesses.

Absence of correct scientific terminology

Grades G–E

- May not know the definition of mass number.
- May not know a simple definition of half-life.

Grades D–C

- May not know what a radio telescope is.
- May not be able to recognise a control variable in a scientific investigation.
- May believe that weight is measured in kilograms.
- May have general weaknesses in scientific vocabulary and definitions.
- May confuse refraction with reflection.
- May not know that comets are made of rock and ice.
- May believe that ultraviolet is an example of nuclear radiation.

Grades B–A

- May not be able to explain the difference between analogue and digital signals.
• May not be able to define thermal radiation.
• May not be able to define an alpha particle.
• May not be able to state the difference between fission and fusion.
• May confuse fission with bonding in a chemical reaction or refer to incorrect terms such as 'daughter cells' rather than 'daughter nuclei'.
• May misspell 'ellipse' and 'eclipse'.

Suggested resources

Key resources

• *Interactive teaching in science* – an e-learning resource which could be used to help to develop strategies to identify pupils' lack of understanding in the *Responsiveness to pupils' understanding* sequence.

Other useful resources

• Science framework study guides: *Strengthening teaching and learning of energy* – supports the teaching of aspects of forces and energy.
• Framework advice – [Barriers to learning for 'Energy transfer'](https://www.dfe.gov.uk), [Barriers to learning for 'Forces'](https://www.dfe.gov.uk) and [Barriers to learning for 'Earth, Space and beyond'](https://www.dfe.gov.uk): guides to common aspects which pupils have found difficult and which can block further learning.
• *Maximising pupil progress* (formerly known as *Progressing to level 6 and beyond in science with added 'How science works'* – Resource library: scientific writing – could be used to support how terminology can be taught in science to strengthen pupils' understanding.
• *Interactive teaching in science* – e-learning containing a number of resources including several physics teaching sequences.

External resources

• [Institute of Physics](https://www.iop.org) and [physics.org](https://www.physics.org) offer a range of resources and advice about teaching physics concepts and practical activities that best support pupils' understanding.

Related Links

• [Institute of Physics](https://www.iop.org)
• [physics.org](https://www.physics.org)
Confusion and/or lack of precision in scientific terms and/or symbols

Grades G–E

• May use wrong or poorly drawn symbols for cell or lamp (may not use those given in data sheets).

Grades D–C

• May not recognise that a watt is a joule per second.

Grades B–A

• May use terms such as 'bounce back' rather than 'reflect'.
• May use terms such as 'weaker or stronger energy' or even 'radioactivity' rather than 'energy'.
• May refer to fusion as fusing of atoms rather than atomic nuclei.
• May confuse ALARA (as low as reasonably achievable) and precautionary principles.

Links to resources

Suggested key resource

• Science Framework study guides: Strengthening teaching and learning of particle theory – supports the teaching of aspects of particles.

Other useful resources

• Framework advice – Barriers to learning for 'Energy transfer', Barriers to learning for 'Forces' and Barriers to learning for 'Earth, Space and beyond': guides to common aspects which pupils have found difficult and which can block further learning.
• Literacy in science: Notes for participants – a guide on to how to develop pupils' recounting and then writing of scientific ideas.
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Example external links

- Institute of Physics and physics.org offer a range of resources and advice about teaching physics concepts and practical activities that best support pupils’ understanding.

Related Links

- Institute of Physics
- physics.org

Mathematical ability

Grades G–E

- May not recognise that answers to calculations of, for example, three months' household electricity bills are not likely to be £120,000 (they key in wrong data and accept the answer).
- May find even simple calculations of power × time difficult.
- When doing simple calculations, may give the wrong units (for example 1 J/2 J = 0.5).
- May not distinguish between watts and kilowatts.

Grades D–C

- In general may calculate poorly, including showing inability to convert units, or giving wrong units in answers.
- May not calculate required figures from averages given (for example if the overall average of two figures is 5 and one figure is 2 they may suggest that the other is 3 rather than 8).
- May not calculate radiation counts per second given a total number of counts in minutes.
- May not be able to calculate the weight of an object on different planets given the mass and gravitational field strength.
- May not relate the time for one orbit to the relative radius of the orbit for planets of the solar system.

