Science

Guidance for Key Stages 2 and 3

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Llywodraeth Cynulliad Cymru

Welsh Assembly Government

Science

Guidance for Key Stages 2 and 3

Audience Teachers at Key Stages 2 and 3; local education authorities; tutors in initial teacher training; and others with an interest in continuing professional development.

Overview These materials provide key messages for planning learning and teaching in science. They include profiles of learners' work to exemplify the standards set out in the level descriptions and illustrate how to use level descriptions to make best-fit judgements at the end of Key Stages 2 and 3.

Action required To review learning plans and activities, and to prepare to make judgements at the end of Key Stages 2 and 3.

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www.wales.gov.uk/educationandskills

Related documents *Science in the National Curriculum for Wales; Skills framework for 3 to 19-year-olds in Wales; Making the most of learning: Implementing the revised curriculum; Ensuring consistency in teacher assessment: Guidance for Key Stages 2 and 3* (Welsh Assembly Government, 2008)

This guidance is also available in Welsh.

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Contents

Introduction

The programmes of study set out the opportunities that learners should be given at each key stage and provide the basis from which you, as a teacher, can plan learning and teaching. They are divided into two sections, Skills and Range. The Skills section lists the skills to be developed in a subject and the Range section comprises the opportunities and contexts through which these skills should be developed and consolidated.

Ongoing formative assessment – assessment **for** learning – lies at the heart of good teaching. Through the assessments that you make in the course of your teaching, you will build up an extensive knowledge of your learners' strengths, as well as the areas that need further development, and you will use this knowledge to help you plan for the next steps in their learning. Learners will also gain understanding of specific learning goals and the associated success criteria so that, supported by you, they can develop their capacity for self-assessment and peer assessment. In this way, they can establish their current position, set and move towards targets, and discover if and when the targets have been reached. Individual targets are linked to improving the quality of a learner's work, as highlighted through formative feedback, and are therefore linked to success criteria for specific tasks. Level descriptions do not make effective targets as these describe attainment across the breadth of the programme of study at the end of a key stage.

Level descriptions can help to inform your planning, teaching and assessment at Key Stages 2 and 3 by indicating expectations at particular levels and progression in the subject. Evidence from assessment for learning will indicate where more time is needed to consolidate learning and when learners are ready to move on. You may wish to keep some evidence so that you can discuss a learner's work and progress with them and/or with colleagues or parents/guardians. However, there is no statutory requirement to keep unnecessarily complex records or detailed evidence on every learner.

The essential function of level descriptions is to help you make rounded summative judgements at the end of Key Stages 2 and 3 about a learner's overall performance. Level descriptions are designed neither to be used to 'level' individual pieces of work nor for the production of half-termly or termly data. It is only by the end of the key stage that you will have built up sufficient knowledge about a learner's performance across a range of work, and in a variety of contexts, to enable you to make a judgement in relation to the level descriptions.

It may be that some learners will be more advanced in some aspects of the work than in others, and that no one level description provides an exact fit. That is to be expected, and the range of individual learners' work included in these materials illustrates the making of best-fit judgements under those circumstances. Many schools/departments have found it helpful to develop their own learner profiles to support moderation of end of key stage judgements. These profiles also help to maintain a common understanding of standards when they are reviewed annually or refreshed when necessary.

When making judgements at the end of Key Stages 2 and 3, you should decide which level description **best fits** a learner's performance. The aim is for a rounded judgement that:

- is based on your knowledge of how the learner performs across a range of contexts
- takes into account different strengths and areas for development in that learner's performance
- is checked against adjacent level descriptions to ensure that the level judged to be the most appropriate is the closest overall match to the learner's performance in the attainment target.

National curriculum outcomes have been written for learners working below Level 1. These are non-statutory and guidance on their use is planned.

Using these materials

This booklet is divided into three sections.

Section 1	highlights key messages for learning and teaching in science.
Section 2	highlights expectations and progression in science.
Section 3	contains a series of learner profiles. These are designed to show the use of the level descriptions in coming to judgements about a learner's overall performance at the end of Key Stages 2 and 3.

This booklet is for reference when you wish to:

- review your learning plans and activities
- consider the standards set out in the revised science Order
- work with other teachers to reach a shared understanding of the level descriptions
- prepare to make judgements at the end of the key stage
- develop your own learner profiles
- support transition from Key Stage 2 to Key Stage 3.

For ease of reference, the level descriptions are included in a leaflet with this booklet.

A CD-ROM is also included with this booklet. It contains a PDF version of *Science in the National Curriculum for Wales, Skills framework for 3 to 19-year-olds in Wales* and this guidance.

A composite poster of the strands in the level descriptions is also included with this guidance. This poster is to aid teachers planning for progression in science and identifying characteristics of level descriptions. It is not designed as a prompt for learners. The use of numbers, as in the level descriptions themselves, is against the fundamental principles of assessment for learning. Therefore, although the sharing of progression in science with learners is essential, the labelling of that progression with numbers is counterproductive in everyday classroom assessments.

This guidance is part of a series of materials that will help teachers at Key Stages 2 and 3 to implement the revised curriculum and its associated assessment arrangements. The series includes:

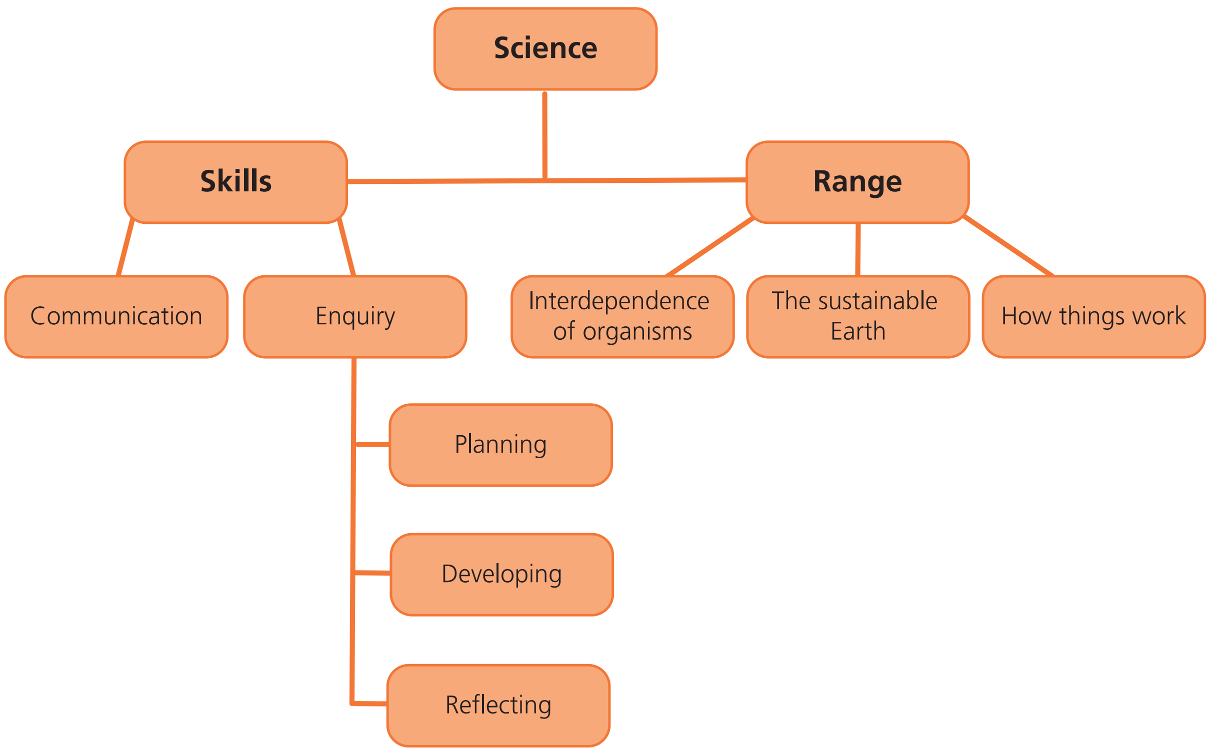
- *Making the most of learning: Implementing the revised curriculum* – overview guidance on implementing the new curriculum
- *Skills framework for 3 to 19-year-olds in Wales* – which includes guidance about progression in skills
- *Ensuring consistency in teacher assessment: Guidance for Key Stages 2 and 3*
- *A curriculum for all learners*: *Guidance to support teachers of learners with additional learning needs*
- specific guidance for all national curriculum subjects, personal and social education, careers and the world of work, and religious education.

Section 1

Key messages for learning and teaching in science

The revised curriculum is learner-centred and skills-focused. Significant changes have been made to the presentation and content of this revised curriculum, giving both opportunities and challenges for schools wanting to provide a relevant and motivating educational experience.

Structure of the science programme of study



Key to learners' successful science experiences will be the planning and teaching of the programmes of study. These have been designed to offer teachers and learners:

- a focus on developing skills, particularly thinking, communication, ICT and number skills, woven throughout the programmes and linking with the non-statutory *Skills framework for 3 to 19-year-olds in Wales*

- continuity and progression 3–19, taking into account particularly the frameworks for the Foundation Phase (especially the Knowledge and Understanding of the World area of learning), personal and social education (PSE), 14–19 Learning Pathways (particularly approved science-related qualifications and careers and the world of work)
- opportunities to engage in contemporary issues and different types of activities to suit learners' and teachers' needs and schools natural and physical resources in different parts of Wales
- maximum flexibility in selecting appropriate, relevant content from the considerable range of opportunities to suit the needs, interests and preferred experiences of all learners
- opportunities to link across the Range of Interdependence of organisms, The sustainable Earth and How things work
- opportunities to link with other subjects, such as geography, design and technology and the PSE framework.

So that the revised science order is **learner-centred**, it has embedded within it assessment for learning vocabulary. It is essential that for learners to make progress, they know where they are in a learning continuum, where they need to get to and most importantly **how** to get there. There are many tools/strategies that can be employed to ensure that assessment for learning is at the heart of classroom pedagogy. These move the teacher away from instructing to being a facilitator of learning. This guidance shows many assessment for learning tools/strategies.

In Sian's profile (Key Stage 3, Level 5), for example, the teacher models two investigative write-ups so that learners can determine success criteria before they carry out and write up their own investigation. The modelling takes place in the 'What makes a good investigation?' enquiry with Sian using these success criteria in 'How does the surface area affect the rate of evaporation?'. In a few of the profiles the teacher uses traffic lights for learners to self-assess their understanding. Mia uses this tool/strategy in 'How can a guitar make a sound' (Key Stage 2, Level 4). Each activity sets out the 'Next steps' required for each learner to progress.

Generally these are written by the teacher however, at times they are written by the learner themselves. In Amy's profile (Key Stage 3, Level 6) she sets her own targets relating to the science knowledge and understanding to be used for her 'Limestone' enquiry.

In order to be **relevant to all learners**, contemporary contexts have been included in the Range that give opportunities for learners to link their own experiences and current issues with scientific theory. In addition, statements within the programmes of study are more general in nature than previously to increase flexibility and better allow teachers to take account of learners' prior learning. This enables teachers to better target gaps or misconceptions in learners' skills, knowledge and understanding. Tom uses a concept map to ascertain his prior learning before he draws a 'Map of the solar system' (Key Stage 2, Level 5).

Both the contemporary nature and flexibility of statements should allow teachers to provide learning experiences that are **relevant to the 21st century**. An example of such a task can be found in Sian's profile (Key Stage 3, Level 5), the 'Energy Resources' enquiry. Here learners are asked to produce a report for the school governors as to the advantages and disadvantages of using 'fast growing' trees as the school's main energy resource. The task allows Amy, working collaboratively, to research sources in order to compare the burning of fossil fuels with 'fast growing' trees. This mirrors the current debate in many parts of Wales.

Science and skills across the curriculum

The revised national curriculum Order for science has a greater **focus on learners' skills development**. It has been written taking due account of the Skills framework, which includes developing thinking, communication, number and ICT, both within the programmes of study and the associated level descriptions. Opportunities to develop these skills are highlighted by the use of icons. The Skills framework has been written to show how learners acquire, develop and apply these skills across the curriculum.

All the programmes of study have been written in two sections; Skills and Range. The Skills section of the science programme of study includes the areas of Communication and Enquiry. This section gives opportunities for learners to develop their thinking, communication, number and ICT across the Range. It is expected that learning will take place through scientific enquiry.

Developing thinking

Learners develop their thinking across the curriculum through the processes of **planning**, **developing** and **reflecting**.

In science, learners follow the processes of planning, developing and reflecting in all areas of Enquiry, through which the Range is taught. Focused paired/group work allows such processes to be articulated within lessons so that learning and thinking strategies can be developed and applied to new situations leading to high quality outcomes.

When good quality learning occurs, the cycle of plan, develop and reflect forms a spiral taking place throughout the learning[1]. Learners reflect as they plan and develop a task, ensuring that they think about their thinking and use these thoughts to amend and refine their learning. By linking their learning to prior skills, knowledge and understanding from both within and outside of school, learners embed their progress and develop their thinking. These skills can then be applied across all aspects of their lives.

[1] The learning is intended here to refer to internal processes. It does not refer to a three part lesson.

Examples of tools/strategies that can be used to support developing thinking are found throughout the profiles. These include a Venn diagram used by David to organise his findings from fieldwork in 'Comparing two environments' (Key Stage 2, Level 3); a metacognitive caterpillar used by Mia to describe how she has learned about sound in 'How can a guitar make a sound?' (Key Stage 2, Level 4); Tom's use of a source square to clarify his thoughts about an image of the Sun and the Earth in 'Questionning a solar system image' (Key Stage 2, Level 5), and a reflection triangle used by Sian (Key Stage 3, Level 5) in the activity 'How can we clean pond water?'.

Developing communication

Learners develop their communication skills across the curriculum through the skills of **oracy**, **reading**, **writing** and **wider communication**.

In science, learners communicate ideas, information and data in a variety of ways depending on the nature of the task, audience, purpose and the learners' own preferences. Communication can take a wide variety of forms, including the use of IT at times, and with increasing maturity should show progression in the use of scientific terminology, symbols and conventions and a more logical, systematic approach.

Much of the evidence in the profiles demonstrates the development of communication skills. Mia makes a simple presentation about Saturn in 'Planet presentation' (Key Stage 2, Level 4) whilst Amy makes a more refined presentation on 'Insulin' (Key Stage 3, Level 6). Sian's work in the classifying and identifying enquiry 'Vertebrate groups' (Key Stage 3, Level 5) shows how clear, systematic organisation of findings is important.

Developing ICT

Learners develop their ICT skills across the curriculum by **finding**, **developing**, **creating and presenting information and ideas** and by using a wide range of equipment and software.

In science, learners use ICT for a number of purposes. They search for, access, collect, process and analyse relevant scientific evidence, information, ideas and data. They use ICT to present their evidence, information, ideas and data in the most appropriate form.

Activities throughout the profiles demonstrate the use of internet searches, whilst in 'Mission possible?' (Key Stage 2, Level 5), Tom uses a spreadsheet to determine the outcomes of a space mission. Many of the activities require learners to use ICT to display data, information and ideas.

Developing number

Learners develop their number skills across the curriculum by **using mathematical information**, **calculating and interpreting and presenting findings**.

In science, learners work quantitatively to estimate and measure using non-standard and then standard measures, recording the latter with appropriate S.I. units. They use tables, charts and graphs to record and present information, which is part of Communication in science. With increasing maturity they draw lines of best fit on line graphs, use some quantitative definitions and perform scientific calculations.

Number skills are used by learners throughout the profiles. In the 'Litter survey' activity, David uses a tally chart, a class pictogram and then draws a bar chart in a given format (Key Stage 2, Level 3). Mia, in the 'Making rockets' activity, draws a table and a simple line graph with given axes (Key Stage 2, Level 4). In the Level 5 profiles, Tom (Key Stage 2) demonstrates he can select the most appropriate type of chart or graph in the activity 'How can the brightness of a bulb in a circuit be changed?'. Sian (Key Stage 3) plots a line graph to describe the relationship between two continuous variables in the enquiry 'How does the surface area affect the rate of evaporation?'. Amy can use appropriate axes and scales for a line graph to show her data effectively in 'How does caffeine affect the heart rate?' (Key Stage 3, Level 6). In Ben's profile (Key Stage 3, Level 7), he demonstrates that he can use some quantitative definitions and perform calculations using the correct units in 'Can you work out work done?'.

Science and learning across the curriculum

Curriculum 2008 provides opportunities for the development of the Welsh Assembly Government's policies and cross-curricular themes, such as the Curriculum Cymreig, personal and social education and careers and the world of work, which includes equal opportunities, food and fitness and sustainable develoment.

At Key Stages 2 and 3, learners should be given opportunities to build on their experiences gained during the Foundation Phase, and to promote their knowledge and understanding of Wales, their personal and social development and well-being, and their awareness of the world of work.

Curriculum Cymreig

Learners aged 7–14 should be given opportunities to develop and apply knowledge and understanding of the cultural, economic, environmental, historical and linguistic characteristics of Wales.

At Key Stage 2 learners are required to compare two local environments, by carrying out fieldwork. A better understanding of the factors that each environment is dependent upon, should lead to greater concern about the environment in Wales.

In the profiles, further links to the Curriculum Cymreig are exemplified by Sian's 'Energy Resources' enquiry, (Key Stage 3, Level 5) where learners are tasked with producing a report for the school governors as to the advantages and disadvantages of using 'fast growing' trees as the school's main energy resource. In addition, in Amy's 'Limestone Enquiry' (Key Stage 3, Level 6) learners are asked to produce a resource for a local steel company's Visitors' Centre.

Personal and social education

Learners should be given opportunities to promote their health and emotional well-being and moral and spiritual development; to become active citizens and promote sustainable development and global citizenship; and to prepare for lifelong learning.

The revised science Order provides a variety of opportunities for learners to explore a wide range of issues related to PSE.

Examples in the profiles include a 'Litter survey' by David (Key Stage 2, Level 3) and a 'Caffeine Enquiry' where Amy investigates the effects of caffeine on heart rate (Key Stage 3, Level 6).

Careers and the world of work

Learners aged 11–19 should be given opportunities to develop their awareness of careers and the world of work and how their studies contribute to their readiness for a working life.

Although the icon is not used in the Range section of the programme of study, the whole of the Skills section is relevant to learners' development for the world of work as well as future employment in a scientific field. It is hoped that following the revised programme of study in its entirety will lead to a more scientifically literate workforce.

Learning in science

Progress from the Foundation Phase in Skills and Range has been mapped through Key Stages 2 and 3 and into the Key Stage 4 programme of study. This should ensure that there is **continuity** for learners across their compulsory schooling in science. The Progression in science statements have been written to give a summary of the whole of a phase or key stage. They show how **progress** in science across the Skills and Range sections is achieved.

The profiles evidence learners articulating their thoughts, ideas and findings providing them with opportunities to develop higher order thinking and focus more on assessment for learning. Classroom tasks and activities include many examples of paired and group work, so that learners are given time to ask questions, think and justify their thoughts to their peers before reaching conclusions. Collaborative learning produces higher quality outcomes and enables learners to take risks without fear of self-failure. The teacher was still able to assess individual learners' progress by listening for a few minutes to their deliberations and asking some pertinent questions. Self and peer assessment by the learners at the end of each activity consolidate the teacher's evidence of the process and the outcomes.

1 Science Enquiry

The science orders reference specific types of enquiry. The titles and definitions have been developed from the AKSIS project[2]. It is recognized that there is some overlap when classifying enquiries in this manner. For example, several enquiry types require learners to look for patterns although overall the enquiry may be classified as a fair test enquiry. Similarly, learners are expected to use models in other types of enquiry. Here is a summary of the types of enquiry exemplified within this booklet.

[2] AKSIS (ASE–King's College Science Investigations in Schools) project, 1998

The project produced teaching materials and research reports for teaching specific aspects of enquiry, and produced recommendations based on an exploration of how enquiry was implemented in schools by using focus groups, and on a national questionnaire survey.

(a) Pattern-seeking

Pattern-seeking enquiries are similar to fair tests but start with the values of the dependent variable and try to identify the cause(s) (the independent variable). Often they are used to study natural events and in most cases they involve variables that are difficult to control. Surveys are also pattern-seeking enquiries where learners compare data to identify relationships and make causal links.

Learner profile			Title of enquiry
David	KS2	L3	Comparing two environments
David	KS2	L3	Litter survey
Ben	KS3	L7	Respiration and combustion

(b) Exploring

Exploring involves learners looking for changes in just one variable at a time. For example, making careful observations of objects or events or making a series of observations or measurements of a natural phenomenon occurring over time. Often these enquiries generate questions that then lead to other types of enquiry, especially pattern-seeking ones.

Learner profile			Title of enquiry
Mia	KS2	L4	The rocket launch
Mia	KS2	L4	How can a guitar make a sound?
Tom	KS2	L5	Questioning a solar system image
Tom	KS2	L5	Moon Crash Landing 2020
Sian	KS3	L5	What makes a good investigation?
Amy	KS3	L6	Melting ice

(c) Classifying and identifying

Classifying is a process of arranging a large range of objects or events into manageable sets according to their features or the way they behave. Identifying is a process of recognising objects and events as members of particular sets and allocating names to them. Classification and identification both involve learners in identifying features, tests or procedures that discriminate between the things or processes being studied.

Learner profile			Title of enquiry
David	KS2	L3	Is any of the litter attracted to a magnet?
Mia	KS2	L4	Fact or opinion?
Sian	KS2	L5	Vertebrate groups
Amy	KS3	L6	Solids, liquids, gases and their particles
Ben	KS3	L7	Is *Euglena* a plant or an animal? Explain.

(d) Making things (or developing systems)

Enquiries that involve making things are often technological in nature and involve learners in designing an artefact or system to meet a human need. Those that require the use of scientific skills, knowledge and understanding can be classified in this way.

Learner profile			Title of enquiry
David	KS2	L3	Shadow puppets
David	KS2	L3	Designing packaging for biscuits
Mia	KS2	L4	Planet presentation
Tom	KS2	L5	Map of the solar system
Tom	KS2	L5	How can you make a model of a lighthouse?
Sian	KS3	L5	Imaginary animal
Sian	KS3	L5	How can we clean pond water?
Sian	KS3	L5	How could people in an economically developing
Sian	KS3	L5	Energy resources
Amy	KS3	L6	Insulin presentation
Amy	KS3	L6	Limestone enquiry
Amy	KS3	L6	Volcanoes

(e) Fair testing

This is concerned with observing and exploring the relationship between an independent variable and a dependent variable. Independent variables are identified and one is manipulated while the others are controlled.

Learner profile			Title of enquiry
David	KS2	L3	Which is the best material for stopping biscuits becoming soggy?
Mia	KS2	L4	Making rockets
Mia	KS2	L4	Does the mixture of lava affect the eruption of a volcano?
Tom	KS2	L5	How can the brightness of a bulb in a circuit be changed?
Sian	KS3	L5	How does the surface area affect the rate of evaporation?
Amy	KS3	L6	How does caffeine affect the heart rate?
Ben	KS3	L7	How does the mass of magnesium added affect the temperature rise in its reaction with copper sulphate?

(f) Using and applying models

Here learners use, apply or develop a model to test an idea or a theory.

Learner profile			Title of enquiry
Tom	KS2	L5	Mission Possible?
Tom	KS2	L5	How can you make a model of a lighthouse?
Sian	KS2	L5	How does the surface area affect the rate of evaporation?
Amy	KS3	L6	Fairground ride
Ben	KS3	L7	Historical reactions
Ben	KS3	L7	How does a space shuttle land?
Ben	KS3	L7	Can you work out work done?

2 Science Range

There are three main areas of the Range at Key Stages 2 and 3. Each area has an overarching statement which gives the 'big picture' to guide teachers towards relevant learning opportunities.

Area of the Range	Key Stage 2	Key Stage 3
Interdependence of organisms	Pupils should use and develop their skills, knowledge and understanding by investigating how animals and plants are independent yet rely on each other for survival.	Pupils should use and develop their skills, knowledge and understanding by investigating how humans are independent yet rely on other organisms for survival, applying this to life in countries with different levels of economic development.
The sustainable Earth	Pupils should use and develop their skills, knowledge and understanding by comparing the Earth with other planets, investigating the materials around them and considering the importance of recycling.	Pupils should use and develop their skills, knowledge and understanding by investigating the materials in the Earth and its atmosphere and how they can change, and apply this in contemporary contexts.

Area of the Range	Key Stage 2	Key Stage 3
How things work	Pupils should use and develop their skills, knowledge and understanding by investigating the science behind everyday things, *e.g. toys, musical instruments and electrical devices*, the way they are constructed and work.	Pupils should use and develop their skills, knowledge and understanding by investigating the science involved in a range of contemporary devices/machines and evaluate different energy resources and possibilities.

These 'big picture' statements should help teachers to plan to make links across the Range and between science and other curricular areas. In this way they give greater opportunity for more thematic based learning and teaching so that learners can link their thoughts more easily and transfer generic skills across subject boundaries.

The revised science order has been reduced so that teachers can allow learners time to construct their learning. The reduction in the number of attainment targets and the generalisation of statements also allows for a variety of links to be made between the traditional science areas. Ben's task interrogating Joseph Priestley's findings (Key Stage 3, Level 7) gives opportunities for links between combustion and photosynthesis. Similarly the 'Moon Crash Landing 2020' activity (Key Stage 2, Level 5) requires Tom to use knowledge and understanding from across the Range. Examples of cross-curricular activities can be found within the profiles, for example, Amy's 'Volcanoes' activity (Key Stage 3, Level 6) links with geography, whilst David's 'Shadow puppets' task (Key Stage 3, Level 3) links with design and technology.

Section 2

Expectations and progression in science

This section is designed to establish a common understanding of the standards associated with Levels 3 to 7 in the context of the programmes of study for Key Stages 2 and 3, although the profiles only evidence some of the level characteristics for Levels 2 to 8.

The level descriptions for science are set out in one attainment target. They show broad lines of progression in Skills in science, including Communication and Enquiry, across the Range of the programme of study. The level descriptions have been revised to reflect changes in the programme of study. The pitch and challenge remain broadly the same.

The level descriptions table[3] found on the composite table on the Welsh Assembly Government website and in the order are written in a linear manner. However, learning is not linear. It is a cyclical spiral, with the need for pupils to revisit previously learned skills, knowledge and understanding so that they can consolidate and make further progress in their learning.

Level characteristics

The processes of planning, developing and reflecting are essential when carrying out scientific enquiries. To mirror this, the level descriptions are written as three paragraphs, relating to these processes, which are described in the developing thinking section of the skills framework. Communication, number and ICT skills are also subsumed. To help teachers to plan for and to review progress in science each process has been split into strands. The tables on the following pages show the level characteristics for each of the strands in planning, developing and reflecting. These should not be seen as 'tick lists' of attainment but should be used to plan for progress and to standardise teachers' ideas of the characteristics of a level description. Some strands do not cover the whole spectrum of level descriptions. Where they do not cover the higher levels, pupils' progress can only be assessed if they are given a more complex, abstract task that requires them to review the 'big picture' and/or one that is set in an unfamiliar context. **Embolden text** in these tables shows which level characteristics are exemplified by the pupil in the stated enquiry.

3 www.wales.gov.uk/educationandskills (see 'Curriculum and assessment' section)

It is necessary to use planning, developing and reflecting flexibly rather than as a specific way of teaching. Each process is inter-linked with the other two so for example, in order to plan an enquiry it is always necessary to reflect on prior learning.

Each level description builds on the previous one and therefore text from previous descriptions is not repeated as the strand is revisited in the next level, i.e. level descriptions are cumulative. Recognising level characteristics is an aid to assessing both formatively and summatively. Many of the teachers involved in developing this guidance kept field notes to remind them of pupils' progress in science. Rather than trying to assess all pupils in a class at the same time, they either concentrated on specific groups of pupils, or on individuals.

Planning in science

To ensure success in a scientific enquiry pupils need to plan what they are going to do and how they are going to do it. Initially pupils will use everyday knowledge and understanding to plan. As they progress, they will use more scientific knowledge and understanding and this knowledge will become more abstract in nature as they progress further. In addition, pupils that initially required support from a teacher to plan an enquiry will become more independent as they progress. The plans produced by pupils become more methodical and eventually systematic in nature as they practice and refine their planning skills.

Finding evidence, information and ideas

In order to plan a scientific enquiry, pupils need to activate prior skills, knowledge and understanding. So they need to think about what they already know and understand and the skills they have. They may then need to supplement these by **finding evidence, information and ideas**. In the profiles the evidence, information and ideas used by pupils are from many different sources, such as peers, teachers, internet searches, leaflets and books.

