

The logo for PIXL, featuring the word 'PIXL' in a bold, dark blue, sans-serif font. The letter 'i' is lowercase and has a white dot above it. The background is a vibrant orange with various geometric patterns including circles, a grid of dots, and concentric rings.

IGNITING LEADERS
CHANGING LIVES

LEADERSHIP THINKING GUIDE

SCIENCE

This document has been developed based on the findings from Ofsted's [Finding the optimum: the science subject report](#) (February 2023). It will support classroom practice in two ways:

1. Understanding the theory behind learning in science lessons.
2. Understanding how to implement strategies in the classroom to develop this knowledge over time.

THE IMPORTANCE OF SCIENCE IN PRIMARY SCHOOLS

According to the UK Commission for Employment and Skills, 43% of STEM (Science, technology, engineering and mathematics) vacancies are hard to fill due to a shortage of applicants with the appropriate levels of knowledge and skills. In 2020 only 29% of the STEM workforce in the UK were women despite the fact that there was a 30% increase in the number of female students starting STEM A-levels between 2009 and 2020 (Government Equalities Office, 2023).

Science in the Early Years and Primary School provides a foundation, enabling expertise to build knowledge and understanding over time. Pupils benefit from regular opportunities to revisit and build this knowledge so that it is not forgotten. By learning about the products and practices of science, pupils can explain the world around them and know how scientific knowledge is established. They learn about its uses and significance to society and their own lives. It is important that science does not just become experiencing 'fun activities' without developing a deep understanding of the associated scientific concepts. 'All young people are entitled to a high-quality science education, to the curiosity it engenders and the understanding and the opportunity it brings' (Ofsted, 2023).

KNOWLEDGE IN SCIENCE

Scientific knowledge can be classified in different ways. For the purposes of this Leadership Thinking Guide, we are going to use the following definitions from the Ofsted Research Review Series (2021):

- **Substantive knowledge** (knowledge of the products of science, such as concepts, laws, theories and models): this is referred to as scientific knowledge and conceptual understanding in national curriculum in England.
- **Disciplinary knowledge** (knowledge of how scientific knowledge is generated and grows): this is specified in the 'working scientifically' sections of the national curriculum in England.

'This type of distinction is useful for curriculum design because it reflects how knowledge is arranged and used in the sciences. By learning substantive and disciplinary knowledge, pupils not only know 'the science'; they also know the evidence for it' (Ofsted, 2021).

DEVELOPING KNOWLEDGE OVER TIME

Pupils' knowledge and understanding of the key components of knowledge in science needs to build over time. To do this a curriculum needs to identify the core concepts, such as forces and habitats, and develop these concepts over time.

Key questions to ask of your science curriculum:

- What are the core concepts that transcend year groups?
- How are these developed over time?
- How are these core concepts connected and related to one another?
- Are there any core concepts that are important for understanding that are not outlined in detail in the curriculum? Storage and transfer of energy, for example.
- How are you ensuring there is sufficient time in the curriculum for pupils to secure knowledge before moving on to new content?
- Although the Early Years Foundation Stage (EYFS) should not just be considered as preparation for learning in Year 1 do consider: How the Early Years curriculum dovetails into Year 1? How does it prepare pupils for the Year 1 curriculum?
- Look at a Year 6 topic. What is the core knowledge underpinning this topic? How has this been developed over time?
- How are misconceptions highlighted in your curriculum?
- How are misconceptions dealt with in the classroom? What teaching is taking place to help pupils avoid misconceptions?

PURPOSEFUL PRACTICAL WORK

A key criticism in the Ofsted review (2023) was the focus on data collection at the expense of other elements of Working Scientifically, with practical activities being carried out in isolation from relevant substantive and disciplinary knowledge. Disciplinary knowledge needs to be sequenced in the same way we have been sequencing substantive knowledge. This involves looking at where the pupils have come from, where they are now and where they are going. This knowledge needs to be integral, embedded into the curriculum and revisited over time.

To help achieve this, practical work needs a clear purpose.

- Why are we carrying out this activity?
- Why is it happening now?
- What are we hoping pupils will learn as a result of completing this activity?
- Do your staff understand the difference between scientific enquiry and enquiry-based teaching approaches?

Pupils do not always learn from practical activities in the way we think they will. The cognitive load involved in following a method, using unfamiliar equipment, measuring accurately, recording data, plotting graphs and drawing conclusions is not always considered by staff. Here we can be guilty of the 'fallacy of induction' (Driver, 1983) – assuming that pupils will learn from the practical activity simply by doing it.

When entering into any practical work, or other strand of working scientifically (e.g. classification), we need to ensure that our staff know the purpose, and this purpose is clear.

- Are we looking to develop substantive knowledge, disciplinary knowledge, procedural knowledge or improve pupils' manipulative skills? Is it a combination of all of these?
- Is this explicit in your scheme of learning?

