Framework for a Future Primary Science Curriculum

Recommendations from the Primary Curriculum Advisory Group to the Royal Society of Biology, the Royal Society of Chemistry, the Institute of Physics, and the Association for Science Education.

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Foreword

This framework is the outcome of the work we carried out as the Primary Curriculum Advisory Group (PCAG). This group was established by the Institute of Physics, the Royal Society of Biology, the Royal Society of Chemistry and the Association for Science Education (ASE) with a brief to produce advice and guidance about the future of the primary science curriculum.

We are a group of educators with significant collective expertise and experience in primary science education. Commencing in 2019 and continuing through the pandemic, we engaged in an iterative process to re-think the curriculum for primary science. We drew extensively on evidence from a wide variety of research sources and from many additional experts in the field. A draft version of the framework and associated guidance was shared at the ASE National Conference in January 2022, and was revised in the light of delegate responses and further feedback from Learned Society colleagues.

These are our recommendations in the form of a PCAG Curriculum Framework. It is both innovative and familiar and intended to be an essential basis of future discussions about curriculum design for primary science. We recommend it is used to inform the Learned Societies' and the ASE's publications relating to the school curriculum from early years to the end of secondary education.

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The Primary Curriculum Advisory Group

1. Introduction

The brief for the Primary Curriculum Advisory Group (PCAG) was to develop a curriculum framework that would form a suitable basis for the construction of relevant, contemporary and future-proof primary science curricula, to prepare children to understand their world, and meet individual and societal needs, both locally and globally. The framework was also required to coordinate with work led by the Learned Societies' development of frameworks in their respective disciplines: the Royal Society of Biology (2021), the Royal Society of Chemistry (2020), and Tracy (2018).

However, the importance of children's scientific education in this phase for its own sake, not just as preparation for secondary science, cannot be ignored, and therefore the specific value, characteristics and purposes of primary science learning are fully embraced in this curriculum framework.

The purpose of the PCAG Curriculum Framework is to:

- inspire educators by communicating a clear vision, aspirational aims and achievable objectives for a primary science curriculum;
- provide educators with a clear and concise description of intent and purpose for children's science learning during the primary phase;
- ensure that all schools will give all children an entitlement to a meaningful, relevant and empowering education in science;
- form the foundation from which curriculum developers organise and implement a whole-school contemporary curriculum for science learning, providing a basis for planning for progression in children's cognitive and affective development.

The Primary Curriculum Advisory Group (PCAG) was convened in March 2019, as a joint advisory group to the Institute of Physics (IOP), the Royal Society of Biology (RSB), the Royal Society of Chemistry (RSC), and the Association for Science Education (ASE).

2. Rationale for the PCAG Primary Science Curriculum Framework

The PCAG Curriculum Framework is underpinned by the principle that a curriculum needs to make clear what it is for and should therefore begin with overarching aims which are then filled out in greater specificity (Reiss and White 2013). Thus, the PCAG Curriculum Framework for primary science starts with vision and aims, rather than content. The vision and aims inform not just what is taught and learned, but why and how. The science content specified is therefore justified as worthwhile knowledge (Stenhouse 1975): this includes the conceptual content (biology, chemistry and physics), the nature and processes of science (how science knowledge is and has been developed), and the application of science (how it can and should be used). The emphasis on purpose means that the different elements must work together so that children develop a coherent and cognitively appropriate understanding of how the world works and their agency within it. This is increasingly important if children are to manage the impact of their developing understanding and awareness of the biodiversity and climate crises on their own mental health (Hickman, 2020).

This primary science curriculum framework lays the foundations for future learning in science, and in its own right, and is therefore relevant and cognitively appropriate for children aged 3-11 years. The curriculum aims are integral to a broader primary curriculum and they strengthen the rationale for the place of science within this.

3. Vision and Aims for the PCAG Primary Science Curriculum Framework

Vision

To enable the design of a contemporary primary science curriculum, this curriculum framework is underpinned by a wider vision for primary education where all children flourish and can take their place in the world as informed and responsible citizens, ready and able to meet the global challenges of sustainable and equitable living.

Aims

The overarching aims of global citizenship are integral to the aims of the PCAG Curriculum Framework. A global citizen is defined as someone who:

- has an understanding of how the world works, and a sense of their own place in it;
- takes responsibility for their actions;
- participates in their wider community, from the local to the global;
- works with others to make the world a more equitable and sustainable place;
- respects and values diversity.