Level characteristics in finding evidence, information and ideas		Example in profile	What the pupil actually does
1	*listen and respond to scientific ideas and react appropriately*		
2	*choose from given options where to find evidence, information and ideas*		
3	*suggest* ***where to find*** *evidence, information and* ***ideas***	'Shadow puppets' (Key Stage 2, Level 3)	David suggests and then looks at a website for ideas as to how to make a shadow puppet.
4	***find and use a variety of evidence****,* ***information*** *and ideas*	'Planet presentation' (Key Stage 2, Level 4)	Mia looks at a website and a leaflet to find information on Saturn. However, some of the information she then uses is questionable as to its scientific relevance.
5	***find and use relevant*** *evidence,* ***information*** *and ideas*	'Vertebrate groups' (Key Stage 3, Level 5)	Sian looks on the internet in order to draw up her table to compare vertebrate groups. She only uses relevant information and inserts pictures to exemplify her findings.

Predicting

For successful planning pupils need to think about the possible outcomes. They need to address the question 'What will happen if . . . ?' in order to **predict**. Predictions can take many forms, for example, when asked to design or invent an organism or artefact, pupils will use predictive thinking to make decisions. In the profiles, Sian (Key Stage 3, Level 5) invents an 'Imaginary animal' and uses scientific knowledge and understanding to think about 'What would happen if . . . ?' in order to develop her design.

Level characteristics in predicting		Example in profile	What the pupil actually does
3	*talk about their ideas and* ***using their everyday experience they make simple predictions***	'Which is the best material for stopping biscuits becoming soggy?' (Key Stage 2, Level 3)	David uses his everyday experiences to predict that plastic will be the most waterproof material as it's commonly used for drink bottles.
4	***use scientific knowledge and skills to…predict outcomes***	'Does the mixture of lava affect the eruption of a volcano?' (Key Stage 2, Level 4)	Mia uses some scientific knowledge to predict that the reaction between vinegar and bicarbonate of soda will be 'bigger' when she uses more vinegar.
5	***making predictions based on scientific knowledge and understanding, including simple models***	'How does the surface area affect the rate of evaporation?' (Key Stage 3, Level 5)	Sian predicts that the greater the surface area the faster the rate of evaporation will be. She supports this with scientific knowledge that includes a simple model of change of state.

Level characteristics in predicting		Example in profile	What the pupil actually does
6	***make predictions using abstract scientific ideas***	'How does caffeine affect the heart rate?' Amy (Key Stage 3, Level 6)	Amy uses abstract scientific knowledge of how caffeine affects the body in order to predict what will happen to her heart rate.
7	***make qualitative predictions using linked scientific knowledge and understanding gained from a variety of sources***	'How does the mass of magnesium added affect the temperature rise in its reaction with copper sulphate?' (Key Stage 3, Level 7)	Ben links his knowledge of displacement and exothermic reactions to make predictions as to the outcome of his enquiry. His knowledge is from past work and the teacher's demonstration.
8	*make quantitative predictions, where appropriate, using detailed scientific knowledge and abstract ideas*		
EP	*justify their predictions by making multiple links between scientific models, theories and systems*		

Methods and strategies

When planning a scientific enquiry, pupils need to think about how they are going to carry out their enquiry. They need to decide on the method or strategy that is going to be used. **Methods** that pupils suggest tend to be from past experiences. Many pupils find it helpful to use a writing frame to organise their thoughts when planning. Any writing frame that does not assist with the scientific knowledge and understanding required for an enquiry will not reduce a pupil's possible attainment. Several examples of such writing frames are given in the profiles.

Learning/thinking strategies are important to ensure that learning in science is consolidated. Pupils will initially suggest simple ideas, such as 'discussing with a partner' to sort out thoughts or 'looking on the internet' for information. Underpinning these are the strategies. For example there is no point discussing if you don't listen. Similarly to search on the internet for information a pupil will need a strategy to decide which key words to use. By making these strategies explicit pupils will more easily be able to transfer them to another context whether in science or in other subjects. A writing frame used to organise the planning of a scientific enquiry, as discussed earlier is actually a learning/thinking tool.

	Level characteristics in methods and strategies	Example in profile	What the pupil actually does
1	*take part in simple activities and through a variety of experiences explore the world around them*		
2	*talk about the steps needed to carry out their enquiries*		
3	***plan, with support, the method to be used for their enquiries***	'Which is the best material for stopping biscuits becoming soggy?' (Key Stage 2, Level 3)	David is supported by his teacher in planning the method for this fair test enquiry. However, his planning to control variables actually shows features of Level 4.
4	***use scientific knowledge** and skills **to plan their enquiries***	'Does the mixture of lava affect the eruption of a volcano?' (Key Stage 2, Level 4)	Mia bases her plan on her scientific knowledge of the reaction between vinegar and bicarbonate of soda. However, she does not state the quantities of any of the variables.
5	***systematically plan their enquiries***	'How does the surface area affect the rate of evaporation?' (Key Stage 3, Level 5)	Sian's plan is written in a systematic manner. She does state the volume of water she will use, although how she will use the hairdryer is vague.

Level characteristics in methods and strategies		Example in profile	What the pupil actually does
6	***suggest a variety of methods*** *or strategies* ***for their enquiries***	Amy's profile (Key Stage 3, Level 6)	Across Amy's profile she suggests different scientific methods for tackling her enquiries.
7	***give some justification for the*** *methods and* ***strategies they plan to use***	'Respiration and combustion' (Key Stage 3, Level 7)	Ben suggests and gives some justification for using a Venn diagram to organise his thoughts.
8	*justify their methods and strategies in view of the reliability of the information and/or the data to be gathered and the accuracy of the equipment to be used* *identify any possible problems with the method/strategy*		
EP	*justify their methods and strategies making multiple links to prior learning and independent research and taking account of possible problems*		

Fair testing

Fair testing enquiries require detailed, systematic planning to ensure that the outcomes are scientifically reliable. Pupils working at lower levels will struggle to fulfil these requirements.

Level	Level characteristics in fair testing	Example in profile	What the pupil actually does
4	***recognise, with support, the variables to change and measure and those to be kept the same***	'Making rockets' (Key Stage 2, Level 4)	Questioning by the teacher helps Mia clarify her thoughts as to the key variables.
5	***identify key variables and distinguish between independent and dependent variables and those that they will keep the same***	'How can the brightness of a bulb in a circuit be changed?' (Key Stage 2, Level 5)	Tom independently notes the key variables of number of batteries (independent) and the brightness of the bulb (dependent). He also recognises that he needs to control any extraneous light.
6	*plan how to control the variables that they need to keep the same* ***and make decisions about the range and values of the independent variable***	'How does caffeine affect the heart rate?' (Key Stage 3, Level 6)	In her plan, Amy lists the key variables and makes notes as to how they can be controlled. She couldn't make decisions about the range and values of the independent variable as this was set by the mass of caffeine in the drink.
7	***identify key variables that may not be readily controlled explaining why this is the case***	'How does the mass of magnesium added affect the temperature rise in its reaction with copper sulphate?' (Key Stage 3, Level 7)	Ben recognises that he cannot control the surface area of magnesium metal used. He explains why he can't control it and then how this could affect his findings.
8			
EP	*plan to track changes in more than one dependent variable*		

Determining success criteria

Any scientific enquiry could start by pupils thinking about what success in the task may look like. However, asking pupils to **determine success criteria** for every task would demotivate them. It is very difficult for most pupils to determine success criteria without first modelling success. The activity 'What makes a good investigation?' in Sian's profile (Key Stage 3, Level 5) is an example of modelling investigation write-ups to enable Sian to suggest success criteria for the write-up of her own investigation.

	Level characteristics in determining success criteria	Example in profile	What the pupil actually does
2	*talk about…what is needed to be successful*		
3	***agree on some basic success criteria***	'Designing packaging for biscuits' (Key Stage 2, Level 3)	David and his partner agree on the simple success criteria for the design of stopping the biscuits from becoming soggy, looking good and using a material that could be recycled.
4	***decide upon some basic success criteria***	'Planet presentation' (Key Stage 2, Level 4)	Mia decides on her own success criteria for her presentation and although they are basic they are her own ideas.
5	***give some justification for their success criteria***	'How can you make a model of a lighthouse?' (Key Stage 2, Level 5)	Tom decides that his model lighthouse needs to have a working light that can be turned on and off and his model needs to be high from the ground. He justifies the latter by explaining that the light could be seen from further away.
6	***justify their success criteria***	'Insulin presentation' (Key Stage 3, Level 6)	Amy verbally justifies her suggested success criteria for the presentation.

Developing in science

Developing an enquiry is the actual carrying out of a method/strategy and the processing of the findings. Once pupils have planned they need to carry out their enquiry in order to gather their findings. The term 'findings' used in this context includes a wide variety of evidence, information, data or ideas. It does not just refer to the findings of a scientific investigation in the traditional sense. Pupils will develop many different types of scientific enquiry in their science career. Some enquiries will be more investigative in nature while others will be developing their own ideas.

Observing and measuring

In most scientific enquiry types pupils are asked to either **observe** or **measure**. As pupils progress they do this in a more systematic way. At the lower levels pupils measure using non-standard measures such as teaspoonfuls, progressing to standard measures using S.I. units. At higher levels pupils measure accurately, which relies on the selection of the necessary measuring equipment with the most useful and appropriate divisions.

	Level characteristics in observing and measuring	Example in profile	What the pupil actually does
1	*observe…simple features of organisms, objects, materials and events*		
2	***make enough observations to be able to sort, group** and compare organisms, objects, materials and events*	'Comparing two environments' (Key Stage 2, Level 3)	David compares the organisms found in a field and in a hedgerow. He sorts them using a Venn diagram provided by the teacher.
3	***follow a simple series of instructions safely to gather their findings***	'Comparing two environments' (Key Stage 2, Level 3)	David follows his teacher's instructions in order to compare the organisms in each environment.
	make observations that they could measure using simple equipment	'Which is the best material for stopping biscuits becoming soggy?' (Key Stage 2, Level 3)	David could have measured the mass of water absorbed by the biscuits but chose instead to observe the outcomes.

Level characteristics in observing and measuring		Example in profile	What the pupil actually does
4	***follow the planned method*** ***make qualitative observations*** *and...* ***use standard measuring equipment to make measurements*** *within a given range* ***using S.I. units***	'Does the mixture of lava affect the eruption of a volcano?' (Key Stage 2, Level 4) 'Making rockets' (Key Stage 2, Level 4)	Mia followed her plan. She made detailed observations of the different 'volcanic' eruptions. Mia measured the distance her rockets travelled in cm.
5	***select measuring instruments that allow them to make a series of accurate measurements***	'How does the surface area affect the rate of evaporation?' (Key Stage 3, Level 5)	Sian selected a stopwatch (the most accurate instrument available) and used graph paper to measure the surface area of each container.
6	*make precise observations and accurate measurements using equipment with fine divisions*		
7	*systematically observe and measure*		

Monitoring progress

When pupils carry out a scientific enquiry, many of them **monitor** their **progress**. However, this is rarely explicit either in written or verbal responses. By making the monitoring process more explicit it is hoped that pupils will take more responsibility for their on-going decisions and therefore their outcomes will be more meaningful to them.

	Level characteristics in monitoring progress	Example in profile	What the pupil actually does
4	*making amendments where necessary*		
5	***regularly check progress and revise the method where necessary***	'How can you make a model of a lighthouse?' (Key Stage 2, Level 5)	Tom built several versions of circuits with differently constructed switches until he was happy that the circuit would work once placed in his structure.
6	***regularly check progress, make ongoing revisions when necessary and begin to justify any amendments or improvements made***	'How does caffeine affect the heart rate?' (Key Stage 3, Level 6)	Amy made an ongoing revision to the method once she recognised that her heart rate was remaining high, past the time they had allocated to take the pulse rate and she simply justified this.
7	*justify any amendments made to the method/strategy*		

Communicating findings

In all scientific enquiries, pupils are expected to **communicate their findings**. Communication in science can take many forms and increasingly involves the use of number skills as pupils progress. However, the emphasis in these profiles is on the written word due to the nature of the guidance. As they progress pupils display their findings in a more scientific and systematic way as they understand and use the conventions of table and chart/graph drawing.

Level	Level characteristics in communicating findings	Example in profile	What the pupil actually does
1	*describe simple features of organisms, objects, materials and events through talking, drawing, mark-making or writing simple words*		
2	***make simple records of their findings by** talking, drawing, writing simple sentences, **constructing tally charts** or pictograms*	'Litter survey' (Key Stage 2, Level 3)	David draws a tally chart to show his findings when comparing the materials that litter is made from.
3	***begin to organise their findings and display them in a given format***	'Litter survey' (Key Stage 2, Level 3)	David draws a bar chart of the class findings of the materials that the litter is made from using axes and scales given to him by the teacher.
4	***organise and communicate their findings using relevant scientific language***	'The rocket launch' (Key Stage 2, Level 4)	Mia uses relevant scientific language in her description and explanation, although her work contains confused scientific ideas.
	display these in tables,** bar charts and **in simple line graphs when the axes and scales are given	'Making rockets' (Key Stage 2, Level 4)	Mia independently draws a table to show her findings. She also draws a line graph using axes and scales given to her by the teacher.

Level characteristics in communicating findings		Example in profile	What the pupil actually does
5	***organise and communicate their findings integrating different forms*** *in various presentations and*	'Vertebrate groups' (Key Stage 3, Level 5)	Sian uses text and images in her table.
	record these systematically using S.I. units *where appropriate*	'How does the surface area affect the rate of evaporation?' (Key Stage 3, Level 5)	Sian records her findings using S.I units.
	select the most appropriate type of graph or chart to display data	'How can the brightness of a bulb in a circuit be changed?' (Key Stage 2, Level 5)	Tom explains that his results should be drawn as a bar chart as the independent variable, the number of batteries, is discontinuous.
	uses a line graph to describe relationships between two continuous variables		
6	***organise and communicate their findings in a variety of ways fit for purpose and audience***	'Limestone enquiry' (Key Stage 3, Level 6)	Amy produces an interesting, clear and informative leaflet for the Visitors' Centre at the local steel company.
	use appropriate axes and scales for graphs to show data effectively	'How does caffeine affect the heart rate?' (Key Stage 3, Level 6)	Amy draws her own line graph that shows the changes in pulse rate effectively and includes the resting pulse.
	begin to use some quantitative definitions	'Volcanoes' (Key Stage 3, Level 6)	Amy tries to quantify the energies involved in the volcanic eruption, although she doesn't draw them to scale.

Level characteristics in communicating findings		Example in profile	What the pupil actually does
7	*draw lines of best fit on graphs* ***use some quantitative definitions and perform calculations using the correct units***	'Can you work out work done?' (Key Stage 3, Level 7)	Ben uses the equation for work done to calculate and then order a list of situations. He uses the correct units.
8			
EP	*develop an organised system to record findings clearly conveying points of interest*		

Reviewing findings

Once pupils have their findings from a scientific enquiry it is important that they recognise whether there is a pattern in them in order to conclude. However, **findings need to be reviewed** and questioned as to whether they can be trusted or not. In a simple way, repeating measurements or tests or finding more information that agrees with the original findings leads pupils to consider reliability. However, the spotting of an anomaly in a pattern, whether it is in readings or information, should lead pupils working at higher levels to question why this is the case and suggest explanations for it. Evidence, information and ideas can be biased therefore pupils need to think about the nature and origin of the sources they have used. At the highest levels pupils also consider the validity of their findings. This usually will require them to think whether their findings could be transferred to a different enquiry or situation.

Level characteristics in reviewing findings		Example in profile	What the pupil actually does
3	***begin to identify simple patterns*** *and trends* ***begin to distinguish between scientific 'facts', beliefs and opinions***	'Litter survey' (Key Stage 2, Level 3) 'Fact or opinion?' (Key Stage 2, Level 4)	David recognises that most of the litter is made from plastic by using his bar chart. Mia is starting to think about 'facts' and opinions and the differences between the way they are written.

Level characteristics in reviewing findings		Example in profile	What the pupil actually does
4	***identify patterns*** *and trends* *distinguish between 'facts', beliefs and opinions and begin to recognise bias*	'How can a guitar make a sound?' (Key Stage 2, Level 4)	Mia reviews her observations and recognises that the thicker strings make a deep sound when plucked.
5	***use line graphs to describe relationships between two continuous variables*** *identify bias and* ***start to consider reliability***	'How does the surface area affect the rate of evaporation?' (Key Stage 3, Level 5)	Mia uses her line graph to describe that the larger the surface area the faster the water evaporated. In her suggestions for improvement she recognises the need to repeat her experiment to check her results.
6	*assess bias,* ***consider reliability*** ***offer some explanations for any anomalies***	'Questioning an image of the solar system' (Key Stage 2, Level 5)	Tom checks the authenticity of the image he has been provided with and offers some explanations for the anomalies the image has suggested.
7	***begin to evaluate their findings in order to gauge bias, reliability and validity***	'Can you work out work done?' (Key Stage 3, Level 7)	Ben makes notes about the sources he has used to gather the data. Within these notes he questions their possible bias, reliability and validity.
8	*evaluate their findings in order to gauge bias, reliability and validity identify and explore uncertainties and explain anomalies*		

Explaining

Pupils working at the lower levels are more able to describe their findings rather than explain them. Comparing in order to group requires pupils to look at similarities and differences. Pupils working at Level 2 and above can describe the basis for their groupings and as such are explaining their decisions based on what they can see, feel or hear. Simple **explanations of the findings** from a scientific enquiry such as those based on pupils' everyday experiences usually take the form of 'This happened because . . . '. In addition pupils working at Level 3 can give similar **explanations for differences and changes**. The use of scientific knowledge and understanding to explain their findings, differences or changes starts at Level 4 and becomes more detailed and abstract in nature as learners progress. Pupils working at Level 5 and above will use simple models to explain. Simple models usually involve more concrete ideas, such as explaining changes of state using the ideas of solids, liquids and gases without discussing what is actually happening to the particles. Pupils working at Level 6 and above understand abstract models such as particle theory and as they progress they apply these models to their explanations. It may be that pupils working below Level 6 try to use abstract ideas of particles in their explanations but do so incorrectly. Pupils working at Level 7 and above link processes and/or systems in their explanations. At times these processes/systems will be from different sections of the Range.

In reality, this strand sets the context and therefore challenge of the level description. It is a direct link to the Range and should be used when planning future learning to achieve progression.

	Level characteristics in explaining	Example in profile	What the pupil actually does
1	*recognise and name a range of common organisms, objects, materials, light sources and sound sources*		
2	***describe the basis for their groupings using simple differences*** *between organisms, objects,* ***materials*** *and physical phenomena*	'Litter survey' (Key Stage 2, Level 3)	David describes why he has grouped the litter into his categories. He struggles to group some of the materials of the litter as they don't quite fit into his categories.

Level characteristics in explaining		Example in profile	What the pupil actually does
3	***give an explanation, based upon their everyday experiences, for their findings, including any patterns***	'Comparing two environments' (Key Stage 2, Level 3)	David explains why there is more plastic in the litter by relating it to the quantities of pop and crisps he and his peers drink and eat.
	give simple explanations for *differences between and changes to organisms, objects,* ***materials*** *and physical phenomena*	'Shadow puppets' (Key Stage 2, Level 3)	David recognises that light cannot pass through solid objects and so a shadow is formed.
4	***use some scientific knowledge and understanding to explain*** *their findings and differences between, or* ***changes to*** *organisms, materials and* ***physical phenomena***	'Making rockets' (Key Stage 2, Level 4)	Mia tries to use her science knowledge to explain why her rockets travel different distances. She relates the movement of the rockets (the force) to the air expelled.
5	***use scientific knowledge and understanding, including simple models, when explaining*** *their findings and differences between, or* ***changes to*** *organisms,* ***materials*** *and physical phenomena*	'How could people in an economically developing country get clean water?' (Key Stage 3, Level 5)	Sian uses a simple model of change of state to explain why her model of cleaning water would work. She shows the processes of evaporation and condensation and states that any impurities will remain in the pond.

Level characteristics in explaining		Example in profile	What the pupil actually does
6	***use abstract scientific knowledge and understanding, including models, when explaining*** *their findings and differences between, or* ***changes to****, organisms,* ***materials*** *and physical phenomena* ***recognise that a number of factors*** *and/or processes* ***may have to be considered when explaining changes***	'Melting Ice' (Key Stage 3, Level 6)	In her verbal presentation to the class Amy uses the particle model to explain change of state. She describes how heat energy would affect the movement of the particles. Had she discussed in more detail how the forces between the particles were affected her response would be more characteristic of Level 7.
		'Fairground ride' (Key Stage 3, Level 6)	Amy shows in her diagram that she is considering energy changes and work done to explain changes in her fictitious ride. She is starting to link abstract ideas and had this been more evident, her response would be more characteristic of Level 7.

Level characteristics in explaining		Example in profile	What the pupil actually does
7	*explain to what extent their findings are consistent with scientific knowledge and understanding, using abstract ideas at times* ***in explanations they apply abstract ideas and make links between processes*** *or systems* ***begin to use their explanations to make predictions***	'Historical reactions' (Key Stage 3, Level 7)	Ben makes links between combustion and photosynthesis when he explains Joseph Priestley's experiment. He goes on to use these explanations to make predictions relating to fossil fuels and the greenhouse effect.
8	*explain to what extent their findings are consistent with abstract scientific ideas* *explain the impact of one system on another*		
EP	*use complex, abstract ideas or combinations of models/systems to explain their findings* *use their knowledge and understanding to critically evaluate predicted effects on systems*		

Conclusions and decisions

In order to **draw conclusions** or to **make decisions**, pupils need to review and explain their findings, whether this be data, ideas or information. Initially pupils will just state what they have found out from their scientific enquiry and make their own decisions. As they progress, their conclusions are increasingly related to their findings and their opinions or decisions are backed by further information. Part of collecting further information requires collaborative working so that pupils listen to others' views and opinions. At the higher levels pupils question their conclusions and opinions as to their scientific validity and discuss this by referring to further scientific evidence.

	Level characteristics in drawing conclusions and making decisions	Example in profile	What the pupil actually does
3	***say what they have found out from their work** and make their own decisions by weighing up pros and cons*	Is any of the litter attracted to a magnet? (Key Stage 2, Level 3)	David says that he has found out that all metals are magnetic from his experiment.
4	***begin to draw conclusions**, form considered opinions*	'Making rockets' (Key Stage 2, Level 4)	Mia attempts to draw a simple conclusion by referring to the big bottle making a big force as there was more air.
	make informed decisions	'How can a guitar make a sound?' (Key Stage 2, Level 4)	Mia discusses her ideas with a partner to improve her ideas about the science behind how the guitar works.

Level characteristics in drawing conclusions and making decisions		Example in profile	What the pupil actually does
5	***draw conclusions that are consistent with the findings***	'How can the brightness of a bulb in a circuit be changed?' (Key Stage 2, Level 5)	Tom draws a conclusion that describes the relationship between the variables of number of batteries and the brightness of the bulb.
	consider others' views to inform *opinions and* ***decisions***	'How can we clean pond water?' (Key Stage 3, Level 5)	Sian works collaboratively throughout her profile and this is especially evident as she monitors progress in this enquiry
6	***consider a wider range of perspectives to inform*** *opinions and* ***decisions***	'Insulin presentation' (Key Stage 3, Level 6)	Amy considers information from a wide range of sources from differing perspectives to write the presentation.
7	*describe how they might collect more information in order* ***to check the validity of their conclusions***	'Can you work out work done?' (Key Stage 3, Level 7)	Ben recognises the need to check the validity but doesn't actually describe how he might do this.
8	*draw conclusions showing an awareness of the degree of uncertainty and a range of views*		
EP	*use detailed evidence to form consistent conclusions/opinions*		

Reflecting in science

Reflecting on learning is an essential part of consolidating new scientific ideas and skills. It is not expected that reflection only happens at the end of the lesson. Reflection is an integral part of an entire lesson and as described earlier, reflecting on prior skills, knowledge and understanding is needed before a pupil can plan what they are going to do. Pupils working at the lower levels will struggle to reflect on their learning either generically or scientifically. They will tend to describe simply what they have done.

Reviewing success

Once pupils can determine success criteria either informally or formally, they can decide whether their method was successful or otherwise. **Reflecting on success** therefore becomes more systematic and meaningful. It can lead to an increased emphasis on peer and self-assessment as well as to pupils setting their own targets for improvement.

	Level characteristics in reviewing success	Example in profile	What the pupil actually does
2	*respond to questions about what worked and what didn't*		
3	***link outcomes to success criteria** and identify what worked and what didn't*	'Designing packaging for biscuits' (Key Stage 2, Level 3)	David has linked his design to his success criteria.
	beginning to think about how the method could be improved	'Shadow puppets' (Key Stage 2, Level 3)	David evaluates his puppet and makes simple suggestions as to how to improve its definition as a shadow.
4	***decide whether their method was successful by referring to their success criteria say how they could improve it***	'Planet presentation' (Key Stage 2, Level 4)	Mia refers to her basic success criteria in her brief evaluation. She suggests other information she could have used, about Jupiter's moons, which in her opinion would have improved her presentation.

Level characteristics in reviewing success		Example in profile	What the pupil actually does
5	***begin to evaluate how far success criteria fully reflect successful outcomes***	'How can you make a model of a lighthouse?' (Key Stage 2, Level 5)	Tom recognises that his success criteria had flaws and realises how he could amend them.
6	*evaluate how far success criteria fully reflect successful outcomes*		
7	***refine success criteria in the light of experience for future occasions***	'Respiration and combustion' (Key Stage 3, Level 7)	Ben reflects on his free-response answer and suggests how he could change his success criteria to ensure better quality of work next time.

Evaluating learning

So that pupils can evaluate **how they have learned** they need to be comfortable with learning/thinking vocabulary in order to express themselves. Pupils working at the lower levels will use terms such as 'talked' or 'looked in a book' to give a more concrete feel to their learning. As they progress they use more abstract terms such as 'analysed' or 'researched'. Using thinking tools helps pupils to clarify their learning/thinking processes. For example, David (Key Stage 2, Level 3) and Ben (Key Stage 3, Level 7) both use Venn diagrams to compare. Ben recognises the importance of using a Venn diagram and goes on to describe how he can refine this tool for future use.

Level characteristics in evaluating own learning and thinking		Example in profile	What the pupil actually does
4	***describe how they have learned and identify the ways that worked the best***	'How can a guitar make a sound?' (Key Stage 2, Level 4)	Mia uses a metacognitive caterpillar tool to show how she has learned. She uses terms such as 'talked' and wrote'. She also identifies that 'talking' was the best way and even goes on to justify her reasons.
5	***identify the learning/thinking strategy they have used***	'How can we clean pond water?' (Key Stage 3, Level 5)	Sian uses learning/thinking terms to describe what she had done. She identifies 'brainstorming' as a strategy she had used. Her other ideas sum up how she worked without getting to the 'How I did this', i.e. the strategies she used.
6	***identify the learning/thinking strategies being used***	'Limestone enquiry' (Key Stage 3, Level 6)	Amy clearly identifies a number of strategies she uses, such as 'brainstorming', 'scanning' and the tool of a 'KWHL grid'

Level characteristics in evaluating own learning and thinking		Example in profile	What the pupil actually does
7	***review their strategies in light of results obtained or the information gathered***	'Respiration and combustion' (Key Stage 3, Level 7)	Ben reviews his strategy in light of his self-assessment by suggesting that he could use a three circled Venn diagram to compare these two processes with photosynthesis.
8	*suggest alternative learning/thinking strategies*		
EP	*evaluate the likely effectiveness of alternative strategies and refine learning/thinking strategies for future occasions*		

Linking learning

Pupils working at the lower levels may need to be asked questions in order to **link** what and how they have learned in science lessons, usually to more everyday contexts or vice versa. As pupils progress they link their learning to other science contexts and eventually make links to other subjects or life outside school with increasing confidence. At higher levels the links become more abstract in nature and are used to make predictions both within science and the wider world. Linking skills, knowledge and understanding in science ensures that learning is consolidated and remembered so that it can be applied in new situations.

Focused questioning is a vital tool in getting pupils to link ideas and methods. Questions such as 'Why do you think that?' or 'Where did you get that idea from?' will push pupils towards making links with what they can already do or what they know. To ensure pupils link what they have found out with other ideas, questions could be asked such as 'Where have you come across this before?' or 'Where could you also use what you have done/found out?'.

Level characteristics in linking learning		Example in profile	What the pupil actually does
3	***link the learning, with support, to familiar situations***	'Designing packaging for biscuits' (Key Stage 2, Level 3)	David is questioned by his teacher to help him to link his design with the materials that biscuits are actually packaged in as well as recycling.
4	***link the learning to similar situations***	'Does the mixture of lava affect the eruption of a volcano?' (Key Stage 2, Level 4)	Mia links her findings from using a model volcanic eruption with what might actually happen in a real-life situation. Therefore she is linking ideas about two 'volcanoes'.
5	***link the learning to dissimilar but familiar situations***	'How could people in an economically developing country get clean water?' (Key Stage 3, Level 5)	Sian links her design of a water purifying model to the video clip about life in an economically developing country. In this case the video clip is classed as being familiar to her.
6	***link the learning to unfamiliar situations***	'Melting ice' (Key Stage 3, Level 6)	Amy links her ideas on ice melting to the **rate** of ice caps melting due to global warming. The science behind the rate of ice caps melting is unfamiliar to her although she has some knowledge of the ice caps melting.