Grades B–A

- May think that resistance = voltage × current.
- May overlook factors in a calculation (for example if the total resistance of 12 bulbs in a series circuit is 720 ohms – when pupils were given a current of
0.333 A and a voltage of 240 V – they fail to divide by 12 when required to find the resistance of one bulb).

• May not always convert minutes to seconds when required by the calculation.
• May have difficulty calculating distance and acceleration from velocity/time graphs.
• May not know the formula relating charge (Q), current (I) and time (t).
• May not remember to square the velocity when quoting or using the formula for kinetic energy.
• May not remember other formulae correctly (for example may think that acceleration = mass × velocity).

Suggested resources

• Practical Physics and Guidance on how to work out calculations in physics.

Related Links

• Practical Physics
• Guidance on how to work out calculations in physics

Not reading and/or answering a question precisely

Grades D–C

• May refer to 'it' rather than a specific object or process (for example 'it' rather than 'the products or nuclear waste' causes cancer, whereas the question was referring to nuclear power).

Grades B–A

• May give imprecise answers such as 'the resistance changes as the temperature changes' rather than 'the resistance decreases as the temperature decreases'.
• May only give a straight conclusion when requested to explain reasoning (for example they may state that the half-life is short, rather than stating that as the person is young they need a longer half-life radioactive source which is unlikely to run out during the person's lifetime).
Suggested resources

Key resource

• *Going for gold: Securing attainment* makes suggestions on how to support pupils in preparation for examinations.

Other useful resources

• *Maximising pupil progress (formerly known as Progressing to level 6 and beyond in science with added 'How science works')* – Resource library: scientific writing – could be used to support how terminology can be taught in science to strengthen pupils’ understanding.

Scientific concept – weaknesses from core science

Grades G–E

• Often draw 'complete' circuits poorly with small gaps.
• May assume that there is a smaller current in bulbs further away from the cell than those nearer to it.
• May not realise that objects that are cooler/hotter than the surroundings will gain/lose heat.
• May not explain why fossil-fuel burning power stations are more reliable than, for example, those that are wind powered.
• May think that microwaves can be used to toast bread.
• May not recognise most, highest, least or lowest amplitude or frequency from given waves.
• May not recognise that sound waves are longitudinal.
• May not know a simple definition of a longitudinal wave.
• May not recognise acceleration lines on velocity/time graphs.
• May not recognise the electron, proton and neutron in simple diagrams of an atom such as lithium.
• May not know the difference between atomic and mass number.
• May not recognise relative size of upward and downward forces on a falling parachutist.

Grades D–C

• May not identify the mantle and the inner and outer core in a diagram of the Earth.
• May not recognise a graph of DC current.
• May believe that the gravity of the moon is zero (in response to a picture of astronauts walking on the lunar surface).
• May think that an object has no weight at the edge of the atmosphere.
• May not realise that a comet orbits the sun.
• May not realise that digital signals are less affected by noise than analogue signals.
• May not understand the role of gel in ultrasound scans.
• May think that a supernova is the remains of a neutron star.
• May not understand that the earth pin of a plug has to be connected to metal rather than electrical insulators.
• May not explain how an electromagnet works in a circuit breaker.
• May not name sources of background radiation.
• May not distinguish the properties of alpha, beta and gamma radiation.
• May not explain simply how stars are formed from gravitational attraction of dust and gas followed by nuclear fusion.
• May think that there are "heat" particles.
• May not be able to explain how foam is a thermal insulator and that trapped air is key to the insulating properties.
• May confuse infrared with microwaves.
• May not realise that all electromagnetic waves travel at the same speed.