We also need to consider what substantive and disciplinary knowledge pupils need before they complete the practical activity.

- Have you considered the sequencing of disciplinary knowledge alongside substantive?
- How do your pupils' skills develop over time?

What does this look like in practice? Let's consider how we might approach a practical activity:



Pupils need sufficient knowledge and vocabulary to talk about a phenomenon they are learning about. If pupils are carrying out a flower dissection, what disciplinary knowledge do they need? A teacher demonstration of how to dissect a flower would be beneficial. Knowing the substantive knowledge of the structure of flowering plants would link well with learning how biologists classify plants (disciplinary knowledge).

- How could all these elements fit together to form a cohesive sequence of learning?
- What apparatus and techniques are integral to this sequence?
- What skills, such as observation and analysis, are also being developed?
- When might we revisit some of these ideas, skills and concepts?

Working scientifically covers several different elements, building pupils understanding of the scientific method.

- How have these elements been integrated into your curriculum?
- How are they sequenced over time?
- How do they link to the substantive knowledge?
- What activities are involved?
- What knowledge and skills are being developed through these activities?

THE VOCABULARY OF SCIENCE

One of the most significant barriers to pupils understanding science is the large vocabulary of science specific terminology, which can often have a different meaning outside the science classroom. Pupils need sufficient vocabulary to be able to talk about a scientific concept or phenomenon, without this they may develop misconceptions.

- Identify the most important words in science e.g. classification, food chain and data.
- Consider what you want pupils in each year group to know about each word. How will their understanding of these terms develop over time?
- Embed oracy in the science curriculum to provide opportunities for pupils to hear and use these terms in context.
- Ensure that when new technical language is introduced, pupils have a secure knowledge and understanding of the core concepts underpinning that term.
- Consider pre-teaching technical terminology to SEND pupils prior to their use in lessons.
- Consider how the use of story, non-fiction texts, rhymes, songs and oral rehearsal might be used to teach vocabulary.

MATHS IN SCIENCE

‘Subject leaders and teachers of mathematics and science should work together to understand how and when knowledge taught in their respective subjects is similar and different. Where there are good reasons for differences, it is important that these are made clear to pupils, including any rationale for this. Pupils will then be clear on what knowledge to use and when. It is also important that teachers do not assume that pupils can easily transfer their learning from mathematics to the science classroom. Pupils will need to be taught how to use mathematics in science.’

Ofsted, 2021

- Identify how key knowledge and vocabulary is taught in mathematics.
- Identify common misconceptions and how to address them.
- Identify when key knowledge is taught and its impact on sequencing – is it being taught first in mathematics or science?
- Sequence the science curriculum to take into account the mathematics curriculum.
- Agree how the concept is taught and use the same methods and vocabulary across science and mathematics.

ASSESSMENT

Assessment can be considered in three different forms:

- Assessment **as** learning – the ‘testing effect’ used to embed knowledge in the long-term memory.
- Assessment **for** learning – formative assessment used within lessons to provide feedback for teachers and pupils, identifying missing knowledge or misconceptions.
- Assessment **of** learning – summative assessment to sample from the domain, identifying whether specific curricular goals have been achieved.

Effective assessment checks help to establish that pupils have learnt the most fundamental knowledge underpinning the curriculum; that which is needed to enable future learning. It needs to assess both the substantive **and** disciplinary knowledge. Outcomes of any assessment should inform teaching and learning. Common misconceptions could be flagged in schemes of work, and explicitly checked in assessments.

Questions to consider:

- Does all assessment have a clear purpose? Why this assessment? Why this point in the curriculum?
- Do assessments consider both disciplinary and substantive knowledge?
- How are the outcomes of assessment used to inform teaching and learning?
- Does your assessment proactively check for specific misconceptions or misunderstandings?
- How does feedback from assessments inform teaching and learning?
- Are common misconceptions recognised and diagnosed?
- What science specific CPD is in place to help improve subject knowledge and formative assessment practices in science?

SUPPORTING PIXL RESOURCES

You will find a range of tools to support all year groups in: developing pupils' substantive and disciplinary knowledge; supporting pupils' acquisition of scientific vocabulary; planning for purposeful, practical investigations and using diagnostic assessments in science.

Science Leads should consider *how* and *when* these materials can be used across all year groups to strengthen the impact and rigour of the science curriculum. All materials provided are editable and we encourage teachers to review and adjust the content to ensure that it precisely meets the needs of their pupils.