Level characteristics in linking learning		Example in profile	What the pupil actually does
7	***link the learning to more abstract situations***	'Historical reactions' (Key Stage 3, Level 7)	Ben links what he has learned about Joseph Priestley's experiment with fossil fuels and the greenhouse effect.
8	***link learning to make further predictions***		He goes on to make predictions about possible effects to life on Earth.

Section 3

Making judgements at the end of Key Stages 2 and 3

This section shows how level descriptions can be used when making judgements about which level best describes a learner's overall performance at the end of Key Stages 2 and 3.

You may find the following points useful when considering the profiles in this section.

- The learner profiles are not presented as a model for how you should collect evidence about your learners. Although you will want to be able to explain why you have awarded a particular level to a learner at the end of the key stage, there is no requirement for judgements to be explained in this way or supported by detailed collections of evidence on each learner. Decisions about collecting evidence, and about its purpose and use, are matters for teachers working within an agreed school policy.
- The commentaries on the pieces of work have been written to explain the judgement made about a learner's performance. They are not intended as an example of a report to parents/guardians.
- The materials in each learner profile can only represent a small part of the information and experiences that make up a teacher's knowledge of each learner. They do not reflect the extent of the knowledge of each learner that you will have built up over time across a range of different contexts. You will use this knowledge to make a rounded judgement about the level that best fits each learner's performance.
- You will arrive at judgements by taking into account strengths and weaknesses in performance across a range of contexts and over a period of time. Opportunities will need to be provided for learners to demonstrate attainment in all aspects of the level descriptions.
- Some of your learners may need to use a range of alternative forms of communication to show what they know, what they understand and what they can do.

Profiles

Key to activities in the learner profiles

Each activity has a reference box situated at the start of the activity. The box gives the title of the activity, the type of enquiry and references to the programme of study. The references attributed to each sample are what the learner actually does. Each activity has opportunities for learners to use other skills and at times apply these skills to other areas of the Range. The statements from the programme of study are then referenced with their respective numbers.

Skills

C = Communication

EP = Enquiry planning

ED = Enquiry developing

ER = Enquiry reflecting

Range

IO = Interdependence of organisms

TSE = The sustainable Earth

HTW = How things work

Key Stage 2

David

Level 3

David is an 11-year-old learner in Key Stage 2.

His teacher knows much more about David's performance than can be included here. However, this profile has been selected to illustrate characteristic features of David's work across a range of activities. Each example is accompanied by a brief commentary to provide a context and indicate particular qualities in the work.

Much of his work is reported orally or in pictures. He receives some help with reading, writing and word processing from his teacher or a support assistant.

David's teacher judges that his performance in science is best described as Level 3.

Litter survey

Pattern-seeking enquiry

Skills
C2; ED2, 4, 5, 7; ER3.

Range
IO7; TSE3, 6.

Within the theme of Sustainability, the class carried out a survey of the litter from their packed lunches. They looked at the material each piece of litter was made from. Pupils were asked to group the litter using their own criteria.

Teacher:
What can you see, David, that makes these two pieces of litter different to each other?

David:
One is a sweet packet and the other's a pop bottle.

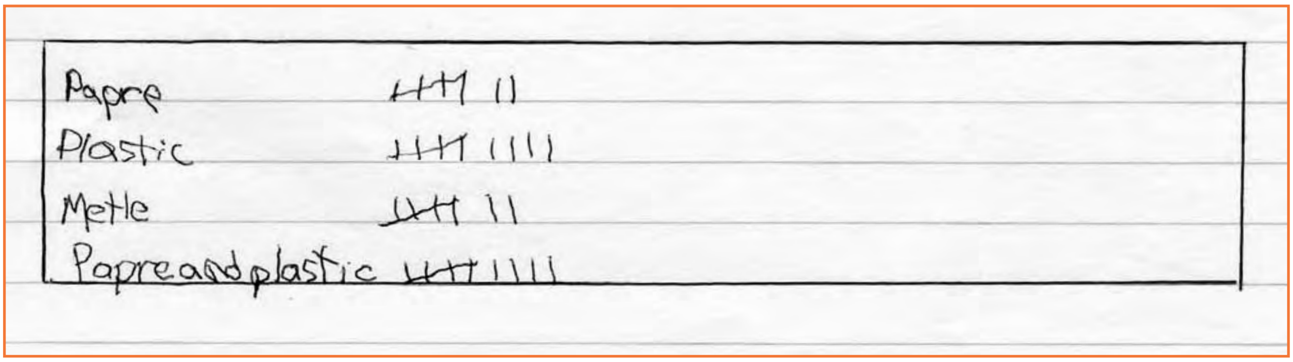
Teacher:
What is each one made of?

David:
That one's paper and the other's plastic.

Teacher:
Can you group the rest of the litter into those made of paper and those made of plastic?

David grouped the litter but left some pieces out of the groups. He made enough observations to group the litter, in this case into ‘paper’ and ‘plastic’. He then went on to make two further groups, one of ‘metal’ litter and one of ‘crisp packets’. The teacher asked him why he put the crisp packets together as a group. He said that it’s because some seem to be made of ‘paper and plastic’ while the others are shiny like metal. After a few minutes thinking he put the shiny crisp packets into the metal group but kept the others in a separate group; ‘paper and plastic’.

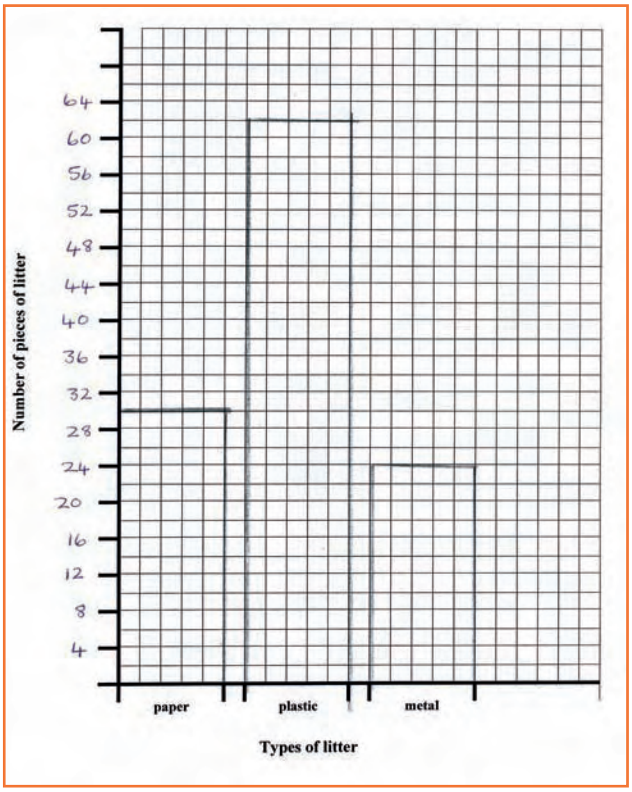
This is his tally chart:



Papre	HHH II
Plastic	HHH IIII
Metle	HHH II
Papreandplastic	HHH IIII

In groups, pupils then discussed their criteria and findings to merge their tally charts. David was persuaded that the litter in his ‘paper and plastic’ group should go into the ‘plastic’ group.

The tally charts of the groups were merged and a class pictogram of the litter was drawn up collaboratively. Each pupil was then asked to draw a bar chart of the pictogram. The teacher gave David and other pupils working at a similar level an outline of the axes on squared paper for the bar chart. The rest of the class was asked just to use squared paper with no pre-drawn axes. David drew the bar chart in the given format.



David's next steps:
Think about the axes. Work with Tia next time and try to draw the next bar chart using just squared paper.

The teacher questioned David as to what he had found out.

David:
The thing that most litter's made out of is plastic.

Teacher:
Why do you think that most of the litter is made of plastic?

David:
Because we eat more pop and crisps than other foods.

Teacher:
Should we be doing this?

David:
No. Pop and crisps are bad for you.

David identified the simple pattern, said what he had found out and gave an explanation for the class findings based on his everyday experiences.

Is any of the litter attracted to a magnet?

Classifying and identifying enquiry

Skills
C2; ED2, 4, 5.

Range
TSE3, 6; HTW2.

Work on recycling included testing litter to see if it was attracted by a magnet. David's table of results is shown below. The teacher explained to the class the terms 'magnetic' and 'non-magnetic' before David was given the table format.

litter	material	all magnetic?	some magnetic?	not magnetic?
niwspepr	pepr			✓
botls	plastoc			✓
pop cans	metl	✓		

Teacher:
What have you found out by doing this experiment?

David:
We can use a magnet to sort out metals from litter.

Teacher:
Could you use a magnet to pick out all the metals in litter.

David:
Yes.

David's next steps:
Find out if all metals are magnetic. You might like to look at the website 'Science is fun' or use a magnet to test more metals in the classroom.

David completed the table and said that he found out from his work that all metals are magnetic. The latter is more of an everyday explanation of the differences between materials than a scientific one.

Which is the best material for stopping biscuits becoming soggy?

Fair testing enquiry

Skills
C2; EP2, 4, 5, 6; ED 1, 2, 4, 5.

Range
TSE4.

David planned his method with support and recorded his investigation on the sheet below. He made an oral prediction that plastic would be the most waterproof because bottles are made from plastic and used for drinks. David used his everyday experience to make a prediction.

Which is the best material for stopping biscuits becoming soggy?

I decided to change

Materials

I decided to observe

a biscit in water

I kept things the same for a fair test

time	Omount of water

Results Table

I changed the type of wrapping	I observed what happened to the biscuit
thick Plastic	No change
Greese prwff papre	Wet around the ej.
Cling Film	Wet around the ej
thin plastic	Wet around the ej
Papre	Dry

I found out that this plastic was water prwff

David's next steps:
Next time we do an investigation, try to plan to measure results rather than just looking at them.

Note: The use of a simple writing frame does not reduce David's attainment.

David recognised with support the variables to change and measure and those to be kept the same. He made observations, which could have been measured using simple equipment, to compare the wrapping materials. He said what he had found out from the investigation but did not relate his findings to scientific knowledge and understanding.

Designing packaging for biscuits

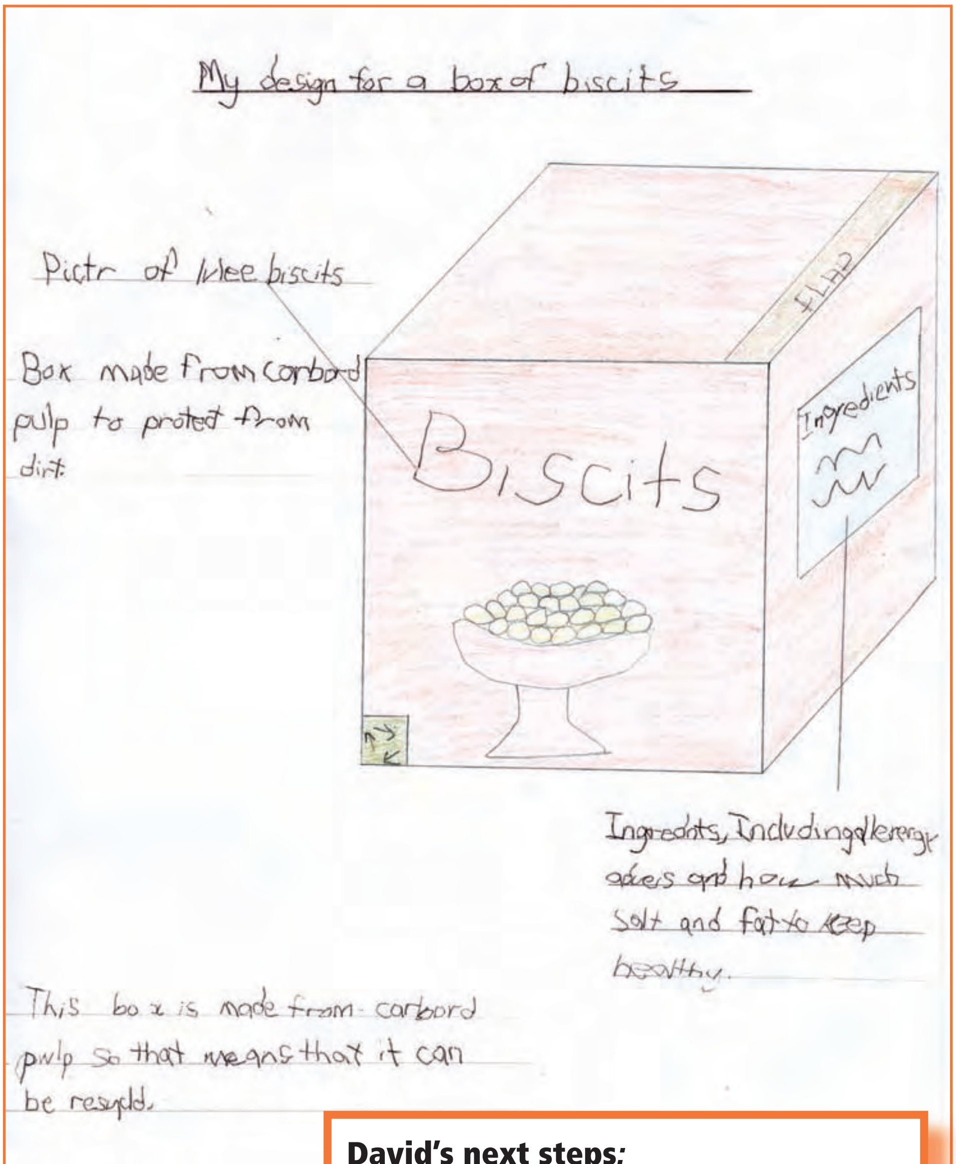
Making things enquiry

Skills
C2; EP1, 2; ED5; ER1, 6.

Range
TSE3, 4.

Following a series of presentations of their findings from the previous enquiry, each pupil was asked to design packaging for biscuits. They were tasked with drawing the packaging, labelling it to show the material(s) it was made of and giving reasons as to why they had chosen this/these material(s).

Pupils worked with their thinking partners to discuss success criteria. David and Fay agreed that they were: stopping the biscuits from becoming soggy, looking good and using a material that could be recycled. They then worked individually on the design.



David's next steps:
Talk to Fay and compare her design to yours. How is it different? How is it the same?

When questioned as to why he had used cardboard, David said that it was more important to recycle than to stop the biscuits becoming soggy. Also that biscuits were in boxes and these were made of cardboard. He found out from his investigation that plastic is the best material for biscuit packaging but prefers the recycling criterion. He linked his design (outcome) to success criteria and linked his learning to familiar situations, with support, such as his experience of biscuit packages and recycling.

Comparing two environments

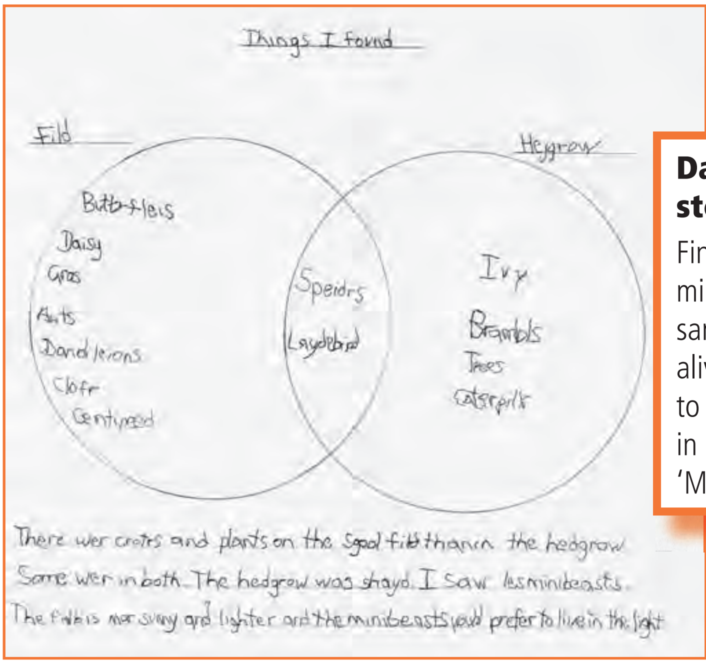
Pattern-seeking enquiry

Skills
C2; ED4, 5.

Range
IO4, 6.

The class carried out fieldwork to compare and contrast two local environments. They first studied the nature of the environment before looking at the organisms that were found in each one. Groups of pupils searched for organisms and tried to identify them, using simple keys.

David's group was given two plastic hoops and card on which to write the names of the organisms they had found. David transferred his findings to a Venn diagram.



David's next steps:
Find out if plants and minibeasts need the same things to stay alive. You might like to look at the book in the library called 'Minibeasts'.

David followed a simple series of instructions safely to gather his findings, displayed his findings in a given format as a Venn diagram, identified simple patterns, showed what he had found out and used everyday experiences rather than scientific knowledge and understanding to try to explain his findings.

Shadow puppets

Making things enquiry

Skills
C1; EP2, 6; ED4, 5; ER2, 4.

Range
HTW5.

As a transition project, working on a cross-curricular design and technology theme, the pupils were asked to make shadow puppets of an animal that could be found in one of the environments. David planned his design after suggesting and looking at one website on the internet, with his partner, for ideas and information. He made a puppet of a rabbit with some support. Although the hand puppet looked like a rabbit, when it was used as a shadow puppet some of the definition was lost.

David was asked to evaluate his puppet.

How did your puppet make a shadow?

The light hit it and couldn't get through. So it made a shadow.

Did the shadow look like your puppet?

Yes but it was Fuzzy.

How could you improve your puppet so that the shadow was clearer?

I could make the ears longer and the whiskas.

David's next steps:
Find out why shadows form. You could look at the textbook in your drawer.

David gave a simple explanation for shadow formation as a change in a physical phenomenon (i.e. how light travels), identified what worked and what didn't and started to think about how his puppet could be improved.

Summary and overall judgement

Levels 2, 3 and 4 were considered and Level 3 was judged to be the best fit.

Overall much of David's work is based upon everyday experiences although he is starting to develop his scientific knowledge and understanding.

Planning

David's work shows that when **planning** an enquiry, he is able to *suggest where to find evidence, information and ideas* (a characteristic of Level 3). He said to his partner that they could look on the internet for ideas about how to make 'Shadow puppets', although he only used one website and so he didn't *find and use a variety of evidence, information and ideas* (a feature of Level 4). In the same enquiry, and when investigating 'Which is the best material for stopping biscuits becoming soggy?', he *planned, with support, the method to be used* (a characteristic of Level 3). In the latter enquiry he *used his everyday experiences to make a simple prediction* (a feature of Level 3). Also in the process of designing 'Shadow puppets' and biscuit packaging, David used his knowledge and understanding to think about 'What would happen if I used . . . ?'. Therefore David was predicting as he worked out his designs. David *recognised with support the variables to change and measure and those to be kept the same*, which is a characteristic of Level 4, in the fair test enquiry 'Which is the best material for stopping biscuits becoming soggy?'. He *agreed on some basic success criteria* (a feature of Level 3) for 'Designing packaging for biscuits'.

Developing

When **developing** an enquiry, David's work on 'Comparing two environments' shows that he can *follow a simple series of instructions safely to gather his findings* (a characteristic of Level 3). In 'Which is the best material for stopping biscuits becoming soggy?' he *made observations that could be measured using simple equipment* (a feature of Level 3). In the 'Litter survey' enquiry he initially *made enough observations to group the litter* and *made a simple record of his findings by constructing a tally chart* (both characteristics of Level 2). However, he went on to *display his findings in a given format as a bar chart* and demonstrated that he is *beginning to identify simple patterns* (both features of Level 3) in both this enquiry and in 'Comparing two environments'. David *gave* *an explanation based upon everyday experiences, for his findings* (a characteristic of Level 3) in 'Comparing two environments'. He gave *a simple explanation for the differences between materials* (a feature of Level 3) when he looked at litter that is attracted by a magnet and *a simple explanation for changes in a physical phenomenon* (a characteristic of Level 3) in the 'Shadow puppets' enquiry.

Reflecting

David consistently *said what he had found out from his work* (a feature of Level 3) in his enquiries. David's work in 'Designing packaging for biscuits' shows that when **reflecting** on an enquiry he can *link outcomes to success criteria* (a characteristic of Level 3). He *identified what worked and what didn't* and showed that he is *beginning to think how his method could be improved* (both features of Level 3) in the evaluation of his 'Shadow puppet'. David *links the learning, with support, to familiar situations* (a characteristic of Level 3) when he designed his biscuit wrapping.

Key Stage 2

Mia

Level 4

Mia is an 11-year-old learner in Key Stage 2.

Her teacher knows much more about Mia's performance than can be included here. However, this profile has been selected to illustrate characteristic features of Mia's work across a range of activities. Each example is accompanied by a brief commentary to provide a context and indicate particular qualities in the work.

Mia's teacher judges that her performance in science is best described as Level 4.

Planet presentation

Making things enquiry

Skills
C1, 2; EP1; ER3.

Range
TSE2.

As part of a theme on Space, pupils were asked to choose and research a planet in the solar system and present their findings to the class. The nature of the presentation was left to individual choice. Mia chose Saturn and used the internet and the school library to collect information.

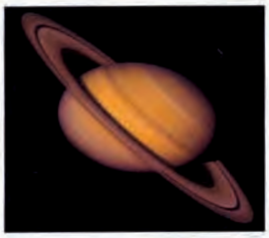
Teacher:
What sort of presentation are you going to do?

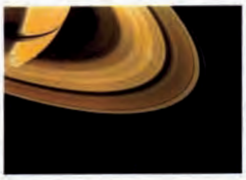
Mia:
A 'fact sheet' for the class to read.

Teacher:
How will you know if your leaflet is good?

Mia:
I want it to be interesting for children to read so it needs some pictures.

SATURN





Name: Saturn is named after the Roman god of agriculture

Size: 74,898 km in diameter

Distance from the Sun (km): 1,429,400,000

Temperature: -185 degrees centigrade

Moons: 33

Iapetus, one of Saturn's moons

Time taken to orbit the Sun: 29 years

Length of day: 10.2 hours

Atmosphere: Rocky core and gas (hydrogen and helium)

Saturn's rings: Saturn has lots of rings made out of ice and rock.

How I found this out: from a leaflet called The Solar System and the pictures are from the NASA website.

Success: ***I liked finding out about this on the internet. I think my fact page is good and interesting which is what I wanted it to be. I could find some more pictures of the moons to make it better.***

Mia's next steps:
Use your dictionary to look up words that you don't understand. Write what they mean on your 'fact sheet'.

All images © NASA

On questioning, Mia had problems understanding some of what she had written. For example, she did not understand the term 'core' or 'agriculture'. Mia found and used a variety of evidence, information and ideas, although this was limited to a leaflet and one website. She organised and communicated her findings using relevant scientific language. Mia decided upon some basic success criteria, referred to these when reflecting upon success and made a simple suggestion as to how she could have improved her work.

The rocket launch

Exploring enquiry

Skills
C2; EP2; ED5.

Range
HTW2, 3.

Pupils watched a video clip of a rocket launch. In pairs they discussed the variables that might affect the launch. Individually they wrote about their fictitious rocket launch.

The Rocket Launch

The launch was successful. The rocket travelled 150m up and about 100m in distance. It was launched by an electrical current being sent to ~~an~~ a small explotion allowing the rocket to defy gravity and travel 150m. When the rocket got perpeld in the air it swayed from side to side because the rocket had spoilers. The wind hit them wich made it move one way and the way the rocket was disigned countered the wind. The speed got less as the rocket went up because gravity got stronger and pulled it down.

Mia's next steps:
Find out more about the forces involved in a rocket launch. You might like to look at the book 'Forces' in the science corner.

Mia used scientific knowledge and understanding to predict the outcome of her launch although her description contains confused scientific ideas. She used relevant scientific language in her description and explanation. She omitted to write about a number of variables, such as weather conditions or the materials the rocket could be made from. Had she discussed the materials, the evidence would also touch upon The sustainable Earth (TSE4) section of the Range.

Making rockets

Fair testing enquiry

Skills
C2, 3; EP4, 5, 7;
ED1, 2, 3, 4, 5;
ER2, 4.

Range
HTW2, 3.

Following a teacher-led lesson on forces, the class investigated their own rocket launch. They made rockets out of paper and put them on top of empty plastic bottles, which they squeezed for propulsion. Each group selected their own variable to change (independent variable). Mia's group changed the size of the bottle.

Teacher:
What are you going to measure?

Mia:
How far the rocket travels longways.

Teacher:
What are you going to change?

Mia:
How big the bottles are

Teacher:
So how is the size of the bottles different?

Mia:
There's one big one, a small one and one in the middle.

Teacher:
Can you measure the size?

Mia:
We can look at the number – it's capacity I think.

Teacher:
What are you going to keep the same?

Mia:
The shape of the bottles.

Teacher:
Will you try and keep anything else the same?

Mia:
We need to squeeze the bottles with the same pressure and stay out of the way when they launch!

Mia recognised, with support, the variables to change and measure and those to be kept the same by answering the teacher's questions.

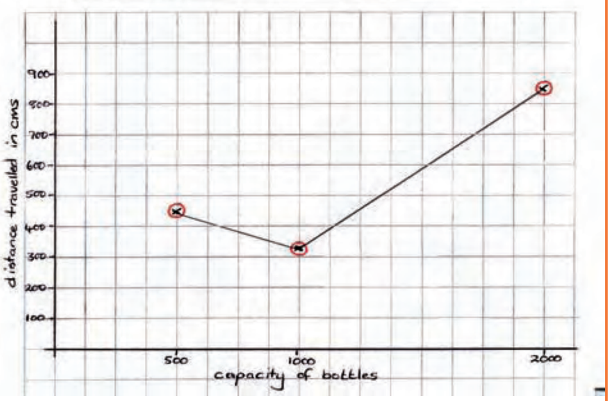
Making Rockets

What we did

On Thursday we went out onto the yard to launch paper rockets. We used paper rockets, plastic tubes and 500ml, 1000ml and 2000ml bottles. We put the end of the tube in the bottle put the rocket on top of the tube. We squeezed the bottle and the rocket prepeled into the air then we measured it the distance of the rocket flight.

Results

Capacity of bottle	Measure 1	Measure 2	Measure 3	Average distance in cm
500	458	455	390	434.33333
1000	325	324	350	333
2000	842	755	935	844



What I found out

The trend of the graph is generally low to high. So if I exstapolate the line will get higher. The 2000ml bottle had more air in it. When we squeezed the bottles the air can out and pushed the rockets. It made a force. The big bottle made a big force as there was more air. The 100ml bottle didn't get the results I expected because the air came out of the top in stead of going into the tube and firing the rocket.

What I could do to improve my results

I need to do the 1000ml rocket again using a bottle with a thinner end so the tube fits in propaerly.

Mia's next steps:

Think about the forces on the rocket that make it move. You might like to talk to George about his ideas to help you.

Mia used standard equipment to measure and displayed her findings in a table she drew up herself and a simple line graph, with the axes and scales given by the teacher. She repeated the test for each bottle twice and could therefore be starting to consider reliability. However, the repeats might have been a group decision and further questioning is needed to clarify Mia's understanding. She identified that one result didn't fit the pattern and tried to explain it. In addition she suggested how to improve her method by repeating this test with a slightly differently shaped bottle. Mia used some scientific knowledge and understanding to explain her findings and draw conclusions.

Fact or opinion?

Classifying and identifying enquiry

Skills
C2; ED4, 6; ER5.

Range
TSE6.

Within the theme of Planet Earth, learners were asked to read a range of newspaper reports about environmental change and its effects. They were asked to choose one article and highlight 'facts' in one colour and opinions in another.

Brits red-faced on green issues

MORE than 80 per cent of Brits think that climate change is impacting on the UK - but 40 per cent of us are doing nothing to reduce our energy use, says research.

The Green Barometer - the first national survey of public opinion on green issues - is launched today by the Energy Saving Trust and will track what we think about the environment.

The poll shows that few people are actually making the necessary lifestyle changes, with 40 per cent doing nothing at all.

And while 32 per cent of Brits are prepared to choose a holiday destination that does not require flying in a bid to reduce carbon emissions, only four per cent have actually done so.

The report shows that when it comes to being green, strong measures are less popular.

The Green Barometer also shows a need for help - 80 per cent of Brits want the Government to let them know what they can do to save energy.

Chief Executive of the Energy Saving Trust Philip Sellwood said: "There's lots of talk by politicians, industry and the media about environmental issues. "

"There are simple actions we can all do in the home to help reduce the amount of energy we use."

If everyone in the UK...

Turned off lights when leaving an empty room, it would save 770,000 tonnes of CO_2 each year - enough electricity to power over half-a-million homes for a year.

Turned their TVs off, rather than leaving them on standby, it would save over 300,000 tonnes of CO_2 per year.

Walked for one short journey each week rather than taking the car, it would save around one million tonnes of CO_2 annually.

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April 02, 2007

= opinion
= fact

Mia's next steps:

Find out what 'bias' means using your dictionary. Read the article again and try to find any possible bias.