Informed by: Science and Global Citizenship (ASE and Oxfam)

The purpose of the PCAG Curriculum Framework is to enable designers to develop a primary science curriculum to give children the knowledge and agency to be responsible global citizens. Each of these curriculum aims is key to this.

Children will:

- have positive experiences of learning science and develop an identity with the sciences;
- learn about the nature and practices of science;
- gain scientific knowledge about some established ideas and explanations across the three key disciplines of biology, chemistry and physics;
- understand how science ideas and explanations have been used, and are used and applied in everyday life in and beyond their communities.

The vision and aims are informed by the following evidence.

- Earth and humanity face global challenges which science can enable us to understand and meet (IPCC report 2022).
- Social justice issues within education. The need for equitable science education to enable all children to develop as scientifically literate and active citizens (Archer et al. 2015).
- "Education must develop every child's personality, talents and abilities to the full. It must encourage the child's respect for human rights, as well as respect for their parents, their own and other cultures, and the environment" (Article 29 - a summary of the UN Convention on the Rights of the Child; Unicef 1989).
- Educators should provide experiences that are meaningful, emotionally charged and imaginatively engaging, and have relevance now, not merely in the future (Dewey 1963, Egan 2008, Rinaldi 2006).
- There is a growing awareness of the impact on mental health, the distress, confusion and anxiety that follows increased awareness of the climate and biodiversity crisis generally, with concern often centred on how this is affecting children and young people (Hickman, 2020).

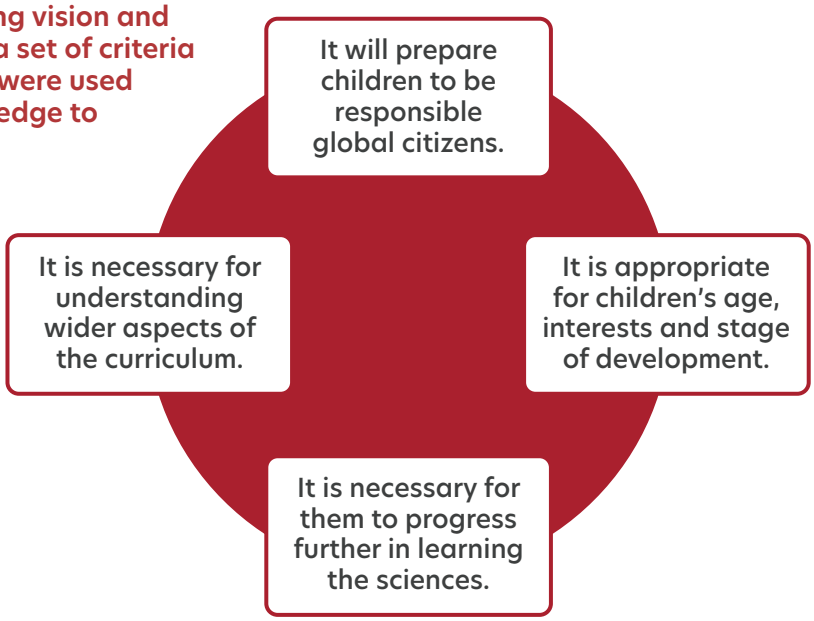
4. Development of a set of criteria to justify knowledge in the PCAG Curriculum Framework

This PCAG Curriculum Framework for primary science was constructed through an iterative process, by a small group of primary practitioners and academics, in regular consultation with a range of sector experts from the following fields:

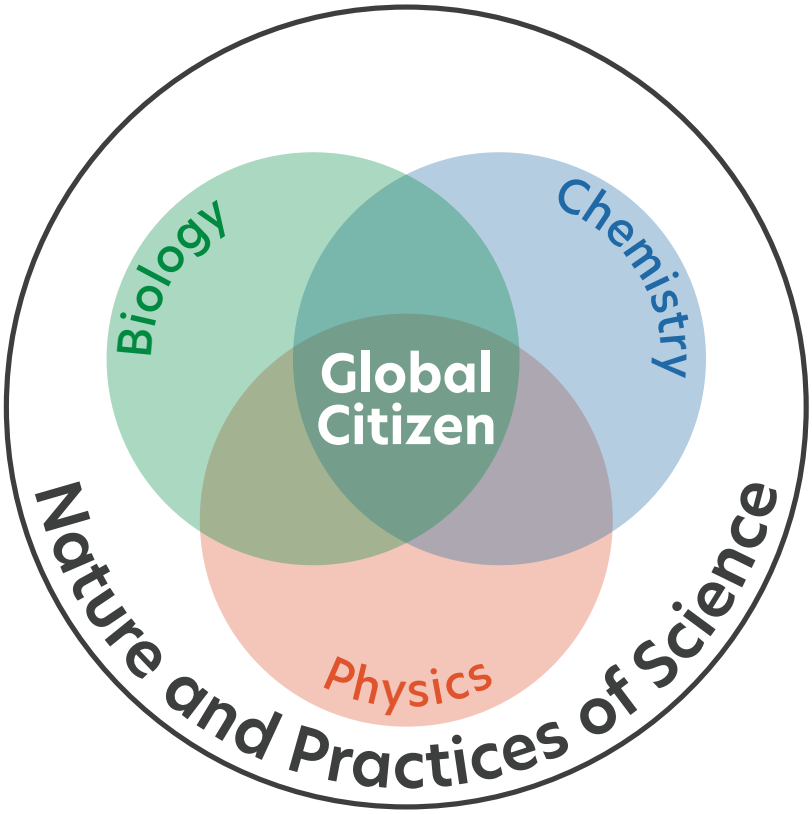
- primary and secondary science education
- the Learned Societies for science and history
- developmental psychology
- curriculum diversification
- curriculum design
- creativity in primary science
- early years

Once the overarching vision and aims were agreed, a set of criteria was created which were used to justify the knowledge to be included.

Importantly, science curriculum content from a wide range of jurisdictions was evaluated against these criteria. Notably, an open-minded approach to the activity was important to allow for the inclusion of content which does not fit into the historically agreed way of organising science curricula. Using the criteria as an organising principle resulted in some content that might be considered conventional not being included. Strenuous efforts were made to resist repeating 'historical' science curriculum content and organisation, although it is acknowledged that the work has been constrained by an epistemological rigidity inherited by the writers' own schooling and teaching experiences.



5. Structure of the PCAG Curriculum Framework



This PCAG Curriculum Framework consists of four knowledge maps.

The **PCAG Knowledge Map for the Nature and Practices of Science** has been compiled so that children gain first-hand practical and enquiry experiences, and can relate these explicitly to why they are undertaking them. As a consequence, primary children are taught about the nature and practices of science at an appropriate level.

Three subject knowledge maps - **PCAG Knowledge Maps for Biology, Chemistry and Physics**, which include key features.

a) **Understanding for global citizenship:** the overarching understanding about planetary well-being, including its inhabitants, that children need to develop as global citizens.

b) **Subject knowledge children need by age 11:** identified from traditional and new national curricula subject knowledge for biology, chemistry and physics.

c) **Equity and inclusion; essential experiences that all children must have by age 11:** which ideally should be first-hand, although virtual experiences are also useful to:
   i) ensure that the abstract ideas of science children learn about in the future are grounded in a real-life context, and
   ii) provide an equitable basis for learning so that all children have the opportunity to relate new learning to personal experience and are more likely to develop an identity with science.

d) **Conceptual boundaries:**
   i) to ensure parity across all age phases, and
   ii) to enhance consistent progression between primary and secondary school
   iii) so that more complex areas of science are taught at a cognitively appropriate point.

This curriculum framework is structured to give educators a clear understanding of the purpose of everything that the children will be learning, and to enable them to make this explicit to the children themselves. This will support children to build a comprehensive and cohesive understanding of key scientific concepts in the context of sustainable living and planetary survival. It will also allow them to see their learning in science as relevant to their lives and to their future selves. Children's participation and engagement in science is central to the curriculum, and this framework offers opportunities for the development of a curriculum that will actively promote awe and wonder and nurture curiosity.