Resource	Further information
<p>Challenge and Stretch in Science for Years 1 to 6:</p> <ul style="list-style-type: none"> - Guidance video - Animals, including humans - Materials <p>Coming soon:</p> <ul style="list-style-type: none"> - Plants (Years 1-3) - Forces and Magnets (Y3) - Living things and their habitats (Y4) - Electricity (Y4) - Forces (Y5) - Living things and their habitats (Y6) - Electricity (Y6) 	<p>The Challenge and Stretch project aims to support school leaders and teachers in ensuring that all pupils, including the most able, meet their potential in English, Mathematics and Science.</p> <p>The Challenge and Stretch in Science materials provide an opportunity for pupils to consolidate, deepen and extend their substantive and disciplinary knowledge linked to key areas of the KS1 and KS2 science curricula.</p> <p>Each session includes:</p> <ul style="list-style-type: none"> - Slides for teachers which highlight relevant links to the national curriculum in England: science programmes of study, identify common misconceptions and provide relevant research to support the professional development of school leaders and teachers. To further support teacher subject knowledge, a glossary is included to ensure that all key vocabulary is used with accuracy and consistency. - Slides to work through with pupils which support pupils' recall of prior knowledge. Pupils' substantive and disciplinary knowledge is then extended further before they apply this learning to a task to deepen their understanding and to provide an effective opportunity for formative assessment. Each session concludes with an open-ended question or prompt to support pupils' ongoing thinking, curiosity and reflection.
<p>Creating awe and wonder in the science in the primary science classroom for EYFS to Year 6</p>	<p>This package aims to provide ideas for creating and nurturing a classroom culture where pupils are inspired, engaged and confident to take ownership of their own learning and thinking in science.</p>

	<p>For each year group, there is a detailed plan for a practical, purposeful scientific investigation and a corresponding video which models the experiment and clearly exemplifies how awe and wonder can be created through it.</p> <p>The plan includes relevant links to the science programme of study and identifies the disciplinary knowledge that pupils will be developing during the investigation as well as the equipment needed and the method.</p> <p>To support the development of teacher expertise, scientific explanations to accompany each investigation are included, as well as recommendations for next steps to further challenge pupils and deepen their understanding.</p>
<p>Science diagnostic tasks for Years 1 to 6</p>	<p>One of the findings in Ofsted’s <i>Finding the optimum: the science subject report</i> (February, 2023) is that, ‘in some schools, there was not enough focus on checking whether pupils had learned the disciplinary knowledge that is needed to work scientifically. These schools only focused on checking that pupils had learned substantive knowledge.’</p> <p>The science diagnostic tasks have been developed to support teachers in their assessment of pupils’ disciplinary knowledge, particularly in relation to the <i>Working scientifically</i> strands. For each year group, a series of tasks, linked to different aspects of the science programmes of study, provide an opportunity for strands of <i>Working scientifically</i> to be addressed.</p> <p>Each diagnostic assessment includes comprehensive teacher guidance, including national curriculum links, scientific explanations to support teacher expertise, prior knowledge and key vocabulary required for pupils to access the task, probing questions and a clear sequence for the session. In addition, assessment grids are provided as well as editable PowerPoints to support teaching.</p>
<p>Materials to support the development of scientific vocabulary</p>	<p>You will find a range of resources to support science-specific vocabulary development on PrimaryWise including:</p> <ul style="list-style-type: none"> - Science recall cards: Available for Y1 to Y6, these flashcards are designed to support the acquisition and rapid recall of science-related vocabulary required for each year group. - Science vocabulary mats: Available for upper and lower KS2, these mats provide an overview of key science-related vocabulary for pupils and deepen pupils’ understanding by providing examples of the

vocabulary being used in context. Speaking frames are also included to support pupils' oracy skills in science.

- Science vocabulary quizzes: Available for KS1, lower KS2 and upper KS2, these quizzes are designed to support teachers in revisiting key science-related vocabulary. They should be used diagnostically to identify misconceptions which can then inform teaching.

REFERENCES

Driver, R. (1983) *The pupil as scientist?* Milton Keynes: OUP

Government Equalities Office (2023) More women to be supported back into STEM jobs in Government-backed training. 11th February. Available from: [More women to be supported back into STEM jobs in Government-backed training - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/news/more-women-to-be-supported-back-into-stem-jobs-in-government-backed-training) [accessed 19th May 2023]

Millar, R. (2009). *Analysing practical activities to assess and improve effectiveness: The Practical Activity Analysis Inventory (PAAI)*. York: Centre for Innovation and Research in Science Education, University of York. Available from: <https://www.rsc.org/cpd/teachers/content/filerepository/frg/pdf/ResearchbyMillar.pdf> [accessed 18th May 2023]

Ofsted (2021) *Research review series: science* April 2021. Available from: [Research review series: science - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/research-review-series/science) [accessed 18th May 2023]

Ofsted (2023) *Finding the optimum: the science subject report* February 2023. Available from: [Finding the optimum: the science subject report - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/research-review-series/science) [accessed 18th May 2023]

UK Commission for Employment and Skills (2015) *Reviewing the requirement for high level STEM skills*. Available from: [High level STEM skills requirements in the UK labour market FINAL.pdf \(publishing.service.gov.uk\)](https://www.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/444444/high_level_stem_skills_requirements_in_the_uk_labour_market_FINAL.pdf) [accessed 19th May 2023]



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