Mia has made decisions that show she is beginning to distinguish between ‘facts’ and opinions in the article. Some of her decisions needed to be questioned.

Teacher:
How did you decide which are ‘facts’ and which are opinions?

Mia:
It’s the words they use. ‘Facts’ have lots of numbers but opinions use words like ‘think‘ and or ‘choose‘.

Mia’s next steps:
Look at another article and try to do the same thing. Do you still think your reasons are good ones? Write some success criteria for deciding between ‘facts’ and opinions.

Does the mixture of lava affect the eruption of a volcano?

Fair testing enquiry

Skills
C2; EP2, 4, 5, 6; ED1, 2, 4, 5; ER4, 6.

Range
TSE3, 5.

Further within the Planet Earth theme, pupils studied St Lucia with a focus on geography and science. The teacher discussed how St Lucia had been formed from volcanic activity. The pupils were shown how to make a volcano using vinegar and bicarbonate of soda. In groups they discussed and carried out the enquiry. They produced individual write-ups.

Does the mixture of lava affect the eruption of a volcanoe?

Prediction

Yes I think it does. If we use more vinegar the reaction will be bigger and so the eruption will be bigger too. More people will be Killed.

Things I could change?

You can change the amount of sand.
You can change the amount of bicarbonate of soda.
You can change the amount of vinegar.

Things I could keep the same.

How much sand you use - so the size of the volcanoe.
How much bicarb you use.
How much vinegar you use.

We are only going to change the vinegar and keep the sand, bicarb of sode and Food colouring the same.

Method

- We will get a tray.
- Then collect the sand.
- Mould the sand into a volcanoe shape inside the tray.
- Get some bicarb.

Mia's next steps:
Think about how you could have measured the vinegar and sodium bicarbonate and the distance that the lava travelled to make the enquiry more scientific.

Note: The use of a simple writing frame does not reduce Mia's attainment.

Mia used scientific knowledge and skills to plan a fair test enquiry and predict outcomes. She identified key variables and distinguished between independent and dependent variables (without actually naming them) and those that she would keep the same. However she used the non-standard measure of a teaspoonful for the bicarbonate of soda, which limits possible attainment. She followed the planned method and organised and communicated her findings using relevant scientific language. Mia displayed her observations clearly in a table to describe her findings and identified the main pattern in her results. In the process she made links to what she thought would actually happen in a real volcanic eruption. Her conclusion describes the relationship between the two continuous variables of volume of vinegar and the speed of flow. It would have been better had Mia measured the distance the 'lava' travelled so that she could have drawn a line graph from which to work out the continuous relationship between the amount of vinegar and the distance travelled. Her reflection describes amending her method to give more spectacular results rather than improve it.

How can a guitar make a sound?

Exploring enquiry

Skills
C2; ED2, 4, 5, 7; ER5.

Range
HTW4.

In the summer term, Mia's class looked at a variety of musical instruments and the science behind how they work. Each group was asked to select an instrument to experiment with. Mia's group chose a guitar. The group then discussed 'How can a guitar make a sound?' and individually wrote their answers.

> My guitar can make a sound in different ways. By knocking or tapping it makes a sound. This is because the tap causes a vibration. The hollow body makes the sound louder. If you pluck the strings it makes a sound. On the thicker strings you can see the string vibrating. The thick strings make loud notes.

Mia was asked how you could hear sounds from the guitar.

> When the string vibrates it makes a sound wave which moves from the guitar to your ear. Your ear hears it.

After using traffic lights for learners to indicate their level of understanding, the teacher decided that further work was needed. She paired up green pupils with amber pupils (Mia was amber by self-assessment) and asked Mia's pair to find out how a guitar can make sounds of different volume and pitch. They played the guitar again. After discussion Mia wrote:

> To make a louder sound you pluck the string harder. when you pluck the strings the thicker strings make a deep sound and the thin strings make a higher sound.

Mia's next steps:

Talk to Ryan about what you have found out and then try to complete the sentence:

The thicker the string the ……….. the sound.

Mia evidenced that she is starting to use some scientific knowledge to explain changes to sound; a physical phenomenon.

Mia was asked to describe how she had learned about sound and which way worked the best. She used a pre-drawn metacognitive caterpillar to show this.

Finding out about sound - how I learnt

The way I learned the best is by talking to Jo. The second time was better than the first because I knew what to talk about better.

Mia described how she learned and identified the way that worked the best.

Teacher:
What do you mean by ‘knowing what to talk about better’?

Mia:
I knew the questions to ask and I had thought about how to say them because I listened to Jo’s answers.

This dialogue evidenced that Mia is beginning to listen to others’ ideas and so has made informed decisions.

As part of the school’s transition arrangements, Mia’s class finished Year 6 on this topic. They continued to investigate sound within the context of energy changes at the start of Year 7. The ‘next steps’ statements and the ‘how I learned’ sections were very useful for teachers in the secondary schools who could use these to plan the first few weeks’ work.

Summary and overall judgement

Levels 3, 4 and 5 were considered and Level 4 was judged to be the best fit.

In general, Mia has a fairly good grasp of scientific language although she occasionally uses incorrect scientific terminology. For example at the start of Year 6 she was still confusing ‘melting’ with ‘dissolving’. However, given further teaching and enquiry work where she had to distinguish between the two processes this is no longer an issue. Her thinking is becoming more scientific and builds on her everyday experiences.

Planning

Mia’s profile shows that when **planning** an enquiry she can *find and use a variety of evidence, information and ideas* (a characteristic of Level 4) as evidenced in ‘Planet presentation’. The relevance of some of the information she used is questionable and therefore she did not *find and use relevant evidence, information and ideas* (a feature of Level 5). If Mia’s success criteria had been more wide-ranging and science specific she could well have been self-directed towards more relevant information. She *uses scientific knowledge and skills to plan her enquiries and predict outcomes* (a characteristic of Level 4) as shown in her write-up of ‘Does the mixture of lava affect the eruption of a volcano?’. This is a fair test enquiry and by *identifying key variables and distinguishing between independent and dependent variables* (without actually naming them) *and those that she would keep the same* she showed an aspect of Level 5. However, in ‘Making rockets’ she *recognised, with support, the variables to change and measure and those to be kept the same* (a feature of Level 4) when she was led by the teacher’s questioning. Mia *uses scientific knowledge and skills to predict outcomes* (a characteristic of Level 4) in ‘The rocket launch’ although her description has some confused scientific ideas. In ‘Planet presentation’ she *decided upon some basic success criteria* (a feature of Level 4) and although these are very simple, they were her own decisions.

Developing

When **developing** an enquiry, Mia's work on 'Does the mixture of lava affect the eruption of a volcano?' is evidence that she can *follow the planned method* (a characteristic of Level 4). She *makes qualitative observations* (a feature of Level 4) in the same enquiry but would have improved her investigation by *using standard equipment to measure within a given range using S.I. units* (a characteristic of Level 4) as she did in the 'Making rockets' enquiry.

Across the profile she demonstrates that she can *organise and communicate her findings using relevant scientific language* (a feature of Level 4). Mia *displays her findings in tables* (a characteristic of Level 4) in both the 'Does the mixture of lava affect the eruption of a volcano?' and 'Making rockets' enquiries, with evidence that she can draw a *simple line graph when the axes and scales are given* (a feature of Level 4) in the latter. In the same two enquiries Mia also *identifies patterns* (a characteristic of Level 4) in her findings. From collaborative work, especially in the enquiry 'How can a guitar make a sound?', Mia shows that she is *beginning to make informed decisions* (a feature of Level 4). However, her teacher knows that Mia is being led by others in making decisions and further teaching is needed to increase Mia's confidence in scientific knowledge so that she uses her own ideas in tandem with those of others. Mia is *beginning to distinguish between 'facts' and opinions* (a feature of Level 3) and is started on the path to recognise bias in the 'Fact or opinion?' enquiry. Mia *uses some scientific knowledge and understanding to explain her findings* (a characteristic of Level 4) in 'Making rockets'. She *uses some scientific knowledge and understanding to explain changes to physical phenomena* (a feature of Level 4) in 'How can a guitar make a sound?', however this is not a strength of Mia's work and needs to be built upon by further teaching of scientific knowledge. She is *beginning to draw conclusions* (a characteristic of Level 4) in some of these enquiries. Her conclusion in 'Does the mixture of lava affect the eruption of a volcano?' shows an aspect of Level 5 as she *describes the relationship between the two continuous variables* of amount of vinegar and the speed of flow, although hesitatingly. However, she would need to have measured the distance travelled rather than just observing the speed of flow in order to draw a line graph from which to work out the relationship to evidence this level description.

Reflecting

When **reflecting** on an enquiry, as in 'Planet presentation', Mia's profile shows she is linking *outcomes to success criteria* (a characteristic of Level 3). In the same enquiry and in 'Making rockets' *she says how to improve the method* (a feature of Level 4) and although she attempts this in 'Does the mixture of lava affect the eruption of a volcano?' her suggested amendments would just give more spectacular results rather than improving the method. Mia demonstrates that she can *describe how she has learned and identify the way that worked the best* (a characteristic of Level 4) when reflecting on her learning in 'How can a guitar make a sound?'. She *links the learning* of her findings of the model volcano *to similar situations* (a feature of Level 4), i.e. what would happen in a real-life volcanic eruption in the enquiry 'Does the mixture of lava affect the eruption of a volcano?'.

Key Stage 2

Tom

Level 5

Tom is an 11-year-old learner in Key Stage 2.

His teacher knows much more about Tom's performance than can be included here. However, this profile has been selected to illustrate characteristic features of Tom's work across a range of activities. Each example is accompanied by a brief commentary to provide a context and indicate particular qualities in the work.

Tom's teacher judges that his performance in science is best described as Level 5.

Map of the solar system

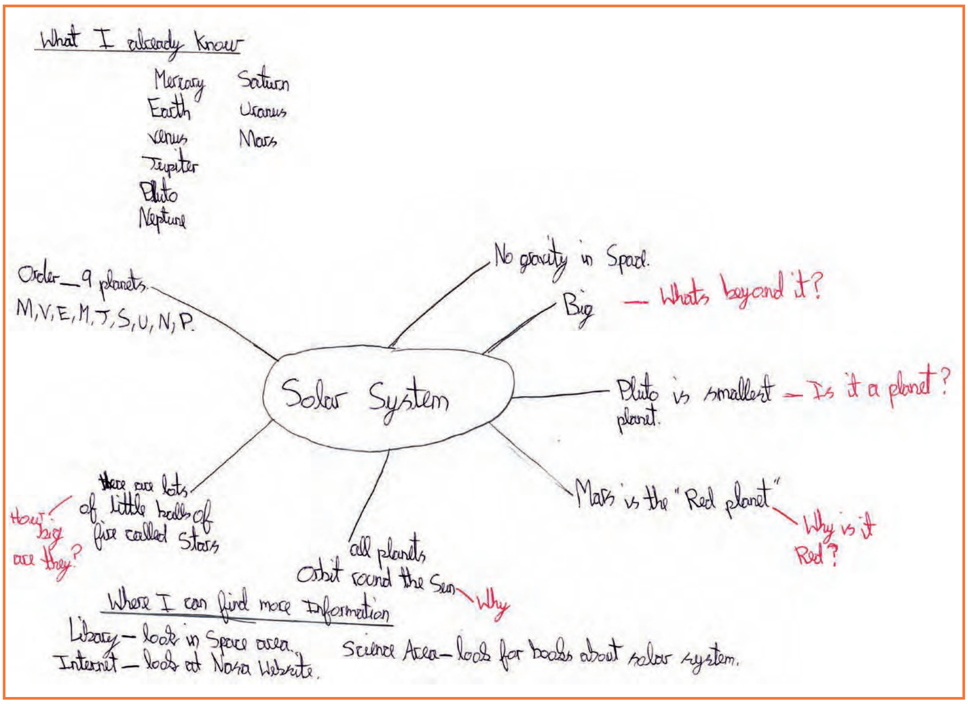
Making things enquiry

Skills
C1, 2; EP3; ED4, 6, 7.

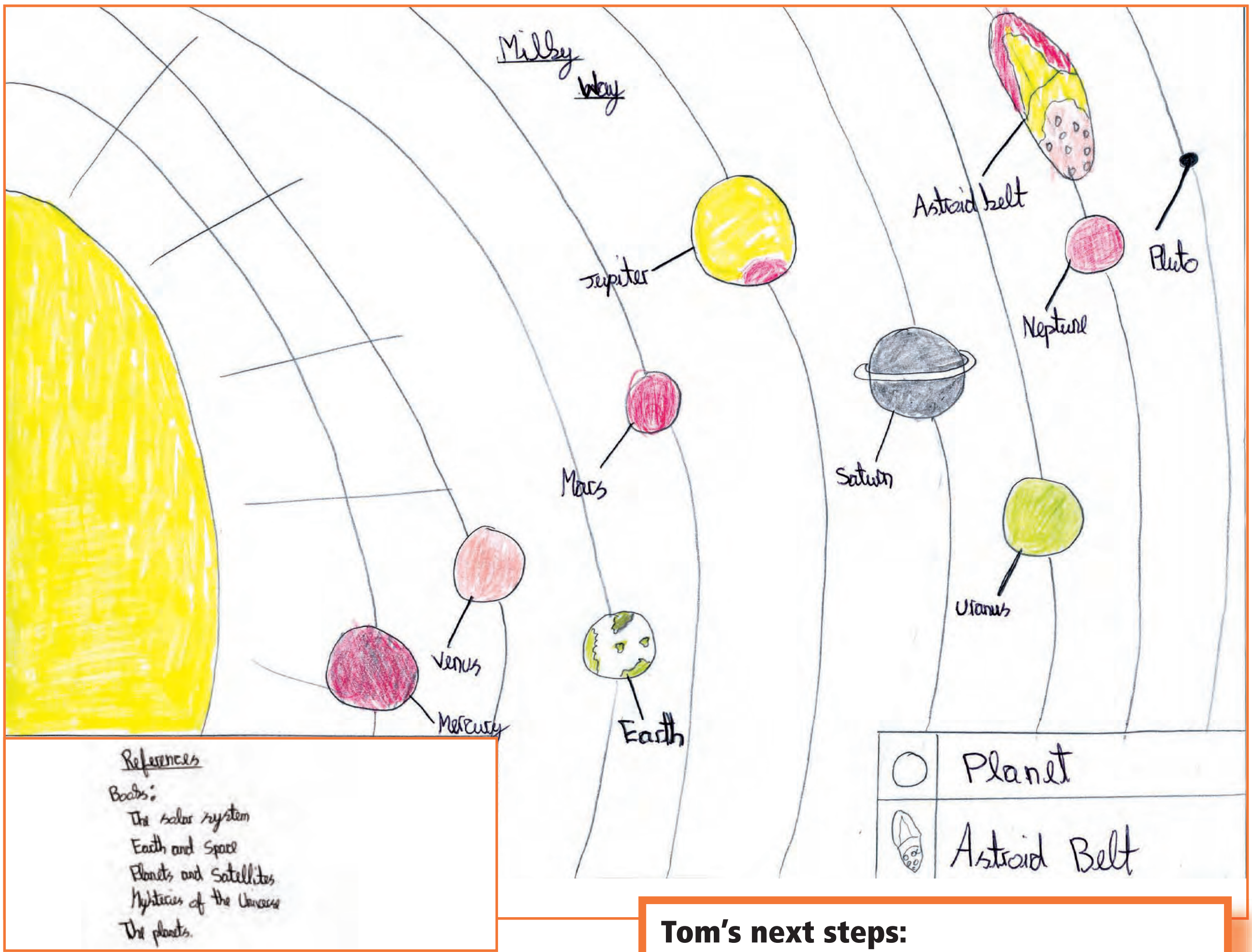
Range
TSE2.

The class has been working within the topic 'Space Missions', linking ideas for space flight with survival.

Pupils were asked to produce a map of the solar system. They independently thought about and made a record of what they already knew, what they needed to find out and where to find it. Tom drew a concept map.



Once he had found relevant information, considered the different interpretations of the solar system and made decisions as to his own map, he drew the map below. Tom also wrote a list of the references he had used.



Tom's next steps:

Do you think any of your sources may be biased? Why do you think this? Add some notes to your references to show your ideas.

Tom found and used relevant information, he organised and communicated his information integrating different forms into his map and produced a simple map of the solar system.

Questioning a solar system image

Exploring enquiry

Skills
C1, 2; EP3, 5; ED2, 3, 4, 5, 6, 7; ER3, 6.

Range
TSE2.

The class were given a ‘source square’ to interrogate in groups, each with different images of the solar system. Tom chaired his group and organised their tasks.

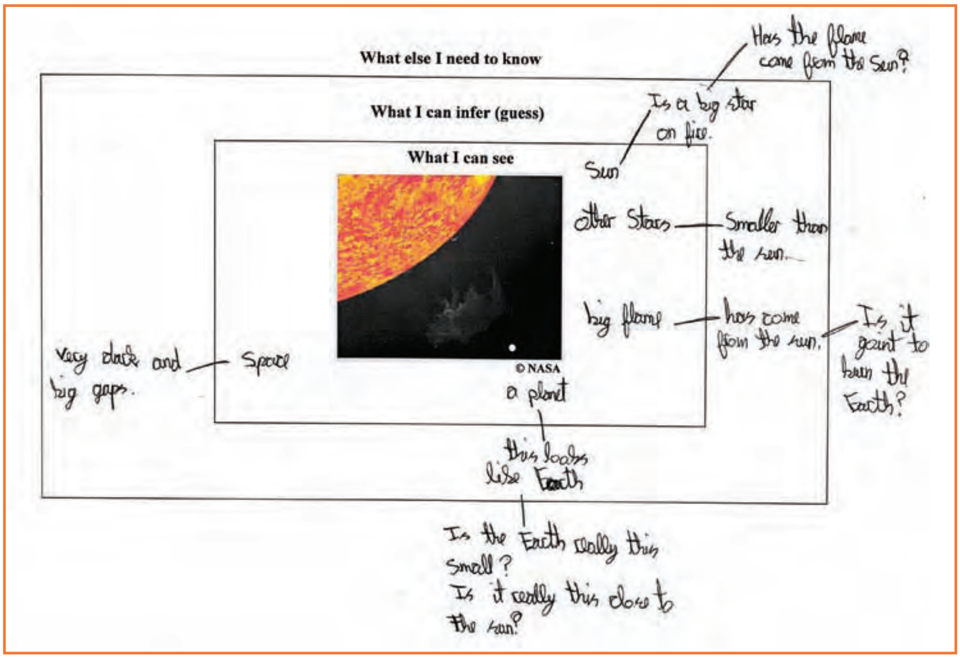


Image © NASA

The group observed the image carefully and used scientific knowledge and understanding to infer. However, the discussion became quite heated when they were deciding what else they needed to know. The teacher listened to the group’s deliberations. Tom asked if the group thought the scale of the photo was correct. The group was worried that the solar plume was about to burn Earth!

Tom:
Can I look at the NASA website to find out more? I think I should check this with other websites too.

Teacher:
Why do you want to check?

Tom:
It’s because the photo is from NASA but I don’t think it’s right – if the Sun was that close it would be so hot that there would be no life on Earth.

Tom wanted to check the reliability of the information. He discovered that the image was not factual but a composite image used for discussion of 'What would happen if . . . ?'. In Tom's opinion NASA is the most famous and knowledgeable source of information about space, although he now recognises that it's not just the source of information that is important but thinking about whether it could be 'factual' or not. Tom wrote his own next steps.

Tom's next steps: (written himself)
Check information and don't always believe it just because it comes from somewhere you think is right.

When Tom reported back to the class as to his group's findings, he used detailed and at times abstract scientific knowledge and understanding. He gave reasons for questioning the image's authenticity, methods he used to check reliability and made links with other learning including Sun spots and solar plumes.

Mission Possible?

Using and applying models enquiry

Skills
C2; ED4, 5, 7; ER2, 3.

Range
IO2, TSE2, HTW3.

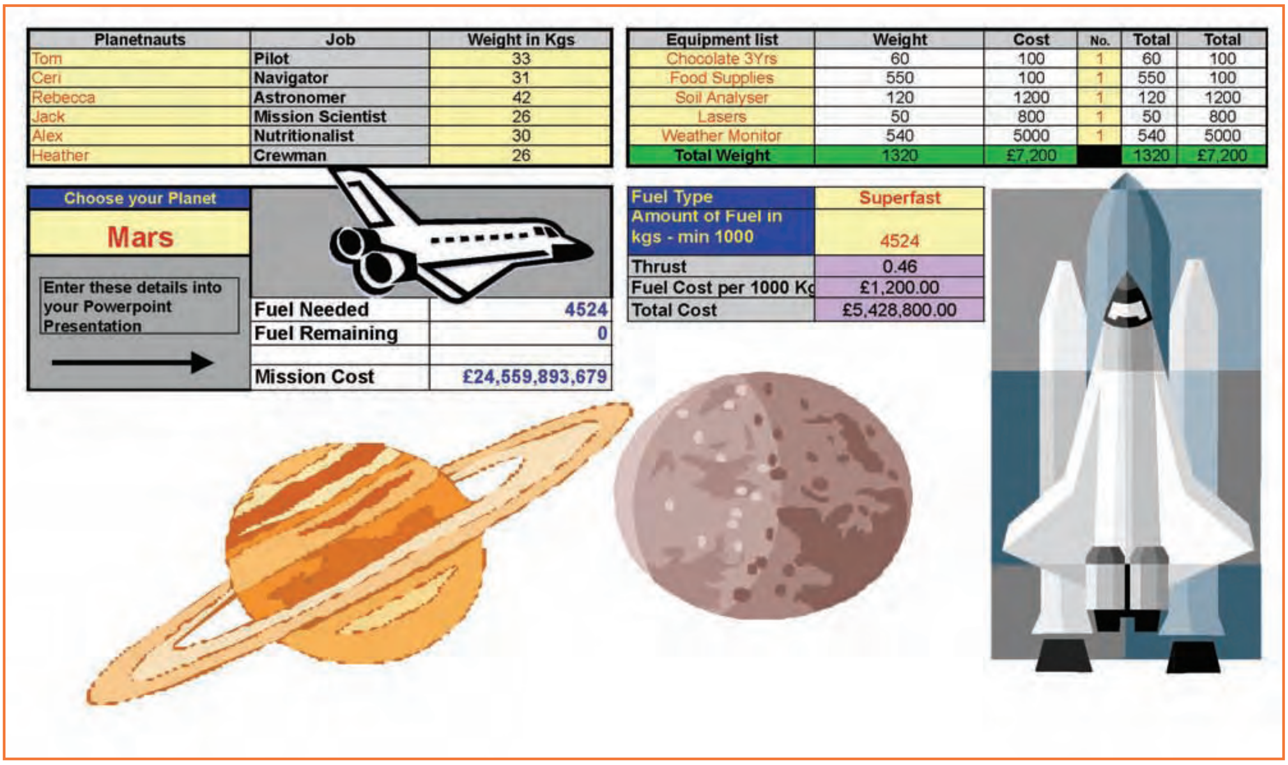
For 'Mission Possible?' the class were given the brief to plan a space journey to Mars using a computer model. They made decisions and manipulated variables to try and reduce the mission cost whilst ensuring its success – their success criteria.


MISSION POSSIBLE??

DEAR PLANETNAUTS,
YOUR MISSION IS THIS..
Your brief is to find out if indeed there is.....
...LIFE ON MARS......

You must plan your space journey across our solar system....

BEFORE EMBARKING ON THIS MISSION....
1.Discuss the equipment to find out if life exists...
2. Discuss the type of fuel to get lift off to get you there...
3. Discuss the number of crew members on board ship and their jobs....
.....GOOD LUCK....
(THIS MESSAGE WILL NOT SELF DESTRUCT IN 5 SECONDS)



Planetnauts	Job	Weight in Kgs
Tom	Pilot	33
Ceri	Navigator	31
Rebecca	Astronomer	42
Jack	Mission Scientist	26
Alex	Nutritionalist	30
Heather	Crewman	26

Equipment list	Weight	Cost	No.	Total	Total
Chocolate 3Yrs	60	100	1	60	100
Food Supplies	550	100	1	550	100
Soil Analyser	120	1200	1	120	1200
Lasers	50	800	1	50	800
Weather Monitor	540	5000	1	540	5000
Total Weight	1320	£7,200		1320	£7,200

Choose your Planet	
Mars	
Enter these details into your Powerpoint Presentation	
Fuel Needed	4524
Fuel Remaining	0
Mission Cost	£24,559,893,679

Fuel Type	Superfast
Amount of Fuel in kgs - min 1000	4524
Thrust	0.46
Fuel Cost per 1000 Kg	£1,200.00
Total Cost	£5,428,800.00

Note: With kind thanks to Stuart Ball, Microsoft Corporation. Please see CD for active spreadsheet.

In the group's discussion, overheard by the teacher, Tom used scientific knowledge and understanding of forces when he considered the thrust required for take-off and he compared this to the cost for each fuel. He also recognised that the rocket needed to use up all the fuel before landing, for safety. He considered others' views to make his decisions. As the variables were manipulated, Tom regularly checked progress. Once the model was complete, each pupil reflected on their success and described the reasoning for decisions. Tom explained independently why his group changed the pay-load of the rocket; the choice of fuel and the choice of personnel.

Mission Possible??

My group's trip to Mars was successful because our price was very low compared with the other groups and we managed to get there and back. The price was very low because we took out the Moon Buggy and the telescope, because they were the heaviest pieces of equipment and we decided we didn't need them. So less force would be needed for take-off and so less fuel. We also took some of the lightest equipment like lasers and a three year supply of chocolate because then it wouldn't take so much fuel to get the rocket off the ground. We needed the lasers in case there was enemy life on Mars and we needed the chocolate as a source of carbohydrates as well as the food supplies.

We used fuel called Superfast because it had the highest amount of thrust. Although Superfast was the highest priced product it would produce more thrust than the other fuels and so we would get there quicker. Also we had reduced the mass of the rocket so it would use less fuel. If we had used Willthisdo fuel, it is the lowest priced fuel, but it has the lowest amount of thrust so we would end up taking so much fuel that the price would have been much more. Also we might not have had room for anything else.

We weighed ourselves without our shoes on because if we are lighter it won't take as much thrust to put the rocket in the air. We were going not to take the nutritionist but we decided to take her with us after all because we thought it was important to take someone who could tell us how to eat a healthy and varied diet. We took the mission scientist so she can explore Mars and check for signs of life. We took the crewman because who else was going to do the cleaning? We took an astronomer because he could study the stars and tell us where we are. We took a navigator to tell us what was coming ahead.

Tom's next steps:

Find out how an astronomer and a navigator might work together. You may like to try the book 'Deepest Space' in the library.

Moon Crash Landing 2020

Exploring enquiry

Skills
C2; EP2, 7; ED5, 7; ER5, 6.

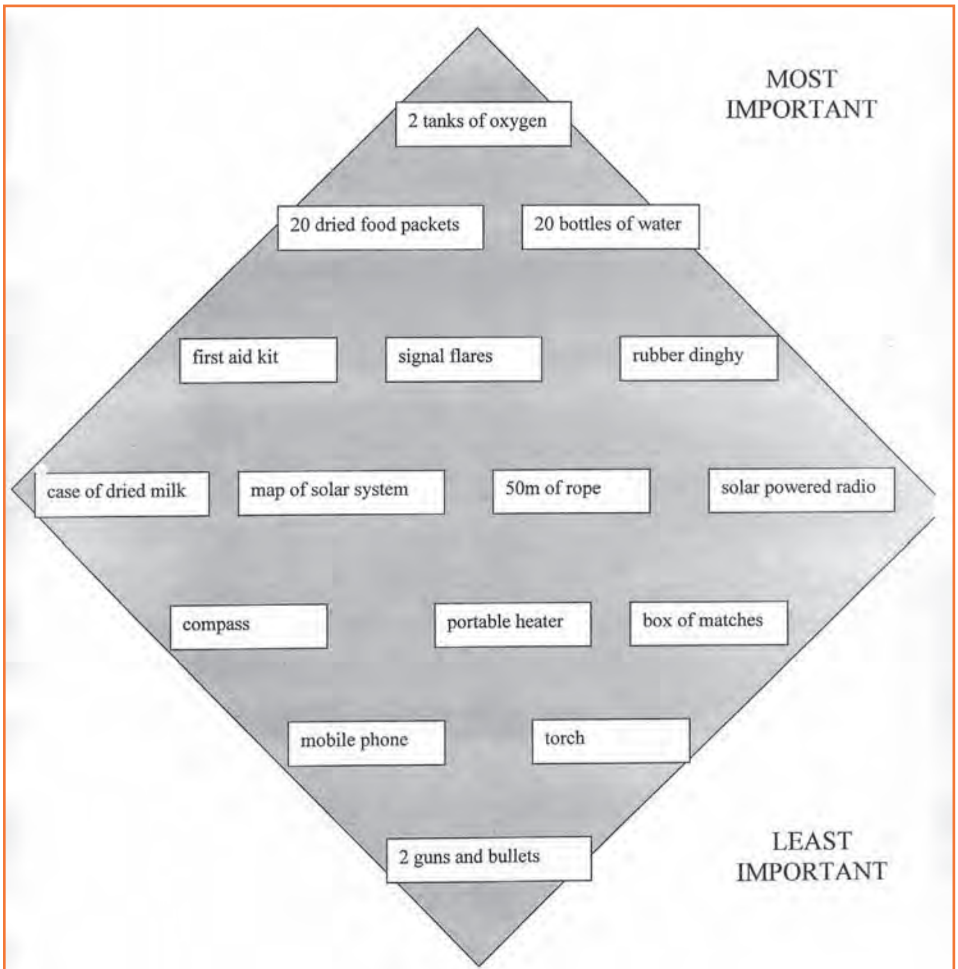
Range
IO2, TSE2, HTW2, 3.