Grades B–A

• May not recognise that the amplification of an analogue signal will wane over long distances but that of a digital signal will not.
• May believe that geostationary satellites do not move.
• May not realise that the time taken for ultrasound waves to be reflected and returned can be used to produce an image.
• May not recognise how an RCCB works (may report that it is the difference in current between the earth and a live wire).
• May believe that x-rays travel faster in space than visible light.
• May not realise that action and reaction forces are of the same magnitude.
• May believe that scientists look for sound waves in the search for extraterrestrial life.
• May have difficulty in explaining the process of conduction (for example across a glass pane from inside air to outside air).
• May not give a variety of uses for ultrasonic waves.
• May not explain that as metal heats up the particles vibrate faster (rather than start to vibrate).
• May have difficulty using the particle model to explain the difference between conduction and convection (may state that particles expand and become less dense).
• May not realise that metal ions are positively charged because they have lost an electron.
• May think that alpha particle emitting isotopes are safe to be used in the bloodstream.
• May not realise that the absorption of microwaves by water molecules increases their kinetic energy.
Suggested resources

Key resource

• Interactive teaching in science – an e-learning resource which could be used to help to develop strategies to identify pupils’ lack of understanding in the Responsiveness to pupils’ understanding sequence.

Other useful resources

• Science Framework study guides: *Strengthening teaching and learning of energy* – supports the teaching of aspects of forces and energy.
• Framework advice – Barriers to learning for ‘Energy transfer’, Barriers to learning for ‘Forces’ and Barriers to learning for ‘Earth, Space and beyond’: guides to common aspects which pupils have found difficult and which can block further learning.

External resources

• The Triple Science network provides a range of resources to develop concepts across the sciences.
• Practical Physics and Guidance on how to work out calculations in physics.
• Institute of Physics and physics.org offer a range of resources and advice about teaching physics concepts and practical activities that best support pupils’ understanding.
• Practical Chemistry and Royal Society of Chemistry offer resources and advice about teaching chemistry concepts and practical activities that best support pupils’ understanding.
• The Association for Science Education’s schoolscience resources cover a range of science disciplines.

Related Links

• Triple Science
• Practical Physics
• Guidance on how to work out calculations in physics
• Institute of Physics
• physics.org
• Practical Chemistry
• Royal Society of Chemistry
• schoolscience
Scientific concept – weaknesses from additional science or physics

Grades D–C

• May confuse the controlled variable with the dependent variable in an investigation.
• May calculate averages that include recognised anomalous results.
• May think that (in static electricity) positively charged objects are the result of gains in electrons or gains in protons.
• May not realise that if a vehicle travels at constant speed the resultant force is zero.
• May believe that a bouncing ball can bounce higher than the drop height.
• May not realise that for objects to be electrically attracted the charges must be opposite.
• May not be able to state how gamma or x-rays are produced.
• May not realise that braking produces negative acceleration.
• May not understand that 'work done' is equivalent to 'energy transferred'.
• May not recognise energy types correctly (for example may give 'electrical energy', rather than 'kinetic', as an answer when discussing the moving part of a motor).
• May not realise that air is an insulator in, for example, double glazing.

Grades B–A

• May not be able to calculate the mass of a moving object from a given momentum and velocity.
• May not be able to describe an alpha or a beta particle in terms of differences in mass or charge.
• May confuse magnetism with electrostatics.
• May believe that gamma radiation goes straight through a human body without damaging cells.

Suggested resources

Key resource

• Interactive teaching in science – an e-learning resource which could be used to help to develop strategies to identify pupils' lack of understanding in the Responsiveness to pupils’ understanding sequence.
Other useful resources

• Science Framework study guides: *Strengthening teaching and learning of energy* – supports the teaching of aspects of forces and energy.
• Framework advice – Barriers to learning for 'Energy transfer', Barriers to learning for 'Forces' and Barriers to learning for 'Earth, Space and beyond': guides to common aspects which pupils have found difficult and which can block further learning.

External resources

• The *Triple Science* network provides a range of resources to develop concepts across the sciences.
• *Practical Physics* and *Guidance on how to work out calculations in physics*.
• *Institute of Physics* and *physics.org* offer a range of resources and advice about teaching physics concepts and practical activities that best support pupils' understanding.
• *Practical Chemistry* and *Royal Society of Chemistry* offer resources and advice about teaching chemistry concepts and practical activities that best support pupils' understanding.
• The Association for Science Education's *schoolscience* resources cover a range of science disciplines.

Related Links

• *Triple Science*
• *Practical Physics*
• *Guidance on how to work out calculations in physics*
• *Institute of Physics*
• *physics.org*
• *Practical Chemistry*
• *Royal Society of Chemistry*
• *schoolscience*