The problem of survival as astronauts in an uninhabitable place was the focus of this activity. Each group was given items typed on card to prioritise. Tom's group prioritised using diamond ranking and then answered questions from the class as to their decisions.

Moon Crash Landing 2020

You have crash landed on the Moon. There is a space station on the Moon about 10 miles away from where you have landed. Look at the list of things you have with you. Decide in your group which things are the most important to take with you.

Hint: A diamond may help you!



Tom's next steps:
Think about what else you might need for survival on the Moon, especially remembering gravity.

Bethan:
Why did you decide that the oxygen was the most important thing to keep?

Tom:
Without oxygen we would die. We need it to breath and the Moon has no oxygen. We also need food and that's at the top too.

Rebecca:
Why did you think the dinghy was important?

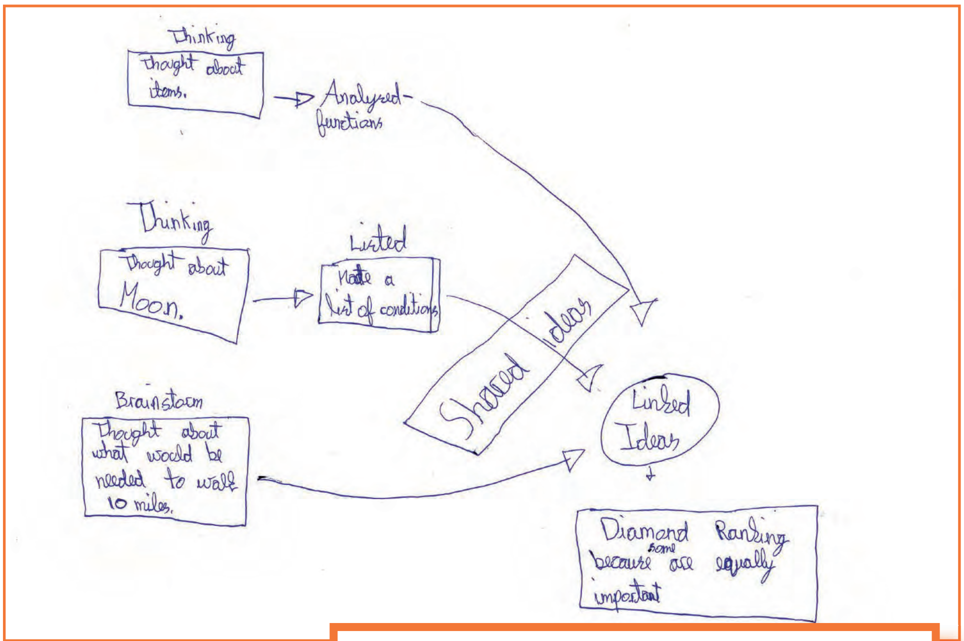
Tom:
We could put the other heavy things on it and pull them like a sledge. This would make travelling much easier and we would use less energy so would need less food.

Hari:
Why did you throw away the gun?

Tom:
There's nothing to shoot on the Moon!

Tom used scientific knowledge and understanding to justify his group's decisions (findings). In order to make each of these decisions, Tom would have had to think 'What would happen if . . . ?' therefore his decisions are based on predictions. He linked his learning to familiar but dissimilar situations by suggesting that using the dinghy as a transport mechanism would reduce the energy expended and therefore require less food.

The class was asked to review and evaluate the thinking/learning strategies they had used in this activity.



Tom's next steps:
Think about the word 'analyse'. What does it mean? Look it up in the dictionary. Can you now add this to your thinking diagram

Tom clearly identified the thinking/learning strategies he has used.

How can you make a model of a lighthouse?

Using and applying models enquiry

Skills
C2; EP1, 2; ED1, 5; ER1, 3, 4, 6.

Range
HTW1, 5.

Having been taught circuit symbols and reminded of the functions of circuit components, the class had been given opportunities to investigate circuits within the theme of Electricity. They were then asked to design and build a lighthouse, selecting their own equipment and bringing other materials from home.

Tom planned his enquiry by thinking about what was needed for success. He listed the following:

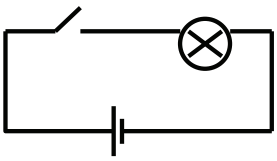
- working light
- turn light on and off
- high from ground.

He justified these to his teacher by referring to his knowledge of a real lighthouse. For example, 'The lighthouse needs to be high from the ground so that the light can travel further with nothing in its way. This means that more ships will be able to see the light from further away.'

He then built several versions of circuits with differently constructed switches until he was happy that the circuit would work once placed in his structure.

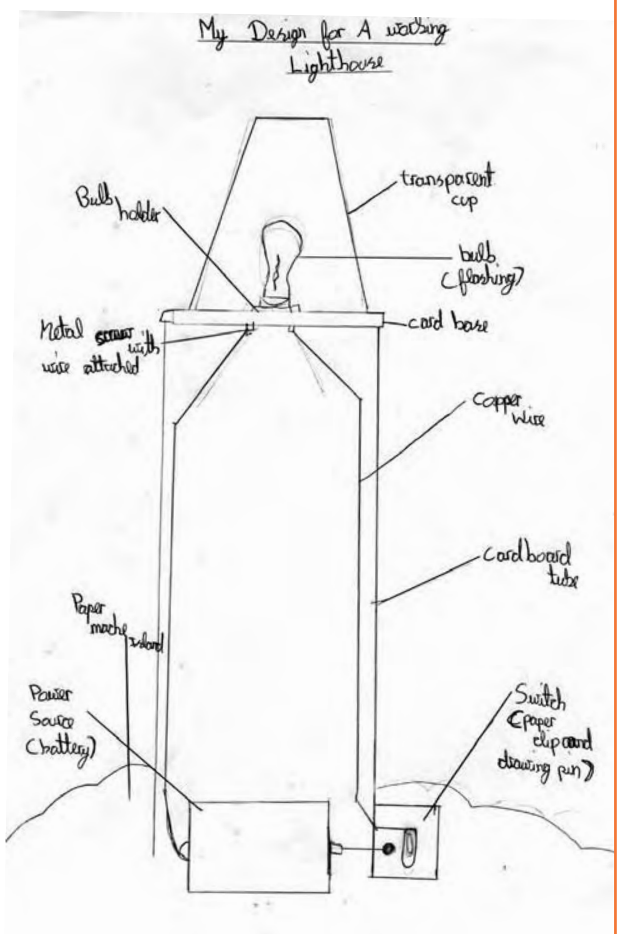
Making a lighthouse

I made a lighthouse by creating a simple circuit which was connected through a cardboard tube and plastic bottle top. My circuit looked like this



When I pressed the switch, the current was able to flow through the wires because my switch is a conductor made from a paper clip. The energy from the battery allowed the current to pass through the wire to the bulb which made the bulb light up. When the switch paper clip did not touch the drawing pin, the current was stopped because the circuit was no longer complete.
I was able to make my lighthouse flash by simply turning my switch on and off, by releasing the paper clip from the drawing pin and putting it back again.

I could improve my design by making it waterproof by using different materials for the outside. Also I could think of other ways to make it look like the light was flashing without turning it on and off all the time as this might break the switch or the bulb.



Tom used scientific knowledge and understanding to build his lighthouse including a simple model of current flow, which he has also used to explain his findings, i.e. changes to a physical phenomenon. He regularly checked progress and revised his method whilst building his lighthouse. His reflections show how he would improve his design to make it more like a real lighthouse.

The teacher asked him about his success criteria.

Teacher:
Did you meet all your success criteria?

Tom:
Yes – because it's a model it can't be that high. But I don't think my success criteria were good enough.

Teacher:
Why weren't they?

Tom:
They were too simple and I thought more about a model than the real thing.

Teacher:
Can you suggest how you might change them?

Tom:
I should have thought more about the materials it was made from. They should have been waterproof and strong.

Tom's next steps:
Try to write a new set of criteria for success next to the original one.

In this conversation, Tom is beginning to evaluate how far his success criteria fully reflect successful outcomes.

How can the brightness of a bulb in a circuit be changed?

Using and applying models enquiry

Skills
C2; EP1, 2; ED1, 5; ER1, 3, 4, 6.

Range
HTW1, 5.

The teacher gave the class a series of questions to guide them through the investigation. This does not reduce attainment but gives a structure for the learners' ideas. Tom systematically planned, carried out and recorded the results of the investigation using a light sensor. He distinguished between independent and dependent variables and recognised those that needed to be kept the same.

How can the brightness of a bulb in a circuit be changed?

How would you do it?
I could put more batteries in the circuit and see if this would change the brightness.

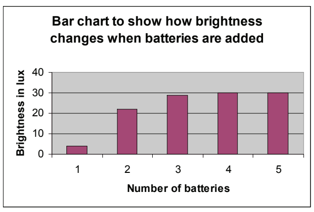
What do you think would happen?
The more batteries I use the brighter the bulb will be.

Why do you think this?
It should do because the more batteries the bigger the current will be.

What are your variables (things that might affect your results)?
If I change the number of batteries – that's the independent variable. The brightness is the dependent variable. I could measure using a light metre. It measures brightness in lux. The experiment needs to be done in a dark room to make sure my test is fair and there is no other light to make the measurements unfair. I would have to keep the equipment the same too.

Results
When I added one battery to the circuit, the bulb was very dim, with only 4 lux. As another battery was added, the bulb became much brighter reading 22 lux. The third battery increased the brightness to 29 lux and 4 batteries was 30 lux. When Ie tried a 5th battery the brightness was the same because it was 30+ and off the scale of our light meter.

Number of batteries (independent variable)	1	2	3	4	5
Brightness in lux (dependent variable)	4	22	29	30	30+



What did you find out?
I noticed that the more batteries, the brighter the bulb. This is because there is more current. This makes the bulb brighter.
If I extrapolated the graph, I think 5 batteries might be 40 lux because it will keep getting brighter. But I think even more batteries would blow the bulb because the current would be too much. Also I would need a different light meter because this one only said 30+ lux.
I think that you see this in a dimmer switch in your house. I know you can alter the brightness by turning the dimmer up or down. You are increasing the current to make it brighter.

Success Criteria

Did you describe what happened?	Yes
Did you repeat your measurements?	No
Did you refer to your results?	Yes
Did you draw a graph of results?	Yes, bar chart
Did you extrapolate the graph?	Yes
Could you apply this idea to everyday life?	Yes

If I was to repeat this experiment I would make sure I repeated my readings of the light metre to check for reliability. I would also get a better light metre that would show a longer scale and go up above 30 lux. I would also like to keep adding the batteries to see how many it took before the bulb blew.

Tom's next steps:
Try to find out more about current flow. Use the BBC website to help you.

The teacher questioned Tom as to his selection of a bar chart to show his findings.

Teacher:
Why did you choose to draw a bar chart?

Tom:
Because each battery is a whole, separate thing.

Teacher:
What do you mean?

Tom:
You can't have half a battery, you have a full one, or two or three or nothing.

Tom used scientific knowledge and understanding to explain his findings, which are changes to a physical phenomenon using a simple model of current flow. His conclusion was consistent with his findings and describes the relationship between the two variables shown by his bar chart. He linked his learning to dimmer switches at home and therefore with a dissimilar but familiar situation. The teacher gave the class success criteria so that they could self-assess. This led Tom to suggest improvements in reliability and the selection of the light meter.

Summary and overall judgement

Levels 5 and 6 were considered and Level 5 was judged to be the best fit.

Tom has a systematic approach to his science enquiries. He has a sound grasp of scientific knowledge and uses this to explain his findings to good effect. He confidently uses scientific language. He enjoys working independently but recognises the importance of sharing ideas to build his understanding.

Planning

Tom's profile shows that when **planning** an enquiry he can *find and use relevant evidence, information and ideas* (a characteristic of Level 5) as in 'Map of the solar system'. When carrying out the fair test enquiry, 'How can the brightness of a bulb in a circuit be changed?', Tom's profile shows that he can *systematically plan an enquiry* and *identify key variables and distinguish between independent and dependent variables and those that he will keep the same* (both features of Level 5). When prioritising the equipment in 'Moon crash landing 2020' he *makes predictions based on scientific knowledge and understanding* (a characteristic of Level 5). In 'How can you make a model of a lighthouse?' Tom *gives some justification for his success criteria* (a feature of Level 5).

Developing

When **developing** an enquiry, Tom's profile shows that he *regularly checks progress and revises the method where necessary* (a characteristic of Level 5). This is evident in 'How can you make a model of a lighthouse?' and in 'Mission possible'. He *organises and communicates his findings integrating different forms in various presentations* (a feature of level 5) as shown in 'Map of the solar system' and *records these systematically* (a characteristic of Level 5) in the fair test enquiry 'How can the brightness of a bulb in a circuit be changed?'. In the latter enquiry he *selects the most appropriate type of graph or chart to display data* recognising the discontinuous nature of the variable and shows that he is *starting to consider reliability* (both features of Level 5). However, in the 'Questioning an image of the solar system' enquiry, Tom explores the image by *considering reliability and offering some explanations for any anomalies* (a characteristic of Level 6). In the same enquiry he is starting to *use abstract scientific knowledge and understanding when explaining his findings* (a feature of Level 6). However, in the main throughout his profile Tom *uses scientific knowledge and understanding, including simple models, when explaining his findings* (a characteristic of Level 5) as shown in the 'How can you make a model of a lighthouse?' enquiry. Also he *uses scientific knowledge and understanding, including simple models, when explaining changes to physical phenomena* (a feature of Level 5) in 'How can the brightness of a bulb in a circuit be changed?' investigation. Throughout his profile Tom *draws conclusions that are consistent with his findings and considers others' views to inform opinions and make decisions* (both characteristics of Level 5).

Reflecting

Tom's profile shows that when **reflecting** on an enquiry he is *beginning to evaluate how far success criteria fully reflect successful outcomes* (a feature of Level 5) in 'How can you make a model of a lighthouse?'. He *identifies the learning/thinking strategies he has used* (a characteristic of Level 6) in 'Moon crash landing 2020'. In several enquiries Tom *links the learning to dissimilar but familiar situations* (a feature of Level 5).

Key Stage 3

Sian

Level 5

Sian is a 14-year-old learner in Key Stage 3.

Her teacher knows much more about Sian's performance than can be included here. However, this profile has been selected to illustrate characteristic features of Sian's work across a range of activities. Each example is accompanied by a brief commentary to provide a context and indicate particular qualities in the work.

Sian's teacher judges that her performance in science is best described as Level 5.

Vertebrate groups

Classifying and identifying enquiry

Skills
C1, 2; EP3; ED3.

Range
underpinning IO4.

At the start of the topic 'Connections', the teacher used the first few lessons to ascertain prior knowledge in the area of classification. She set pupils the task of finding out the names, features and examples of the vertebrate groups. The research was carried out in pairs with the pupils independently presenting their findings.

Type of Vertebrates	Features of Vertebrates	Examples
Mammals 	They all have hair and are all warm blooded. They feed their young on milk and give birth to baby animals.	Cows, dogs and cats, humans
Reptiles 	Reptiles are cold blooded animals, which have dry scaly skin. They lay eggs.	Crocodiles, snakes, iguanas or turtles
Amphibians 	Amphibians always have moist skin which allows them to absorb some oxygen from water. They are cold blooded. They lay eggs.	Frogs, newts and toads, salamanders
Fish 	Fish have hard bones and scales on their skin they have fins for swimming. They are cold blooded. They lay eggs.	Trout, salmon and sardines
Birds 	Birds mostly fly but some live on land. Birds have hollow bones so that they are light and feathers. They are warmblooded. They lay eggs.	Sparrows, eagles and hawks.

Sian's next steps:

Next time you find information give the references and start to think about whether you trust the source of information.

Sian found and used relevant information, organised and communicated her findings integrating different forms into the presentation and used scientific knowledge when explaining the differences between organisms.

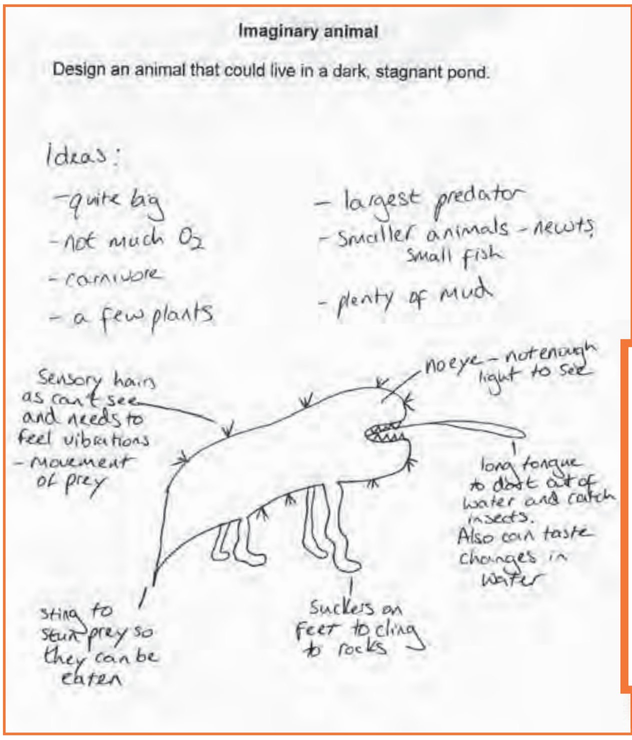
Imaginary animal

Making things enquiry

Skills
C1, 2; EP2, 3; ED4.

Range
underpinning IO4.

Further into this topic the learners were asked to research the features of an environment and then design an imaginary animal that could live there.



Sian's next steps:
How do you think your animal would breath? Look at the table of vertebrate groups. Try to add something about this to your diagram.

The teacher asked Sian how she had decided on her ideas about the conditions in the pond.

Sian:
I looked up the word 'stagnant' and it said this meant the pond had no current. I didn't understand this so I looked in a couple of science books in the library. They said it was a pond with very little oxygen.

Sian again found and used relevant information about the conditions in the pond, this time from books. She has used scientific knowledge and understanding to predict, describe and explain the features of her animal, which are all related to the conditions in the pond. As her target shows she had not taken the limited oxygen in the pond into account in her design.

How can we clean pond water?

Exploring enquiry

Skills
C2; EP1, 2, 6, 7; ED1, 4, 7; ER1, 2, 3, 4.

Range
IO7; TSE1, 2.

The pupils were then shown a video clip of life in an economically developing country where water is scarce. They were asked to think about how a sample of pond water could be changed to water that is fit to drink. In pairs they decided on their success criteria and recorded as many ways as they could to clean the water.

How can we clean pond water?

Success criteria	Ideas	Prediction
• Clean water • No bits in it	• Decant • Filter • Boil • Sieve	I think that if we slowly tip out the water into another beaker the bits will stay in the bottom. Because they are heavier. If we boil the water it will clean it, as all the bacteria will be killed.

Plan
• Slowly tip the beaker so the water flows into another beaker and the bits stay at the bottom (Decant).
• Boil the water without the bits to 100°C.

Did you end up with clean water? If not, why not?	Can you think of anything you could do to improve your method?
No Because the clean water evaporated off when it boiled.	We need to collect the water. If the evaporated water hit a cold metal surface it would condense and we could collect the pure water in another beaker. We would have to be careful we didnt burn ourselves on the steam.

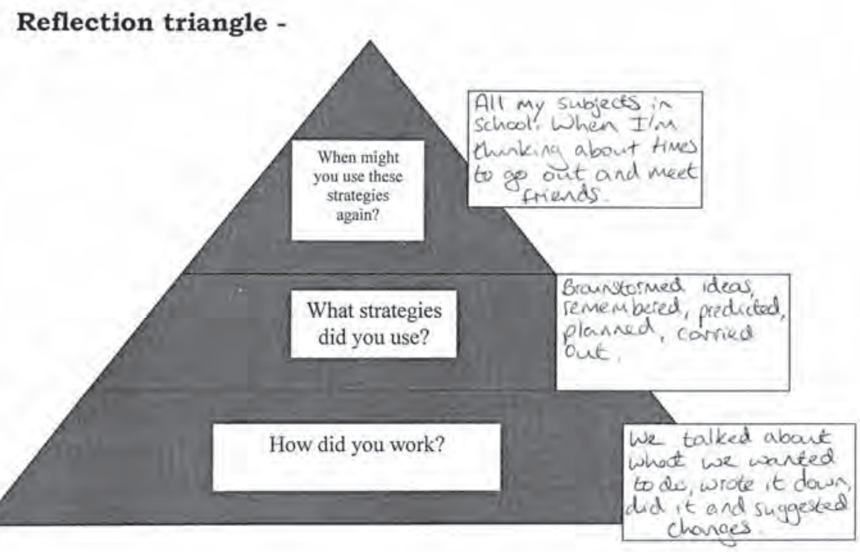
Other success criteria:
· work safely
· write a clear plan
· check progress

Sian's next steps:
On your sheet think about and write down the reasons as to why each method would work. Use science knowledge to explain.

Once the pond water was boiling they realised that the water was being evaporated off and they would have been left with debris rather than water. Sian suggested they try to collect the steam. Recognising the safety issues the girls spoke to their teacher and decided not to do this but to add it as an improvement in their write-up.

Sian made predictions based on simple scientific knowledge and by regularly checking progress she tried to revise the method when she recognised that it wasn't working. She amended her original success criteria and therefore demonstrated that she is beginning to evaluate how far her success criteria fully reflect successful outcomes. By working well collaboratively she considered others' views to inform her decisions.

The teacher asked Sian to reflect on her learning and thinking by using a reflection triangle.



Sian's next steps:

Did you use any strategies or tools to help you – in remembering and planning? Look in your thinking log for the names.

Sian used learning and thinking terms to describe what she had done. She identified 'brainstorming' as a strategy she had used in order to learn. Her other ideas sum up how she worked without getting to the 'How I did this'. Sian linked her learning to dissimilar but familiar situations by mentioning the possible use of her strategy and the ways she worked in other subject areas and in her life outside school.

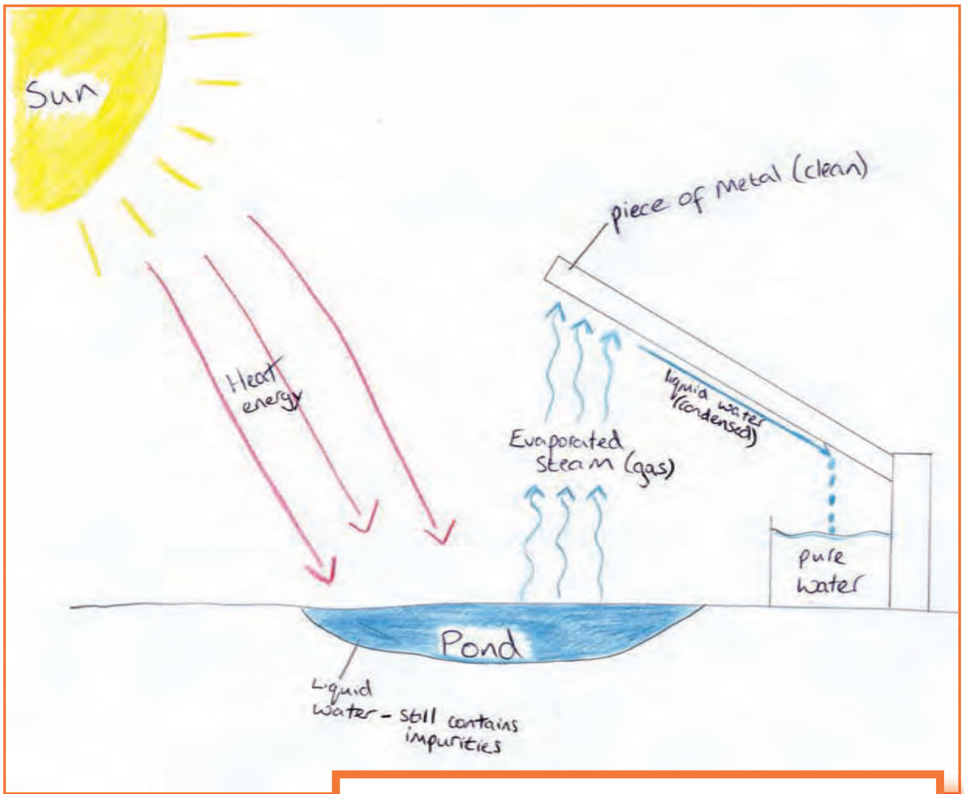
How could people in an economically developing country get clean water?

Making things enquiry

Skills
C2; ED4; ER4.

Range
IO7; TSE1, 2.

The pairs were asked to think about how their method of cleaning pond water could be amended and scaled-up to use in the economically developing country. Individually they produced a poster suitable for the class.



Sian's next steps:
Look in your text book to find out the difference between steam and water vapour. Make any changes to your diagram to take this into account.

Sian used scientific knowledge and understanding to explain her ideas and changes to materials and has linked the learning to a dissimilar but familiar (from the video clip) situation.

What makes a good investigation?

Exploring enquiry

Skills
C2; EP1; ED7.

Range
TSE1.

Before carrying out an investigation on changes of state, the class was given two samples of fictitious pupils' investigations. They were asked to discuss in groups what features make one piece of work better than the other and individually to write a 'checklist for success' for their own investigation plan and write-up.

Task 1

Name: SAMPLE (A)........... Class:...........

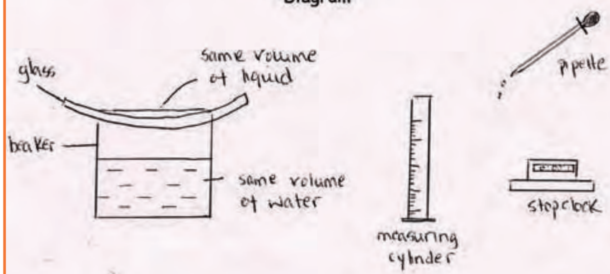
How does the temperature effect the evaporation of a liquid ?

Prediction:
I think that the higher the temperature the faster the liquid will evaporate

Why does this happen ?
This happens because at a higher temperature there is more energy in the particles. The liquid particles will move faster and they will move firther apart from each other. This makes it easier for the liquid to change into the gas. The particles will now be far apart and there will be no attraction force between them.

Plan: (you may decide to draw a diagram to help you plan this invesigation)

Diagram



1. I am going to place 10 drops of the liquid onto the glass using a pipette
2.I will measure out 100cm 3 of water and place it in a beaker
3.I will find the temperature of the water using a thermometer
4.I will put the glass ontop of the beaker as shown in my diagram
5.I will time how long it takes for all the liquid to evaporate
6.I will do the experiment using 5 different temperatures of water
7.I will repeat the whole experiment and place my results into my results table

Variables:
What I change
The temperature of the water that is heating the liquid

What I measure
The time it takes for all the liquid to evaporate

Fair testing
1.Same amount of liquid (10 drops)
2.Same amount of water (100 cm 3)
3.Same distance between the water and the glass
4.Same size of glass in area and thickness

Comment on variables
It is going to be difficult to have exactly the same amount of liquid by counting the number of drops.It maybe difficult to decide when all the liquid has evaporated as it is a clear liquid.We will have to use the same beaker and glass each time otherwisethe distance between the hot water and the liquid could change.

Comment on reliability
I can only check that my results are reliable if I repeat the experiment. If they are reliable then the times should be close together at each temperature. If they are far apart I would have to that test again to decide which is the reliable time to use for my results.

Sian identified the main features and so decided on her success criteria giving some justifications. Again Sian considered others' views to make decisions, this time on her success criteria.

Task 1

Name: SAMPLE Ⓒ......... Class:...........

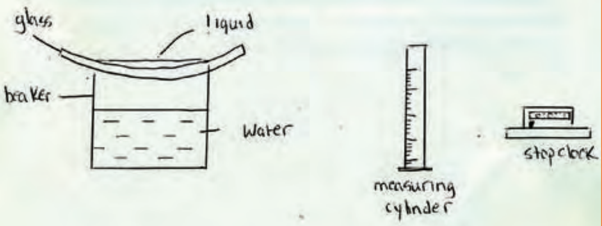
How does the temperature effect the evaporation of a liquid ?

Prediction:
I think that when a liquid is hot it will evaporate quickly.

Why does this happen ?
This happens because when a liquid is hot it is easier for it to change into a gas. It is like what happens to a puddle of rain in the summer when it quickly goes because it is hot but it takes longer for it to go when its cold in the winter.

Plan: (you may decide to draw a diagram to help you plan this invesigation)

Diagram



I am going to put some of the liquid onto the glass and then put intop of a beaker full of water. I will time how long it takes for the liquid to disappear. I will do this again but I will use hotter water in the beaker every time that I do it. I will draw a results table for my results that I get for my experiment.

Variables:
What I change
How hot the water is that I use
What I measure
The time it takes for all the liquid to go

Fair testing
use the same glass to put the liquid on
try to start and stop the clock at the right time
don't use more liquid for one experiment than another
repeat my experiment.

Comment on variables
I think that it will be difficult to see this liquid and to stop the clock at the right time
Comment on reliability
I will have to do the experiment the same way each time or it will not be fair .If I do repeat it the same way my results will be more accurate

PLANNING INVESTIGATIONS
'CHECKLIST FOR SUCCESS'

You have studied and then discussed within your groups the two science investigations. You should have identified features of a good and complete report on an investigation. In the space below attempt to write a 'checklist for success' for the report on the investigation that you are going to plan.

'checklist for success'

- use compare words in the prediction so it's easier to understand
- use science to explain the prediction
- show in the diagram how to make it a fair test and all the equipment
- write the plan in numbers so its easy to follow
- write about a fair test clearly
- think about measuring when writing about variables to make it more scientific
- try to explain repeating for reliability to get a better investigation

How does the surface area affect the rate of evaporation?

Fair testing enquiry that requires the use of a model

Skills
C2, 3; EP2, 4, 5, 6; ED1, 2, 3, 4; ER1.

Range
TSE1, 2.

Sian then planned and carried out her investigation.

How does the surface area affect the rate of evaporation?

What is your prediction?

I think the bigger the surface area the faster the water will evaporate because more water is in contact with the heat. The heat will make the water change from a liquid to a gas because it will move faster and spread out more. So more surface equals more heat touching the water equals faster evaporation.

Plan

What is your independent variable? The surface area of the container

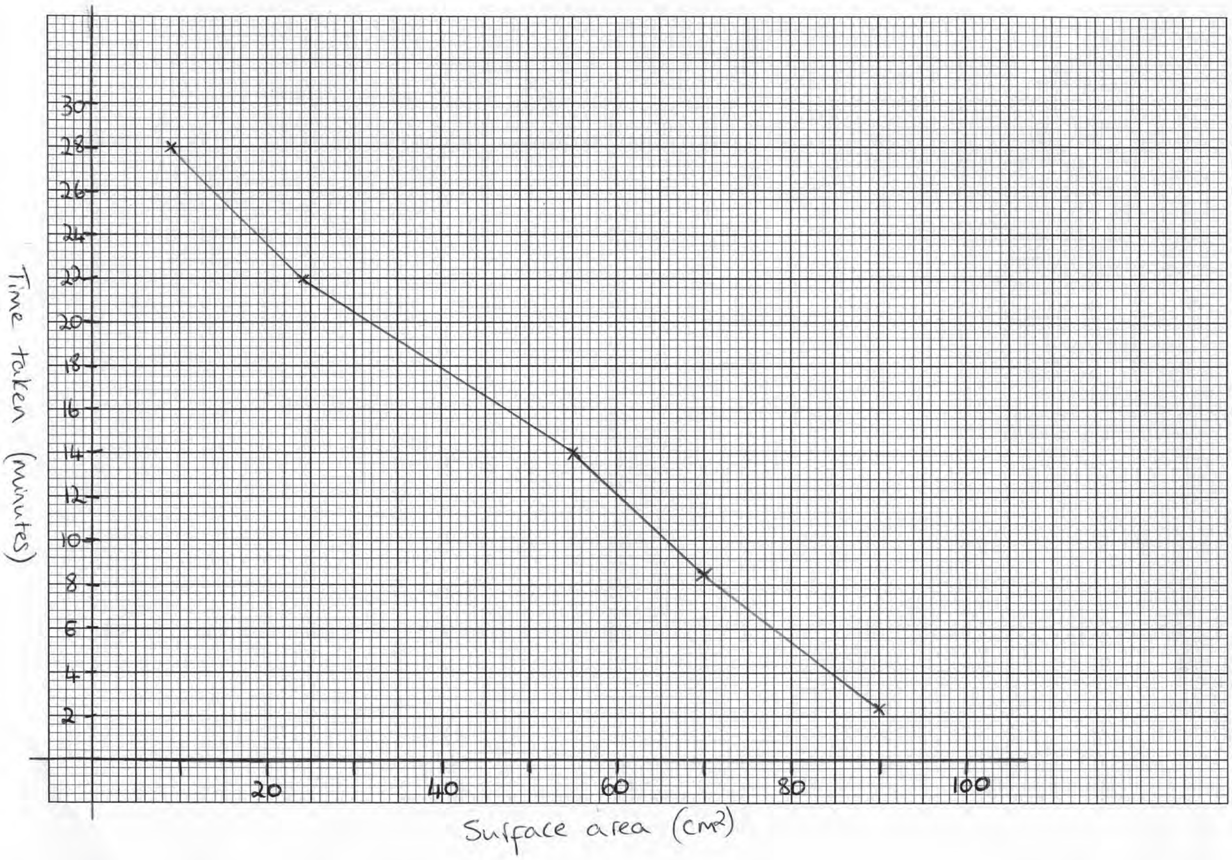
What is the dependent variable that you will measure? I will measure the time it takes to evaporate the water.

What other variables need to be controlled?

I will keep the amount of water and the hairdryer the same. The amount of water is 2cm³

Method

1. Set up five containers with different surface area.
2. Put the same amount of water in each one
3. Use a hairdryer to speed up the evaporation
4. Time how long it takes the water to evaporate from each container.
5. find out the surface area of each container by putting each container upside down on graph paper and drawing round it. Then count the number of squares
6. Write a table to show the results
7. Draw a graph of the surface area against the time it takes to evaporate.



Results

Container	Surface area (cm²)	Time taken (minutes)
1	9.0	28.0
2	24.0	22.0
3	55.0	14.0
4	70.0	8.5
5	90.0	2.4

What have you found out? I have found out that the larger the surface area the faster the water evaporated. This is because the heat from the hair dryer made the water turn into steam and it evaporated into the air as a gas.

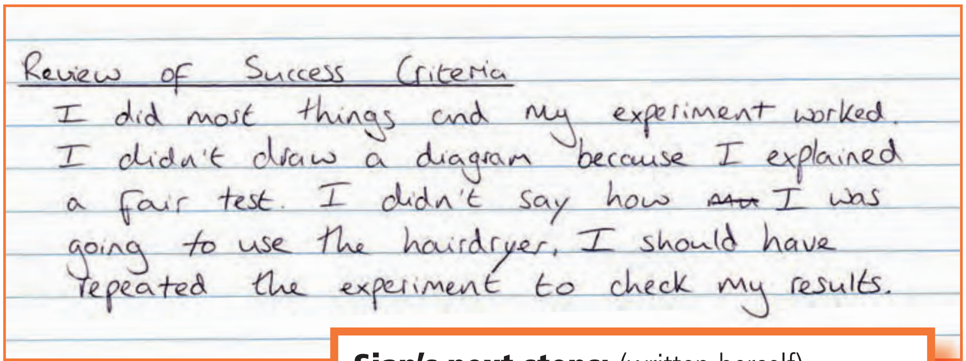
How could you improve your method? If I could do this again I would make sure that the hairdryer was on the containers for the same amount of time because this was hard to do. I would also use less water as we had to do the experiment over two science lessons.

Sian's next steps:
Read your conclusions again. Try to rewrite them using the ideas of 'particles'. Look in your text book to help you.

Sian made a prediction based on a simple model of change of state.

Her model is not an abstract one as she didn't use ideas of particles. She systematically planned and carried out a fair test although her method could have been more specific by stating how the hairdryer was to be used. Within this she identified key variables, distinguished between independent and dependent variables, selected measuring equipment to make a series of measurements and recorded her findings systematically using S.I. units. Sian used her line graph to describe the relationship between the continuous variables of surface area and the time taken to evaporate. Therefore she drew a conclusion that is consistent with her findings.

The learners were asked to review their success criteria against their write-ups in pairs so that they could set their own next steps.


Review of Success Criteria
I did most things and my experiment worked.
I didn't draw a diagram because I explained
a fair test. I didn't say how ~~and~~ I was
going to use the hairdryer. I should have
repeated the experiment to check my results.

Sian's next steps: (written herself)
Repeat the experiment to check my results.

Sian demonstrated that she was beginning to evaluate how far her success criteria fully reflect successful outcomes and is starting to consider reliability.

Energy resources

Making things enquiry

Skills
C1, 2; EP3; ED4, 6, 7.

Range
IO6, HTW6.

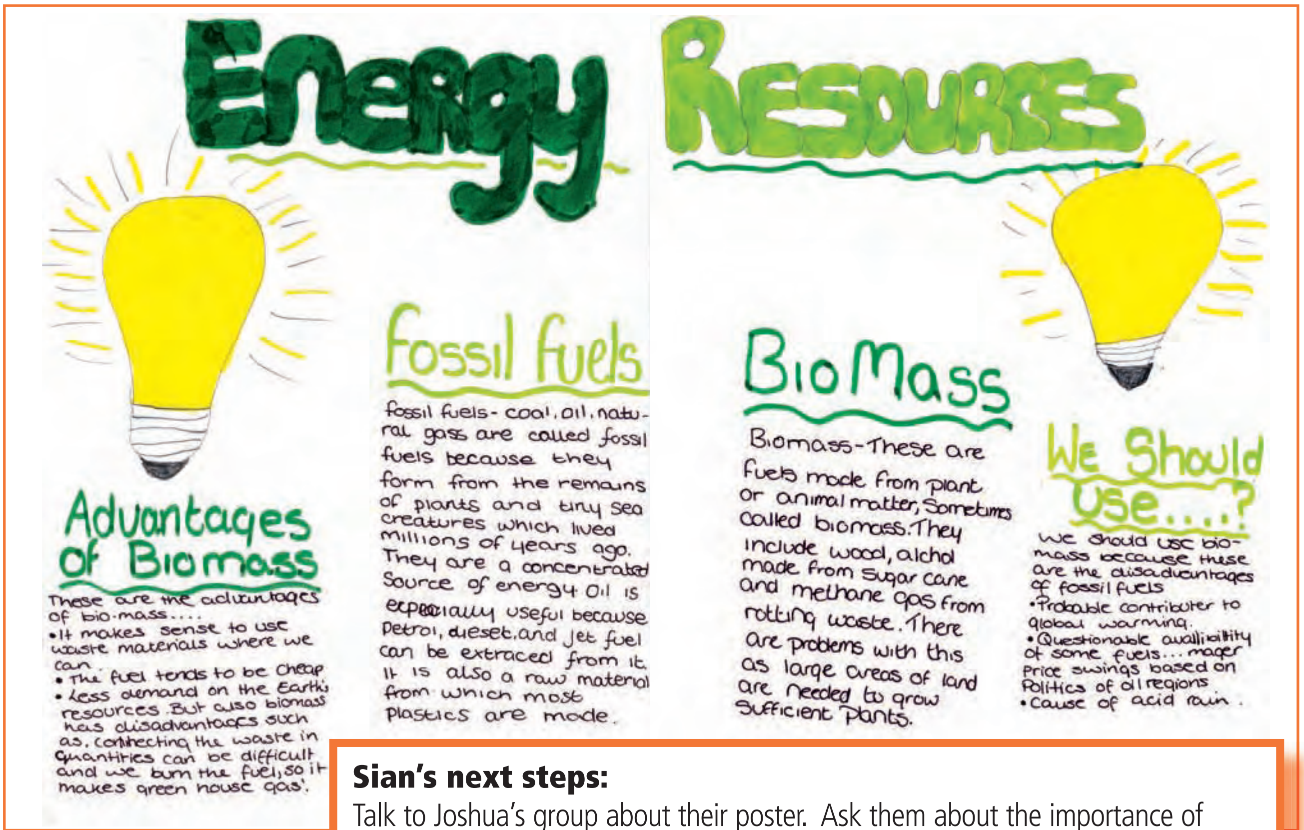
The teacher gave the class the task ‘Energy resources’ to assess their learning of a topic they had just completed. The assessment focused on the learners’ use of scientific knowledge and their understanding of bias and the reliability of information. These aims were shared with the class at the start. The class worked in pairs to gather evidence and present their findings as a report for the school governors.

Energy resources

Recently the school was successful in gaining the ‘Eco Schools’ award. However, the school’s Governors have a concern over the choice of energy resources used by the school. At present the energy used by the school is obtained from the burning of fossil fuels. It has been suggested that as a school we should be using a more sustainable energy resource, e.g. burning ‘fast growing’ trees.

The Governors would like learners to research the potential advantages and disadvantages of changing the energy resource used from fossil fuels to ‘fast growing’ trees.

Your task is to produce a report for the Governors.



Sian’s next steps:
Talk to Joshua’s group about their poster. Ask them about the importance of using ‘fast growing’ trees rather than normal trees. Add these ideas to your poster.

Sian and her partner found and used relevant information from a text book and from their own work. They organised and communicated their findings integrating these different forms into the report and used scientific knowledge and understanding to explain them. However, the report only discusses biomass rather than recognising the full implications of using ‘fast growing’ trees. Once they had finished, the teacher asked the pupils to evaluate their sources of information using a writing frame.

Evaluating sources

Which sources did you use?

Websites about renewable energy (National energy) and the use of biomass (BBC) website about burning fossil fuels (friends of the Earth)

Why did you decide to use these sources?

I typed in the words and these came up. I used BBC before

Do you trust the sources you used? Yes

Could any of the sources have been biased? If so, why do you think this?

Friends of the Earth – because maybe they want to egsagerate the numbers to get in the news.

How could you check the reliability of the sources you used?

I could look at more websites to check if they say the same things

Sian’s next steps:
Look up in a dictionary what the word ‘reliable’ means. When else do we need to think about reliability in science lessons?

Sian’s responses indicate that she identified possible bias and has started to consider reliability of information.

Summary and overall judgement

Levels 4 and 5 were considered and Level 5 was judged to be the best fit.

Sian is using scientific knowledge and understanding throughout her work. However, she struggles with more abstract scientific ideas and lacks confidence when applying her scientific ideas to new situations.

Planning

Sian's profile shows that when **planning** an enquiry she can *find and use relevant evidence, information and ideas* (a characteristic of Level 5). This is evident in several of her enquiries, such as 'Vertebrate groups'. However, in each case the number of information sources she used was minimal. In 'How does the surface area affect the rate of evaporation?' she shows that she can *systematically plan an enquiry*, and *make predictions based on scientific knowledge and understanding, including a simple model* of changes of state (both features of Level 5). Also in the process of inventing her 'Imaginary animal' and her design to clean pond water in an economically developing country, Sian used scientific knowledge and understanding to think about 'What would happen if . . . ?'. Therefore Sian was using predictive thinking to work out her designs. In the fair test enquiry 'How does the surface area affect the rate of evaporation?', she *identifies key variables and distinguishes between independent and dependent variables and those that she will keep the same* (a characteristic of Level 5). Sian decided upon some basic success criteria (a feature of Level 4) in 'How can we clean pond water?'. She took this further as she gave *some justification for her success criteria* (a characteristic of Level 5) in 'What makes a good investigation?'.

Developing

When **developing** an enquiry, Sian *selects measuring instruments that allow her to make a series of measurements* (a feature of Level 5) in the enquiry 'How does the surface area affect the rate of evaporation?'. She *regularly checks progress and revises the method* (a feature of Level 5) as evidenced in 'How can we clean pond water?'. Throughout her profile she *organises and communicates her findings integrating different forms in various presentations* (a characteristic of Level 5) and this is especially evident in 'Vertebrate groups'.

In 'How does the surface area affect the rate of evaporation?' she *records her findings systematically, using S.I units and uses a line graph to describe the relationship between two continuous variables* (both features of Level 5). In the same enquiry and in 'Energy resources' Sian shows that she *is starting to consider reliability* and she also *identifies bias* in the latter (characteristics of Level 5). Throughout her profile Sian *uses scientific knowledge and understanding, including simple models, when explaining her findings* (a feature of Level 5). In 'Vertebrate groups' she *uses scientific knowledge and understanding when explaining differences between organisms* whilst in 'How could people in an economically developing country get clean water?' she uses *a simple model when explaining changes to materials* (both characteristics of Level 5). Sian *draws conclusions that are consistent with her findings* (a feature of Level 5) throughout her profile and also works collaboratively and *considers others' views to inform opinions and decisions* (a characteristic of Level 5).

Reflecting

Sian's profile shows that when **reflecting** on an enquiry she is *beginning to evaluate how far success criteria fully reflect successful outcomes* (a feature of Level 5) in 'How can we clean pond water?' and 'How does the surface area affect the rate of evaporation?'. She *identifies the learning/thinking strategy she has used* (a feature of Level 5) in her reflection triangle in 'How can we clean pond water?'. In the latter enquiry and in 'How could people in an economically developing country get clean water?' she *links the learning to dissimilar but familiar situations* (a characteristic of Level 5).

Key Stage 3

Amy

Level 6

Amy is a 14-year-old learner in Key Stage 3.

Her teacher knows much more about Amy's performance than can be included here. However, this profile has been selected to illustrate characteristic features of Amy's work across a range of activities. Each example is accompanied by a brief commentary to provide a context and indicate particular qualities in the work.

Amy's teacher judges that her performance in science is best described as Level 6.

Insulin presentation

Making things enquiry

Skills
C1, 2; EP1, 3, 5; ED4, 5, 6, 7; ER1, 2, 4.

Range
IO3, 7.

The class worked on a cross-curricular theme of 'Drugs in Society' with PSE. Initially the teacher asked paired pupils to draw a concept map of everything they already know about drugs. She used these to plan the next few weeks' work.

Each pair was asked to choose a drug, from the list of insulin, steroids, paracetamol and caffeine, to find out about and present to the class. Amy and Chloe chose insulin.

The teacher listened to the pair's planning.

Chloe:
We know that insulin is used to treat diabetes. Where shall we look for information?

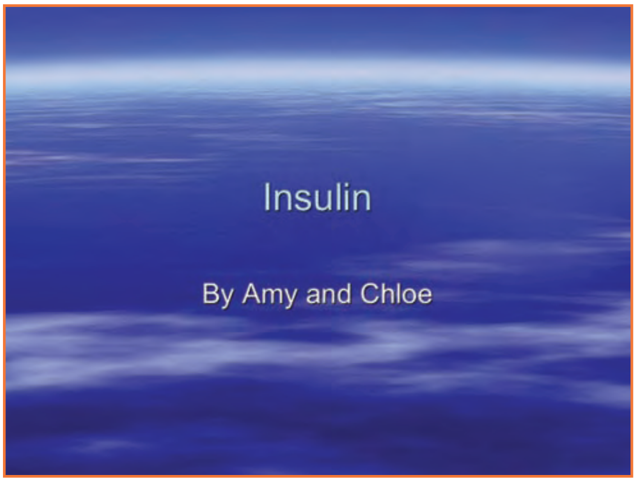
Amy:
We could look on the internet; on the NHS website or on one of the doctors' help sites. We could go to the doctor's and ask if they have any leaflets, talk to someone who's diabetic and look in medical books.

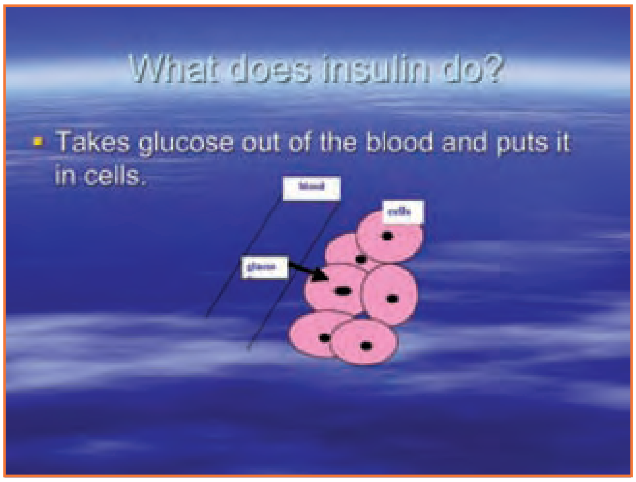
Chloe:
What shall we have as our success criteria?

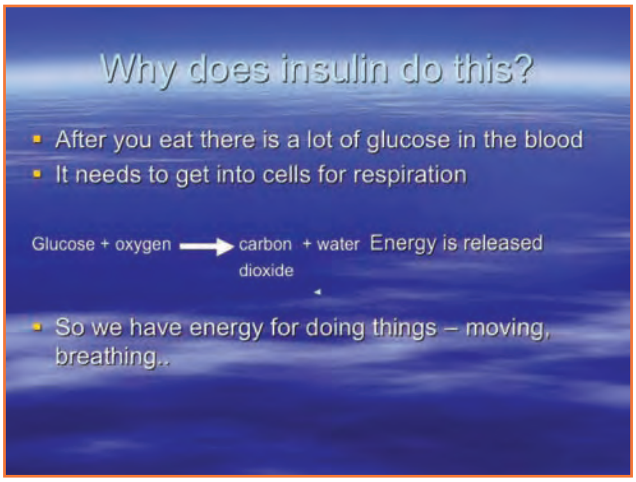
Amy:
It needs to be clear and simple and easy to read or listen to – so we'll use bullet points – just giving the important scientific information. It needs to be interesting otherwise people won't listen or read it – so we'll also put some pictures in. The language needs to be easy enough for everyone in the class to understand. We might need to do that with the science too! Could we put sound in – maybe a real interview or something? We could ask Mark – he's diabetic, about how it affects his life. The best way would be to do a PowerPoint so all these could be in it and it would be easy to tell the class about it all.

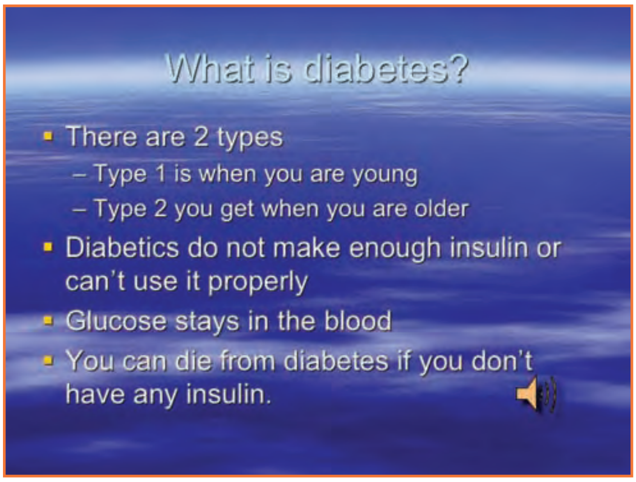
Amy suggested a variety of methods to gather information for her enquiry and justified her success criteria for a successful presentation.

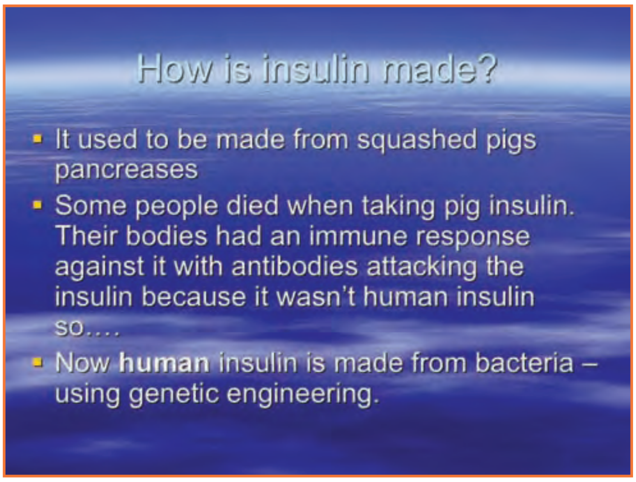
They researched and presented their findings as a PowerPoint presentation.

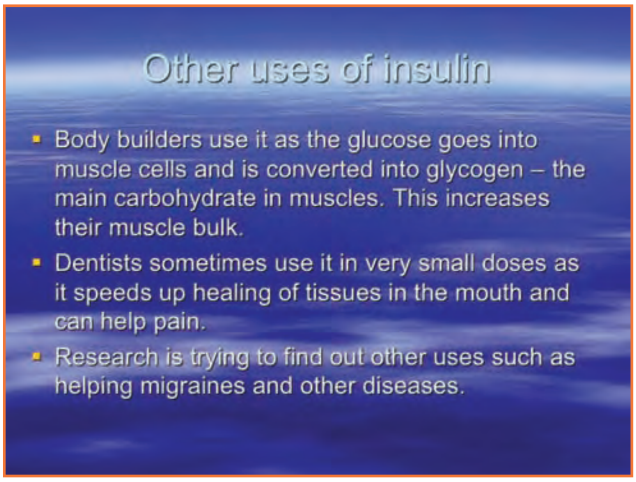



What does insulin do?
Takes glucose out of the blood and puts it in cells.


Why does insulin do this?
After you eat there is a lot of glucose in the blood
It needs to get into cells for respiration
Glucose + oxygen → carbon dioxide + water Energy is released
So we have energy for doing things – moving, breathing..


What is diabetes?
There are 2 types
– Type 1 is when you are young
– Type 2 you get when you are older
Diabetics do not make enough insulin or can't use it properly
Glucose stays in the blood
You can die from diabetes if you don't have any insulin.


How is insulin made?
It used to be made from squashed pigs pancreases
Some people died when taking pig insulin. Their bodies had an immune response against it with antibodies attacking the insulin because it wasn't human insulin so….
Now human insulin is made from bacteria – using genetic engineering.


Other uses of insulin
Body builders use it as the glucose goes into muscle cells and is converted into glycogen – the main carbohydrate in muscles. This increases their muscle bulk.
Dentists sometimes use it in very small doses as it speeds up healing of tissues in the mouth and can help pain.
Research is trying to find out other uses such as helping migraines and other diseases.

They organised and communicated their findings in a way that was fit for purpose and audience. Amy presented to the class. She explained the function of insulin and its effect on the human body; what diabetes is; how insulin is manufactured and how it works when used illegally as a body-building drug. The presentation also had a brief interview with Mark, a Year 10 learner, who is diabetic, explaining how the disease affects his life. She explained their findings using abstract ideas, recognised that a number of factors and/or processes may have to be considered when explaining changes and showed some evidence of starting to link these. The pair had used a wide range of perspectives to inform their decisions and also linked the science learning to body-building, an unfamiliar situation.

The teacher asked the class to suggest two questions for Amy and Chloe, to help them improve their work.

Amy's next steps:
(from the class)
Did you meet your success criteria?
Are there any other success criteria you could have used?

Amy:
I think we did meet our success criteria. But what's important is whether you all think we did. We wanted it to be clear, simple, informative, interesting and enjoyable.

Teacher:
Are there any other success criteria you could have used?

Amy:
(thinks for a minute) I suppose the main one we missed was that the science in it had to be spot on.

Teacher:
What do you mean by that?

Amy:
The science should be 'right', not biased and we need to think about how reliable the information was.

Teacher:
How could you check this?

Amy:
We did use trustworthy sources but maybe we could have checked the information more with other ones we trusted too.

Amy demonstrated she is beginning to evaluate how far her success criteria fully reflect successful outcomes and considers the reliability of the information as she justifies why amendments need to be made to her methodology.

How does caffeine affect the heart rate?

Fair test enquiry

Skills
C2, 3; EP2, 4, 5, 6; ED1, 2. 3, 4, 5, 6; ER2, 4.

Range
IO3.

A presentation on caffeine from another pair of learners caused much discussion in class especially as there had been recent newspaper articles about how caffeine affects the body. The teacher decided to try and help learners answer some of the questions that arose by carrying out an investigation on caffeine.

For homework the class was asked to find out which foods and drinks contain caffeine and how much caffeine per 100g each one contains. In class they used this information to plan and carry out an enquiry in pairs to find out how caffeine affects heart rate. They produced their own write-ups. The teacher had permission from parents/guardians to carry out this experiment.

How does caffeine affect the heart rate?

What I know

Caffeine is a stimulant drug. It makes people feel more alert and able to concentrate. It speeds up the heart rate and increases blood pressure. Some athletes use it to give them an energy burst just before they start a race this might make them have a faster start. Caffeine is found in lots of drinks, such as cola, coffee and tea. It works because it has an effect on the heart itself and an effect on the part of the brain that controls heart rate. It speeds up the messages between nerve cells. If the heart beats faster the muscles will have more oxygen and glucose for respiration and so will release more energy.

Glucose + oxygen ⟶ carbon dioxide + water with released energy

What I am going to do

Compare the heart rate of two people. One will drink a caffeinated fizzy pop and the other will drink a decaffeinated pop. The caffeinated drink contains 45.6mg of caffeine and the decaffeinated drink contains no caffeine.

Prediction

From what I know I think that the pulse rate of the person who has drunk the caffeine pop will go up in about 2 minutes – as athletes take the caffeine just before a race. It will stay high through the 15 minutes. I think this because the caffeine is in a liquid so it will pass down the digestive system quickly and be absorbed quickly maybe in the stomach like aspirin. As athletes use caffeine to give them an energy burst to get through a race and races can take longer than 15 minutes.

Variables

Independent variable – mass of caffeine in the drink– 45.6mg or none.
Dependent variable to measure – heart rate by taking the pulse rate per minute. We will carry on taking the pulse rate for 15 minutes after the drink.
Control variables

- type and quantity of pop – the same type, 330ml can, one with caffeine and the other without
- caffeine already in the body. It's important that the two people don't have any caffeine in any food or drink before you start the experiment. So no caffeine before 9am that day.
- temperature of body and room. The temperature of the room will stay the same and so should the body temperature.
- movement. We must both stay as still as we can because movement might speed up the heart rate. Also we must not run around before the lesson.
- level of excitement. We will both try and stay calm throughout the experiment so our heart rates stay the same except for the caffeine.

Plan

1. Rest for 10 minutes then get your partner to take your pulse rate. This is called the resting pulse.
2. Take the resting pulse again and again until you get three readings the same. This makes sure that your resting pulse is reliable.
3. Drink the can of pop, one person with caffeine and one without, in 3 minutes.
4. Take your pulse again every minute for the next 15 minutes.

resting pulse.
2. Take the resting pulse again and again until you get three readings the same. This makes sure that your resting pulse is reliable.
3. Drink the can of pop, one person with caffeine and one without, in 3 minutes.
4. Take your pulse again every minute for the next 15 minutes.

5. Record your results in the table.
6. We are going to take our pulse over 30 seconds and then multiply it by 2 to get rate in a minute – as we did in the exercise investigation.

Amendments

We noticed that my pulse rate was still very high after 15 minutes so decided to carry on taking it until it started to drop.

Results

Resting pulse

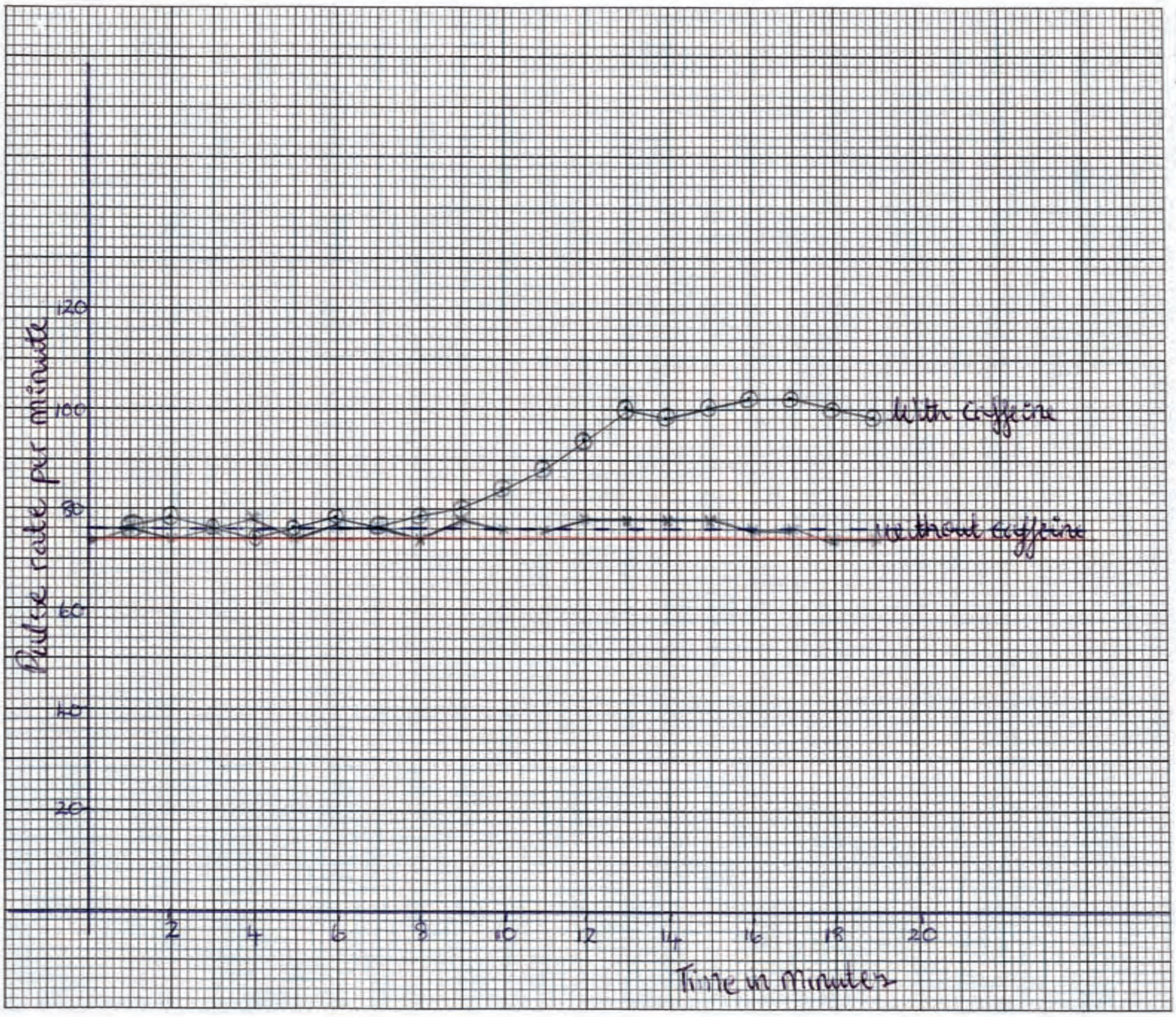
In beats per minute	
Eleri	Amy
72	72
74	76
74	76
74	76

So the resting pulse is 74 for Eleri and 76 beats per minute for Amy.

Experiment

Time, in minutes	Pulse rate per minute	
	Without caffeine - Eleri	With caffeine - Amy
1	76	76
2	74	78
3	76	76
4	78	74
5	74	76
6	76	78
7	76	76
8	74	78
9	78	80
10	76	84
11	76	88
12	78	94
13	78	100
14	78	98
15	78	100
16	76	102
17	76	102
18	74	100

Graph showing pulse rate per minute against time in minutes
(with caffeine and without caffeine)



Description of results

My heart rate stayed the same – around my resting pulse - for 8 minutes after drinking the caffeine. Then it went up and reached a maximum of 26 beats per minute over my resting pulse after 16 minutes. It then stayed level for 3 minutes before it started to go down again. Eleri's heart rate stayed about the same – around her resting pulse - but did go up a bit between 12 and 15 minutes.

Explanation of results

The caffeine made my heart rate increase quickly between 8 and 16 minutes. It then stayed the same because the caffeine was all being used or that's as fast as it could work. Eleri hadn't taken any caffeine so her heart rate stayed about the same. It went up in the middle because we were trying to decide what to do, whether to carry on beyond 15 minutes so she was a bit jumpy then.

Explanation of any anomalies

We didn't really have any anomalies but I was surprised how much Eleri's heart rate changed when she hadn't had any caffeine. It went up and down probably as she was jumpy about what to do next. This might have looked bigger than it was because we took the pulse for 30 seconds each time and so any differences or mistakes in our counting were doubled.

Suggested improvements to the method

The graph was very hard to draw especially with the results for the first 8 minutes. It would have been better to use graph paper on a bigger piece of paper so the results were not as squashed.
I would take the pulse rate for a minute to get rid of any mistakes.
To make my results more reliable I would have to do the whole experiment again but this would be very difficult to make sure the variables were all the same as this time.
I could also try the experiment on different people as they might have different results – their pulse rate may not go up at all or it could go up less or more than mine did.
I would like to find out how long it takes for my pulse rate to go back to resting.
I would like to try the experiment using different pops each with different amounts of caffeine in them to see how the amount of caffeine affects the heart rate. I could also do another investigation to see if caffeine affects reaction time, using a ruler.

Conclusion

I showed that even one can of pop with 45.6mg of caffeine in it increases the heart rate dramatically so I have shown that the science I researched was correct. From my research it's not fully known how caffeine works so I believe the ideas I found that say it affects the heart and the brain. In both cases it probably affects the speed that nerves work – making them send messages out faster. I can see why it is a banned drug in athletics as it would give an athlete an unfair advantage. It could make them start faster in sprint races of give them an advantage to sprint after a few minutes into a longer race. I also found out that the cheating athletes take much larger quantities of caffeine than was in the pop. I don't think that would give them an effect much faster as the caffeine still needs to be absorbed into the blood and carried around the body to the brain and heart. It probably would increase their heart rate to a higher level and so they would release more energy from glucose.

Amy's next steps:
Discuss with Eleri, which variables were difficult to control and why were they difficult?

Amy made predictions using abstract scientific ideas and planned how to control the variables they needed to keep the same.
She couldn't make decisions about the range and values of the independent variable as this was set by the mass of caffeine in the drink. They selected a stopwatch that allowed her to make a series of accurate measurements and Amy recognised the limitation of these and considered their reliability. She is also starting to consider validity by suggesting further enquiries to which her findings could be transferred. The pair made an ongoing revision to the method once they had recognised that Amy's heart rate was remaining high and Amy gave simple justifications for her revisions. Amy used appropriate axes and scales for the line graph to show her data effectively, drew a line graph and offered explanations for possible anomalies. She explained her findings and changes to organisms using abstract ideas and recognised that a number of factors have to be considered when explaining changes in heart rate.

Solids, liquids, gases and their particles

Classifying and identifying enquiry

Skills
C2; ED3; ER4.

Range
TSE1.

Within the topic of Particles, the class collaboratively drew a concept map about the particulate nature of solids, liquids and gases to assess their prior knowledge. The teacher asked pupils to rate themselves as 'red', 'amber' or 'green' as to their level of understanding. She put 'greens' in pairs with 'ambers' and they were given an extended response exercise from the *Optional Assessment Materials, ACCAC 2001.* The 'reds' were grouped together for her to teach. Amy is a 'green' as she feels confident in her knowledge.

Name..........................

Write what these three words mean to you.

Solid: Solids are one of the states of matter. They are hard, dense, do not flow and you can not compress them. They have these properties because of the way their particles are arranged. The particles are close together in regular parallel rows. The particles don't move but they start to vibrate to and fro as they are heated. The solid has strong forces of attraction between the particles keeping them in place.

Liquid: Liquids are not as dense as solids but they can flow and they always take the shape of their containers. It is very difficult to compress liquids. Again these properties are due to their particle arrangements. In liquids the particles are close together but in a random arrangement. The particles can move about as the forces between them are weak.

Gas: Gases are the least dense, they flow and so fill a space. It is easy to compress a gas. I can explain these properties from particle arrange-ments. In a gas the particles are very far apart and in a random pattern. The particles can move very quickly and now there are no forces of attraction between the particles.

Science Ideas Sheet 7.2

Amy's next steps:
Read through your work and write three sentences to compare the particles in solids, liquids and gases.

Amy worked with Jon and their response shows that they used abstract ideas of particles including the particle model to describe the differences between solids, liquids and gases.

Melting ice

Exploring enquiry

Skills
C2; ED3, 4, 7; ER4.

Range
TSE1.

To challenge them further, Amy and Ben were given a Thinking Card about changes of state to discuss and then report their findings back to the class.

Changes of state	Thinking Card 5
Explain, in terms of particles, what happens when an ice cube melts.	
What would make the ice melt faster?	
Where might your ideas be seen on the Earth?	

Amy reported back:

> For an ice cube to melt it's given heat energy. The particles then have more energy. This energy means that they vibrate more and more and as they vibrate the forces between them get weaker. As the particles gain more and more energy the particles' vibrations get bigger and bigger until they move apart. This is then liquid water. Ice would melt faster if it was given more heat energy. The particles would then have more energy quicker and so would move apart faster. An ice cube would melt faster if it was in smaller pieces as there would be more outside in contact with heat. Salt can be added to ice to make it melt faster – like grit on the roads. On Earth an increase in global warming may lead to the ice caps melting. The warmer the Earth and the air become the faster the ice caps and glaciers would melt.

Amy considered Jon's ideas to inform her decisions. Again she used abstract ideas of particles this time to try and explain changes of state. However, links between the particles' energy and the forces between them could be more detailed. She recognised that a number of factors would have an impact on the speed of melting, i.e. the rate of change of state. Amy linked the learning to the **rate** of ice caps melting due to global warming.

Limestone enquiry

Making things enquiry

Skills
C1, 2; EP1, 3; ED3, 4; ER1, 3, 4.
Range
TSE1, 2.

Once the teacher was happy that the class has an understanding of particles, she set them an enquiry on limestone. The pupils 'brainstormed' their ideas in groups before individually planning and carrying out their enquiry.

Limestone enquiry

Limestone is a rock which contains calcium carbonate ($CaCO_3$). In South Wales there are a number of limestone quarries as limestone is needed during the making of steel. The steel company have asked if we can provide them with different styles of display materials containing information on rocks. They would like to use these in their Visitors' Centre.

Limestone Enquiry

Where could you find information to help you complete this project?
You could find information from books, the internet, quarry, leaflets and posters, visit a museum, a person who works in a limestone quarry, ask a classmate, and you can ask a science teacher or a scientist.

What do you think you will need to include in your presentation for it to have the required scientific detail?
You would need to include the different types of rock and how they are formed. You also would need to know what type of rock limestone is also what type of chemical substance is calcium carbonate. You also need to describe the difference between elements, compounds and mixtures to compare limestone with other substances. You would also need to make it look interesting so that people would read it.

How could you present your report on this project?
You could present your report in a leaflet form, a DVD, poster display and a booklet. We will make a flyer with flaps to lift which are pictures.

You should now carry out the research for this project. Your completed report may be presented in any style you consider to be appropriate.

List the sources of information that you did use to complete your report below.
I got my information from the internet. There were many sites I went on but the main one being bitesize website. I checked the information with the RSC website - so it's reliable.

Evaluate your success criteria:
I included the different types of rock and I showed where limestone fitted in to the sedimentary group. I made it look interesting with pictures and flaps. But I didn't include enough information about how limestone is made up from the elements Calcium Carbon and Oxygen to make the compound. This would have improved the science.

Amy gave some justifications for her success criteria when questioned.

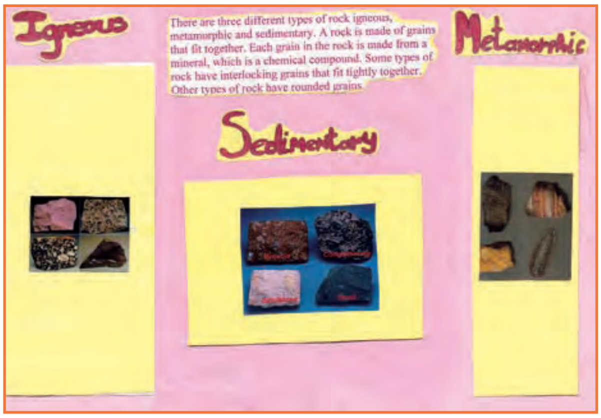
Teacher:
Why did you decide on these success criteria?

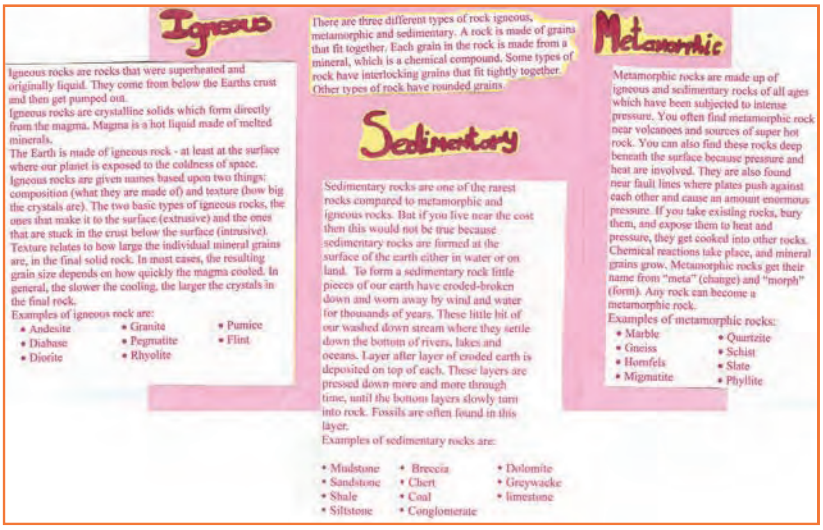
Amy:
People at Visitors' Centres want to know the science. So I need to show how limestone has formed and maybe other rocks too. To do this properly I need to talk about elements and compounds and explain what they are. People at Visitors' Centres will all know different amounts of science. So I need to keep it simple. Also I'd like to find out more!

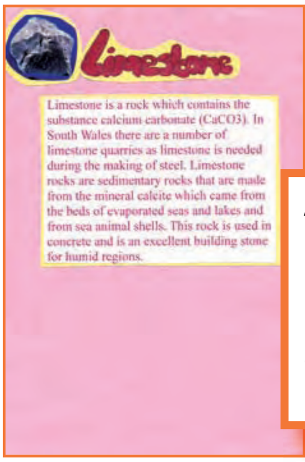
Amy organised and communicated her findings as a flyer, which was fit for purpose and audience. She used abstract scientific knowledge to explain her findings, recognised that a number of processes have to be considered when explaining rock formation and evaluated how far her success criteria fully reflect successful outcomes. In doing so she set her own targets relating to the science involved in the flyer.

As part of the class's reflection on their enquiry, they are asked to complete a table to identify the strategies they have used to learn.

Amy's flyer







Amy's next steps:
(written herself)
Look up how limestone is made up from the elements calcium, carbon and oxygen to make the compound.

Strategies I used	Strategies that worked	Strategies that didn't work so well	When or where else these might be used
Brain storming when planning		√	To decide on really good ideas – inventing and being creative
Asking questions of other people – open questions that made them think		√	To find out others' opinions and ideas to see if they are better than mine - debates
Using specific search terms on the internet – thinking about ones I'd used before	√		When trying to find any information or ideas. The doctor does this sometimes to work out what drug to give a patient.
KWHL grid – to plan and reflect	√		In other subjects to make sure that I've done what I'm supposed to.
Success criteria and reflecting on them to make improvements next time		√	When cooking – a chef so that he will cook it better next time!
Scanning – when reading	√		In other subjects when I am asked to look for specific information in text.
Writing – redrafting	√		Writing a poem in English.

Amy's next steps:
Can you think of any other learning/thinking strategies or tools you could also have used? Add them to the bottom of your table.

Amy has identified the learning strategies she has used, and has started to link the learning to unfamiliar situations.

Volcanoes

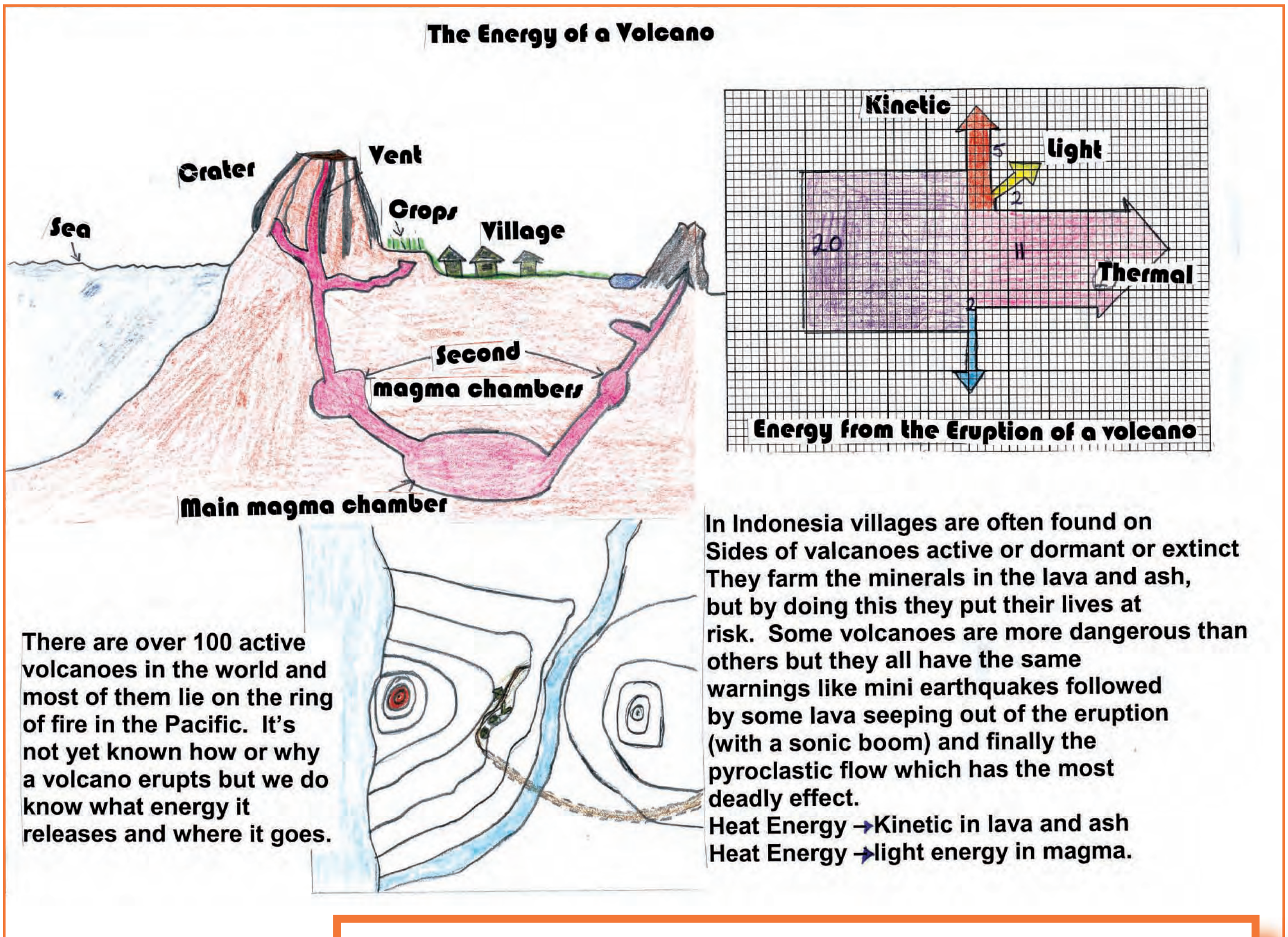
Making things enquiry

Skills
C1, 2; EP1, 3; ED3, 4; ER1, 3, 4.

Range
TSE3; HTW2.

As part of a cross-curricular topic on volcanoes in Indonesia, with geography, Amy produced a poster to summarise her learning.

She used abstract ideas of energy transfer chains and changes and tried to quantify her predictions but did not manage to draw them to scale. Amy recognised that a number of processes have to be considered when explaining what happens in a volcanic eruption and linked the learning to unfamiliar contexts to produce the poster.



Amy's next steps:
How does a volcanic eruption link to the rock cycle? You might like to look through your exercise book and then write a few sentences.

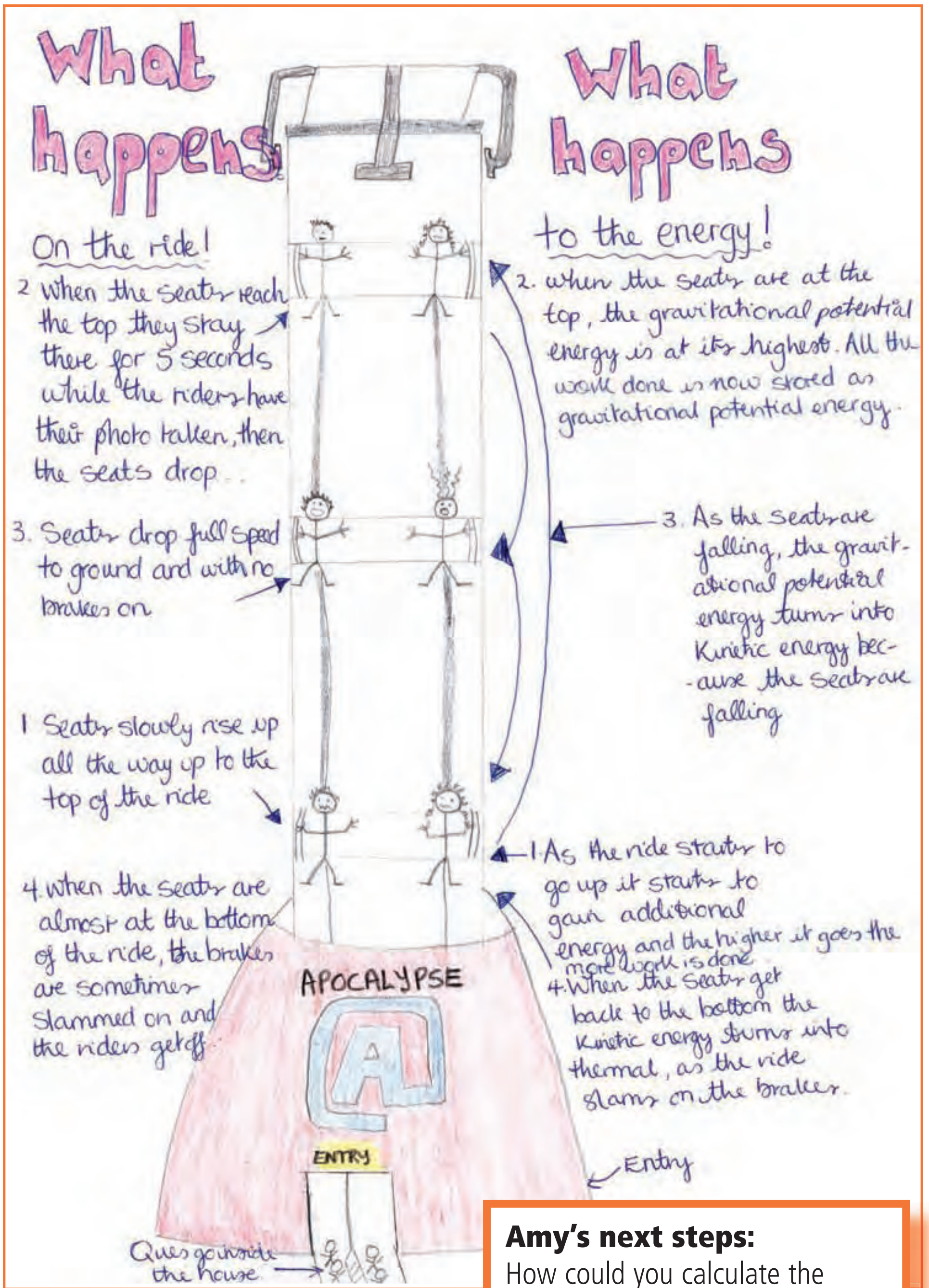
Fairground ride

Using and applying models enquiry

Skills
C2; ED3, 4; ER4.

Range
HTW2, 4.

The class worked individually to apply what they have learned about energy changes and work done to a fictitious fairground ride.



Amy's next steps:
How could you calculate the work done when a person is at the top of the ride? Add this to your diagram.

Amy explains the changes in terms of work done and energy therefore recognising that a number of factors have to be considered when explaining changes. Some of her explanations also make links between energy and work done.

Summary and overall judgement

Levels 5, 6 and 7 were considered and Level 6 was judged to be the best fit. Amy uses abstract ideas in her scientific explanations.

Planning

Amy's profile shows that when **planning** an enquiry she can *suggest a variety of methods or strategies for her enquiries* (a characteristic of Level 6) as evidenced in several enquiries such as 'Insulin presentation'. She *makes predictions using abstract scientific ideas* (a feature of Level 6) directly in 'How does caffeine affect the heart rate?' and indirectly in 'Volcanoes'. In the latter enquiry she develops her own scientific ideas from prior knowledge and predicts comparative quantities of energies released from a volcanic eruption. *In a fair test enquiry she plans how to control the variables that she needs to keep the same* (a characteristic of Level 6), as is shown in 'How does caffeine affect the heart rate?'. When Amy is asked to *justify her success criteria* (a feature of Level 6) she can, but doesn't always develop her ideas fully. Therefore at times it could be said that she only *gives some justification for her success* criteria (a characteristic of Level 5).

Developing

When **developing** an enquiry Amy *selects measuring instruments that allow her to make a series of accurate measurements* (a feature of Level 5) as shown in 'How does caffeine affect the heart rate?'. In this enquiry she *regularly checks progress, makes ongoing revisions when necessary and is beginning to justify any amendments or improvements made* (a characteristic of Level 6). Across her profile Amy *organises and communicates her findings in a variety of ways fit for purpose and audience* (a feature of Level 6) and this is especially evident in 'Insulin presentation'. She *uses appropriate axes and scales for graphs to show data effectively* (a characteristic of Level 6) in 'How does caffeine affect the heart rate?'. Her work shows that she is *beginning to use some quantitative definitions* (a feature of Level 6) in 'Volcanoes' although this is a target for her in 'Fairground ride'. She *considers reliability* of information (a characteristic of Level 6) in 'Insulin presentation' and that of data in 'How does caffeine affect the heart rate?'. In the latter enquiry Amy *offers some explanations for anomalies when considering her findings* (a feature of Level 6) even though she decides that she doesn't really have any anomalous results. She *uses abstract scientific knowledge and understanding, including models, when explaining her findings* (a characteristic of Level 6) in enquiries such as 'Insulin presentation', 'Solids, liquids, gases and their particles' and 'Limestone enquiry'.

Reflecting

She *uses abstract scientific knowledge and understanding, including models, when explaining changes to organisms* in 'How does caffeine affect the heart rate?'; *to materials* in 'Melting ice' and *to physical phenomena* in 'Volcanoes' and 'Fairground ride'; all aspects of Level 6 performance. Amy also *recognises that a number of factors and/or processes may have to be considered when explaining changes* (a feature of Level 6) in most of her enquiries. She is starting to *make links between processes and systems* (a characteristic of Level 7) as in the enquiries 'Insulin presentation' and 'Fairground ride'. Amy *considers a wider range of perspectives to inform opinions and decisions* (a feature of Level 6) as evidenced in 'Insulin presentation'.

Amy's profile shows that when **reflecting** on an enquiry she is *beginning to evaluate how far success criteria fully reflect successful outcomes* (a feature of Level 5) in 'Insulin presentation' and 'Limestone enquiry'. This isn't a strength of Amy's work as her justifications for her success criteria need to be more detailed. She *identifies the learning/thinking strategies being used* (a characteristic of Level 6) in 'Limestone enquiry'. Throughout Amy's profile there is evidence in several enquiries that Amy can *link the learning to unfamiliar situations* (a feature of Level 6).

Key Stage 3

Ben

Level 7

Ben is a 14-year-old learner in Key Stage 3.

His teacher knows much more about Ben's performance than can be included here. However, this profile has been selected to illustrate characteristic features of Ben's work across a range of activities. Each example is accompanied by a brief commentary to provide a context and indicate particular qualities in the work.

Ben's teacher judges that his performance in science is best described as Level 7.

Is *Euglena* a plant or an animal? Explain.

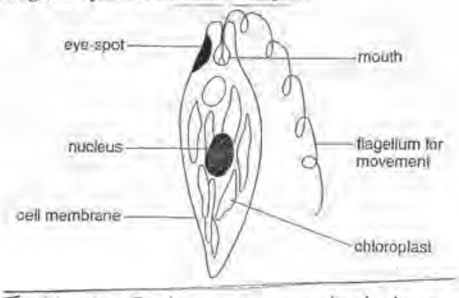
Classifying and identifying enquiry

Skills
C2; ED3, 4; ER4.

Range
IO1.

The class have been studying Cells. The task about *Euglena* is part of an assessment for the teacher to decide if it is time to move onto the next topic.

Is Euglena a plant or an animal? Explain.



I think Euglena is a plant because in an animal cell there are only a cell membrane, nucleus and cytoplasm. In this particular cell there are chloroplasts which would not be found in an animal cell as animals do not produce their own carbohydrates by photosynthesis - plants do. They trap sunlight energy in the chlorophyll in their chloroplasts and convert it into chemical energy stored in carbohydrates. Although it does have an eye and a mouth, which are usually found in animals and not in plants which could suggest it is an animal!

Ben's next steps:
Compare your reasons with Rebecca. List the reasons and prioritise them. Can you make a clearer decision now?

Ben applied the abstract ideas of, and made links between, cell structure and photosynthesis in his reasoning.

Respiration and combustion

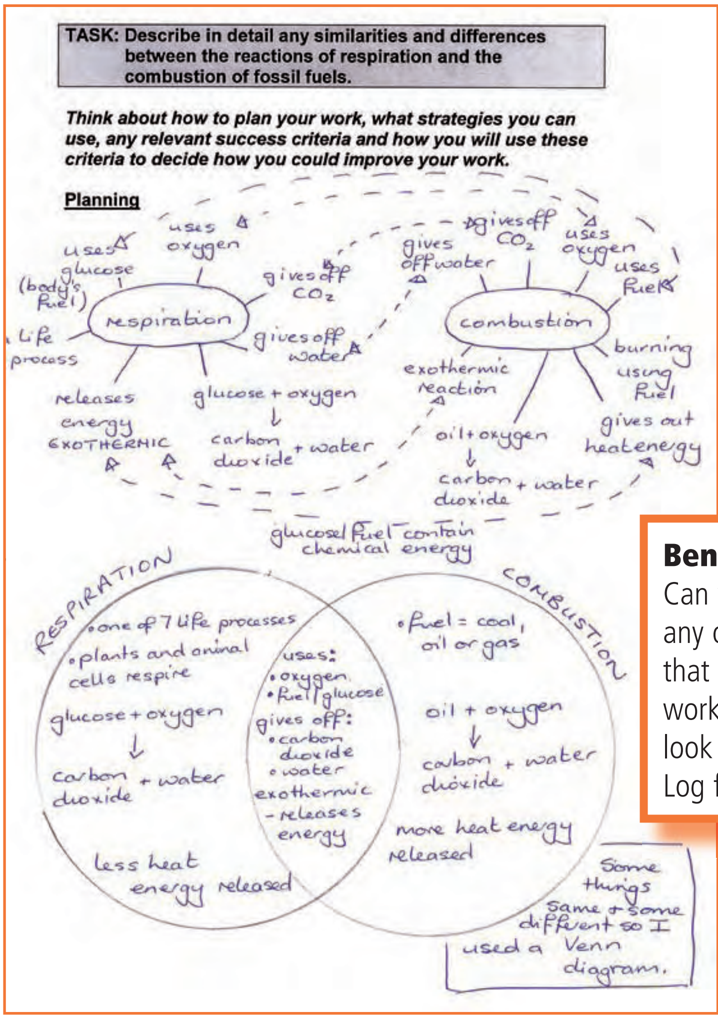
Pattern-seeking enquiry.

Skills
C2; EP1; ED3, 4; ER1, 3, 4.

Range
IO2, TSE3, HTW2.

During the topic 'Reactions', Ben is asked to write down his ideas about respiration and combustion. He chose a previously used strategy (a two circled Venn diagram) to structure his ideas. He told the teacher that he chose this strategy as it worked well last time when he compared two different sections of a river in geography, which had some similarities and some differences.

Therefore Ben gave some justification for the planned use of a Venn diagram by linking to work already undertaken in another subject.



Ben's next steps:
Can you think of any other strategies that may also have worked here? Have a look at your Thinking Log for some ideas.

Ben started by drawing a concept map to capture his ideas. He then transferred the information into a two circled Venn diagram. Both these strategies he chose himself. In the diagram he has compared the processes of respiration and combustion and made links between them.

From the information in his Venn diagram Ben decided upon his success criteria, which he used to write a piece of continuous prose. On completion he self-assessed his prose by checking against his success criteria and then made suggestions for improvement.

Success criteria

Checklist for success — What I did

- I should describe respiration in detail, naming gases, reactants and energy
- I should describe combustion in detail, naming gases, reactants, energy and fossil fuels.
- I should write the word equations for respiration and combustion
- I should always read over my work when I've finished
- I should describe the similarities
- I should describe the differences
- I should try to include as many scientific terms as possible.

1

Describe in detail any similarities and differences between the reactions of respiration and the combustion of fossil fuels.

The similarities are; that combustion and respiration both need oxygen for the reaction to take place. They also give off carbon dioxide and water. They are both exothermic reactions and they both release heat energy from chemical energy.

The differences between respiration and combustion are that; respiration uses glucose but combustion uses fossil fuels (oil, coal or gas). Glucose and fossil fuels are stores of chemical energy but they are different substances. Respiration gives off less ~~the~~ heat energy than combustion. Respiration occurs in living cells combustion doesn't.

Word equations;

Respiration glucose + oxygen → carbon dioxide + water

Combustion fuel + oxygen → carbon dioxide + wate

2

Comment on the quality of your work and on how it could be improved.

My answer is quite good but it could be improved by including more scientific terms. I could also describe combustion and respiration in more detail by including names of more gases and energys in the reactions. I should also read over my work when I've finished. I used the word equations and described the similarities and differences between respiration and combustion very well.

I think I'd like to use a 3-circle Venn diagram to compare respiration and combustion with photosynthesis.

3

Ben's next steps:
Look in your book at the work on Energy Transfers. Try to compare respiration and combustion in this way.

Ben used linked scientific knowledge and understanding gained from a variety of sources, including past work. He has started to refine his success criteria in the light of experience for future occasions by suggesting improvements to them. He reviews his strategy in light of his self-assessment by suggesting that he could use a three circled Venn diagram to compare these two processes with photosynthesis.

Historical reactions

Using and applying models enquiry

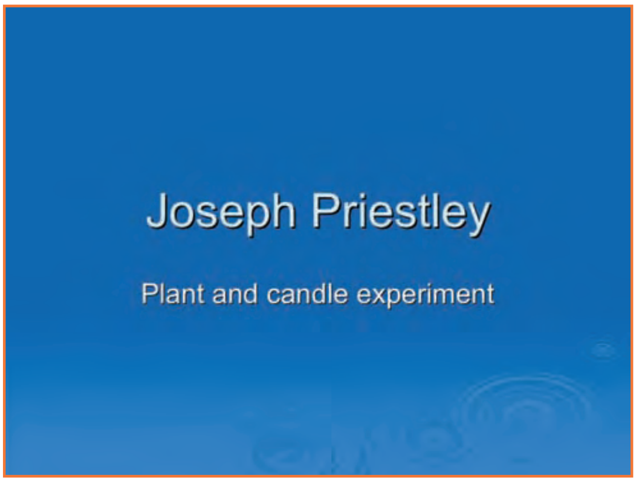
Skills
C2; ED3, 4, 7; ER4.

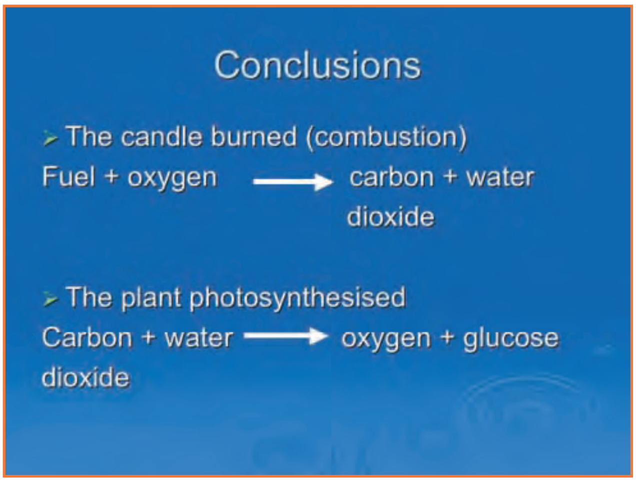
Range
IO7; TSE3, 5; HTW2.

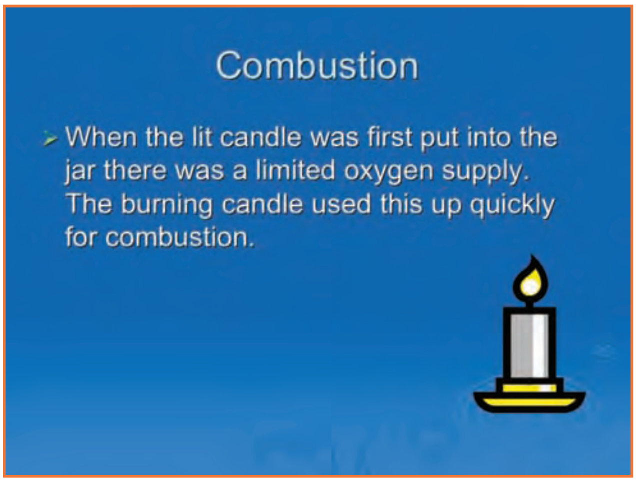
Further into the topic of 'Reactions', the class was given information about historical scientific experiments. Each group had a different experiment. Ben's group was given an experiment carried out by Joseph Priestley.

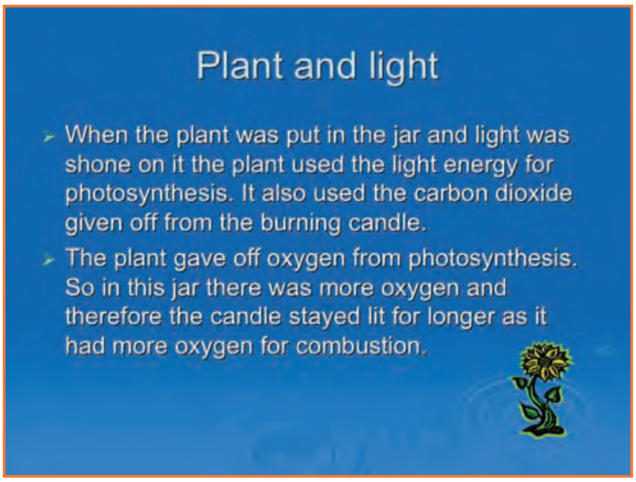
Joseph Priestley found that a lighted candle in a jar soon went out. He put a plant in a jar and shone a light on it for a week. He found that the candle now burned for much longer

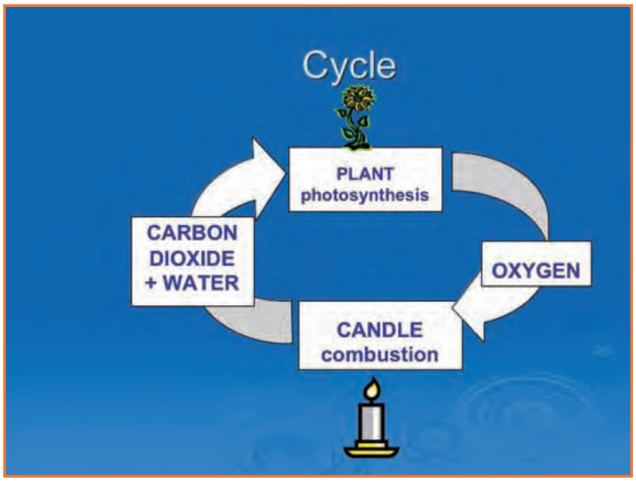
The group was asked to think about how to explain the experiment and present their findings to the class.

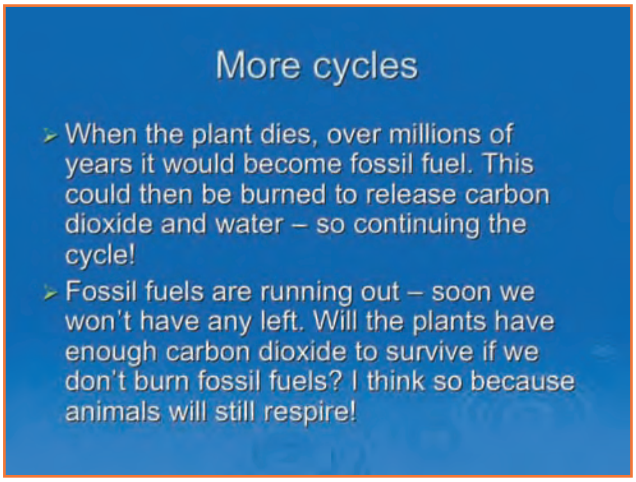


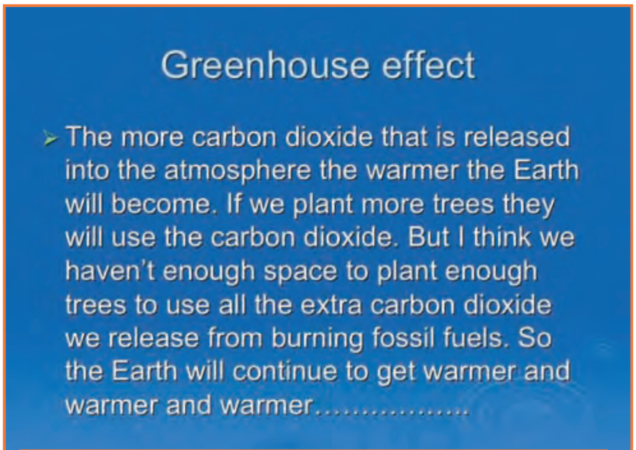












Ben presented his group's findings. He showed a good understanding in his presentation of how combustion and photosynthesis can act in a cyclical manner. He linked and applied abstract ideas not only of these processes but also he discussed fossil fuels and the greenhouse effect. He is starting to make predictions using his own explanations as to conditions on the Earth in the future. Therefore Ben is also linking his science learning to more abstract situations.

Ben's next steps:
Again look at Energy Transfers and compare combustion, respiration and photosynthesis.

How does the mass of magnesium added affect the temperature rise in its reaction with copper sulphate?

Fair test enquiry – (predicting only)

Skills
C2; EP2, 4.

Range
TSE4.

Still within the 'Reactions' topic, the class have moved on to learn about displacement of metals. They are planning to carry out an investigation into the temperature change when magnesium and copper sulphate react.

You have observed the reaction between magnesium metal and copper sulphate solution. How do you think that the mass of magnesium added will affect the temperature rise in this reaction?

Prediction
The greater the mass of magnesium metal the higher the temperature rise will be. I think there will be a point when the temperature rise is at a maximum because all the copper sulphate has reacted.

Why does this happen?
This is an example of a displacement reaction. A displacement reaction is one where a metal is more reactive than one in a salt so it takes its place. In this reaction magnesium is more reactive than copper so it will take copper's place in the copper sulphate. The word equation is:

copper sulphate + magnesium → magnesium sulphate + coppper

This reaction is an exothermic reaction. As it occurs it gives out heat energy.

So the more magnesium used the more displacement reactions can happen, more heat energy will be given out and so the greater the rise in temperature. But this will only be to a point when all the copper in the compound has been replaced with magnesium. On a graph the line would level out at this point. The problem that I might have will be with the surface area of the magnesium metal as it won't be easy to keep this the same. If there is more magnesium in contact with the copper sulphate then more displacement reactions can take place at the same time. I think this will mean that the temperature will rise faster but it should still reach the same highest temperature as the same amount of copper sulphate is used each time.

Ben's next steps:
Can you think of any ways in which these key variables could be controlled? You might like to think about links to other situations.

Ben made qualitative predictions using linked scientific knowledge and understanding gained from a variety of sources including past work on exothermic reactions and his observations of the teacher demonstration. With direct teacher questioning he could have made this a quantitative prediction. He also realised that although he was measuring the temperature rise, this variable would have an influence on the rate of reaction and he explained his reasoning. In this way he is identifying a key variable that may not be readily controlled and explaining why this is the case.

How does a space shuttle land?

Using and applying models enquiry

Skills
C1, 2; EP2, 3; ED3, 4; ER4.

Range
HTW2, 3, 4.

Within the topic of 'Space', Ben's class studied the space shuttle. Part of this work included trying to predict how a space shuttle lands. They had already studied the flight of an aeroplane.

How does a Space Shuttle land?

Think about and discuss in pairs how a space shuttle comes down from orbiting the Earth to land.

© NASA Space Shuttle Endeavour

The space shuttle orbits the Earth travelling at high speeds and held in orbit by gravity (gravitational pull to the Earth). It slows down and moves itself out of orbit so that it can come down to Earth. The weight of the shuttle pulls it down towards the Earth as this force is greater than the other forces acting on it. As the shuttle enters the atmosphere it is travelling so fast that some of its kinetic energy is converted to heat energy. Also it is constantly being hit by air particles at very high speed so this kinetic energy is converted to heat energy. As it speeds up it has more collisions with more air particles more often giving more heat energy. The shuttle needs to have a very strong covering of an insulating material to stop it from burning up on re-entry.

It needs to slow down very quickly when it lands so when it has landed it releases a parachute to slow down the forward movement ~~caused by its engines~~. ~~Because it's like an aeroplane it could put its engines into reverse to reduce the wear on the brakes.~~ As the shuttle moves forwards the air tries to stop it. This is air resistance, a sort of friction. The air particles are being hit by the shuttle which slows it down. Because the parachute is open there is more air resistance to slow down the shuttle. This is because there is more surface area in contact with the air particles. Friction is also caused as the tyres move across the ground this also slows down the shuttle.

Ben's next steps:
Review your work and try to look at the forces involved in each situation. How do they compare? Use your work on flight to help you.

Originally in his prediction of how a space shuttle lands, Ben applied abstract ideas and made links between physical phenomena. These included air resistance, kinetic energy converted into heat energy and the need for insulation to stop the shuttle burning up. He took these ideas further with research and redrafting so that he could explain how the space shuttle reduces its speed of descent to reduce the heat energy from collisions with air particles.

Can you work out work done?

Using and applying models

Skills
C1, 2, 3; EP2, 3, 5; ED2, 3, 4, 5, 6, 7; ER4.

Range
HTW4.

In the topic 'Energy and Work done' the class are given an enquiry to assess their understanding.

Work done

Look at the list of events below.

- You climbing to the top of Snowdon
- An Asian elephant walking 400m
- A new mini car travelling 5km
- You pushing against a brick wall for 30 minutes
- The Orbiter of the space shuttle taking off and reaching space
- You lifting a box from the floor to your desk
- The Moon buggy travelling 200m during the Apollo 17 Moon landing

Put the events in order with the most work done at the top and the least at the bottom.
Discuss your decisions with a partner and come up with a consensus view.

	Estimate
1. Orbiter taking off to space	millions J
2. mini car going 5km	hundreds of thousands J
3. elephant walking 400m	thousands J
4. me climbing up Snowdon	thousands J
gravity 1/6th 5. Moon buggy on Moon	hundreds J
6. lifting a box from floor to desk	10 J
7. pushing against a brick wall	0 J

What evidence could you use to support your decisions?
Note down the reference sources you use.

We estimated the work done to put them in order. Then we used the internet to find out the unknown measurements + calculated the work done.

1. orbiter mass = 109,000kg ≈ 1,090,000N (Force) } NASA website
distance = 560 km = 560,000m
work done = 610,400,000,000 J.

Autoexpress website

2. Mini car mass = 450kg ⇒ 4,500N (Force)

distance = 5km = 5,000m

work done = 22,500,000 J

3. Elephant mass = 4,000kg ⇒ 40,000N (Force; Elephant encyclopaedia website)

distance = 400m

work done = 16,000,000 J

4. Me up Snowdon mass = 62kg ⇒ 620N (Force)

~~wer~~ distance = 1,085m — Walk Snowdon website

work done = 672,700 J

5. Moon buggy mass = 209kg ⇒ 2,090N (Earth) (Force) — NASA website

So on Moon: 1/6th = 348N

work done = 348 x 200 = 69,600 J

6. Can't calculate this but a light box has a mass of about 1kg = 10N of force + it's about 1m from floor to desk so work done = 10 x 1 = 10 J.

7. Pushing against a brick wall – there's no work done as nothing moves.

So we put them in the right order but our estimations weren't really big enough.

Evaluate the reference sources, looking at bias, reliability and validity.

NASA website - hard to check reliability as this is the source of most of the information on the web. Maybe if we could speak Russian we could have looked at their space agency. Walk-Snowdon website could be biased to make people feel better having walked that far. Autoexpress probably not biased as they have no reason to be biased. Elephant Encyclopaedia – we used the middle of a range given for Asian elephants so this might not be accurate. It would be impossible to check validity of the data as we can't go out and measure the distances and masses ourselves.

Ben's next steps:
Draw a flow chart to show the strategies you have used in your Thinking Log. Could you have used any others?

Ben and his partner ranked the events and recognised that pushing against a brick wall does not constitute work done. They selected the strategy of estimation and calculated the work done in each event – using quantitative definitions and performing calculations using the correct units. However, the resultant force in the examples where the motion is horizontal could not be calculated by using weight. Therefore this shows only a partial understanding of the concept of work done. They have begun to evaluate their findings in order to gauge bias, reliability and validity. Although they haven't actually described how they might collect more information in order to check the validity of their conclusions they have recognised the need to do so.

Summary and overall judgement

Levels 6 and 8 were considered and Level 7 was judged to be the best fit.

Ben enjoys applying scientific ideas in new and novel ways. He applies his number skills in a variety of ways in science. Given challenging, rich tasks he excels.

Planning

Ben's profile shows that when **planning** an enquiry he can *suggest a strategy* (a feature of Level 6) in 'Can you work out work done?'. Here he estimates before calculating his answers but gives no justification for doing so. He *gives some justification for the strategy he plans to use* (a characteristic of Level 7), in 'Respiration and combustion.' He chooses to use a Venn diagram as he recognises that there are common elements in the two processes. He *makes qualitative predictions using linked scientific knowledge and understanding gained from a variety of sources* (a feature of Level 7) as evidenced in 'How does the mass of magnesium added affect the temperature rise in its reaction with copper sulphate?'. In the planning of this enquiry he also *identifies a key variable that may not be readily controlled explaining why this is the case* (a characteristic of Level 7).

Developing

When **developing** an enquiry Ben *uses some quantitative definitions and performs calculations using the correct units* (a feature of Level 7) in 'Can you work out work done?'. Had his ideas been further developed with focused questioning in 'How does the mass of magnesium added affect the temperature rise in its reaction with copper sulphate?' he could have evidenced *making quantitative predictions using detailed scientific knowledge and understanding* (a characteristic of Level 8). In the former enquiry he is *beginning to evaluate his findings in order to gauge bias, reliability and validity* (a feature of Level 7), and although he hasn't actually described how he *might collect more information in order to check the validity of their conclusions* (a characteristic of Level 7), he has recognised the need to do so. Ben *applies abstract ideas and makes links between processes or systems in explanations* (a feature of Level 7) in several enquiries, such as in 'Is Euglena a plant or an animal? Explain 'where he makes links between cell structure and photosynthesis. Also in

‘Historical reactions’ he applies and links the abstract ideas of photosynthesis and combustion and in ‘How does a space shuttle land?’ he applies and makes links between air resistance, kinetic energy and insulation. In ‘Historical reactions’ Ben *begins to use his explanations to make predictions* (a characteristic of Level 7) on the future of the Earth in the contexts of fossil fuels and the greenhouse effect.

Reflecting

When **reflecting** on an enquiry Ben *refines his success criteria in the light of experience for future occasions* (a feature of Level 7) as evidenced in ‘Respiration and combustion’. In the same enquiry he *reviews his strategy* (a characteristic of Level 7) and suggests how to amend it to suit a slightly different and more complex task. He *links the learning to more abstract situations* (a feature of Level 7) across his profile, for example in ‘Historical reactions’ as he develops his ideas on fossil fuels and the greenhouse effect and could be said to be *linking the learning to make further predictions* (a characteristic of Level 8).

Useful information and websites

Materials developed by or in conjunction with DCELLS

Skills framework for 3 to 19-year-olds in Wales

National curriculum Orders

Developing thinking and assessment for learning programme (WAG)

- Why develop thinking and assessment for learning in the classroom
- How to develop thinking and assessment in the classroom
- Developing thinking and assessment for learning poster

All these materials are available from the 'Curriculum and assessment' section at: www.wales.gov.uk/educationandskills

Aiming for Excellence: Developing thinking (BBC, Estyn, WAG) 2006
A coaching/training DVD pack.

Other useful references with websites

King's College London

- The ASE – King's Science Investigation in Schools Project (AKSIS)
  www.kcl.ac.uk (search for AKSIS)
- Cognitive Acceleration through Science Education (CASE)
  www.kcl.ac.uk (search for CASE)
- SKEES Project (Science Enhancement Programme – King's Enhancing Enquiries in Schools)
  www.kcl.ac.uk (search for SKEES)
- Talking to Learn, Learning to Talk in Secondary Science (ESRC: Principal Investigator: Professor Jonathan Osborne, King's College, London)
  www.kcl.ac.uk (Search for talking to learn)

The University of York (Nuffield Curriculum Centre)

- 21st Century Science
  www.21stcenturyscience.org

Encouraging experimentation and investigation in school science learning (NESTA) – Real Science
www.nesta.org.uk (search for Real Science)

Other publications

Improving teaching and learning in schools (TLRP, ESRC) 2006

Science Education in schools, Issues, evidence and proposals (TLRP: Gilbert, J (Ed)) 2006

Science Inside the Black Box
(Bethan Marshall, Jeremy Hodgen and Chris Harrison)
ISBN: 9780708714447/N0078

Scientific Enquiry materials (Cripsat, University of Liverpool) 2007 sponsored by WAG
ISBN: 978-0-9557200-1-7
www.cripsat.org.uk

The role of teachers in the assessment for learning (E) (Nuffield Foundation: Harlan et al) 2006
www.k1.ioe.ac.uk

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Ysgol Gyfun Cwmtawe, Neath
Ysgol Gyfun Gartholwg, Rhondda Cynon Taff
Ysgol Gyfun Gymraeg Bryntawe, Swansea
Ysgol Gyfun Llangefni, Anglesey
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