A key feature of the PCAG Curriculum Framework is the inclusion of essential experiences. In learning to make sense of the world around them, children draw on evidence they have encountered throughout their lives. While there is huge variation within this between one child and another, children with limited first-hand experiences are undeniably at a disadvantage. This is a fundamental equity issue, and the provision of rich essential experiences for children (particularly in the early and lower primary years) will go some way in addressing this. These concrete experiences form a basis from which children can draw evidence for their ideas, making children ready for the more abstract learning they will encounter at secondary school. Repeated and progressive experiences can provide new evidence and challenge children's current thinking, instilling good scientific habits of mind.

There is an increased focus on children learning that science began before the European Renaissance and enabling them to reflect on the scientific endeavours of a global scientific community. The PCAG Curriculum Framework seeks to make explicit the contribution to science of multiple cultures and ethnicities, as well as minority and suppressed groups in particular societies.

Appendices to the Curriculum Framework have been included to provide examples of how the scientific knowledge could be contextualised and enriched to develop understanding for global citizenship. The final column of these extended versions of the three Knowledge Maps makes links to the behaviours of humans as they apply and extend scientific knowledge and develop new technologies. Human actions and innovations are listed along with impacts, both positive and negative. The positive agency of humans to mitigate negative effects through scientific and technological solutions is also recognised, providing children with examples of how societies and individuals can take action in line with global citizenship.

6. The Nature and Practices of Science

It is vital that as children develop as global citizens they understand how scientific knowledge has been created and used in the past, how it is created and used now, and the types of questions that the discipline can and cannot answer. The emphasis in the PCAG Curriculum Framework is on science as a human endeavour which is influenced by our global, historical, and societal context. A primary science curriculum should build an understanding of how ideas change over time, how knowledge produced by science has strengths and limitations, and how it informs the decisions that society makes. Children should learn to evaluate these decisions and their positive and negative implications on the people and the world around them. Through this, they will learn how to use evidence from science to inform their own decision making towards positive action in their own lives.

Learning about the nature and practices of science therefore includes, but is not limited to, developing a range of prescribed scientific skills.

The PCAG Knowledge Map: Nature and Practices of Science offers descriptors for what the discipline of science is, what children should know about how scientists work and the experiences children should have to enable them to understand and apply the nature and practices of science.

7. The PCAG Knowledge Maps

PCAG Knowledge Map: Nature and Practices of Science

The learning descriptors within this Knowledge Map were compiled using ideas from the Understanding Science resources from the University of Berkeley, the Scientific Habits of Mind (Çalik and Coll, 2012), and the OECD (2017) definition of scientific literacy.

The nature and practices of science:	This knowledge underpins children's understanding of how:	Equity and inclusion: all children should be taught to:
• Science is universal, has been and is carried out in all cultures at all ages, creating a diverse scientific global community.	• scientists apply what they know to inform decisions and solve problems related to local and global challenges.	• apply their scientific knowledge and findings to different contexts and problems, including personal, local and global.
	• science began before the European Renaissance, and has taken place across history and the globe.	• value and respond to the contributions of others within and beyond their own community.
		• learn about scientific endeavours throughout history with examples from different cultures and historical periods.
• Science is a creative human endeavour which builds new knowledge to explain natural phenomena.	• scientists make inferences, are curious and imagine possibilities.	• be curious, demonstrating a passion for discovery,imagining possibilities.
	• scientists observe to ask and answer scientific questions to build explanations about the natural world.	• ask, plan and answer their own scientific questions to explore possibilities and help explain the natural world.
	• scientists work through an iterative enquiry process, in which answering one question often leads to other questions.	• identify new questions that have arisen from an enquiry.
• Science is an empirically based process (based on or derived from observation of the natural world).	• scientists make observations and collect, analyse and interpret data to test their ideas.	• gather data by making and recording observations and measurements.
	• scientists identify links, patterns and relationships.	• analyse data to identify links, patterns and relationships.
		• understand how to differentiate between questions that science can or cannot answer.
• Scientific knowledge is tentative and subject to change based on new evidence or new interpretations of existing evidence.	• scientists present and explain their ideas and evidence, are receptive to new ideas and may not always agree with each other.	• present and explain their findings to a range of audiences, inviting peer-review on their conclusions.
	• scientists are sceptical, develop their ideas by using what they already know and new evidence.	• review and question their own ideas and understanding, as well as those of others, to appreciate that over time, areas of science can change and develop in response to new evidence.
• Science is a rigorous discipline where it is important to know how the evidence was collected and whether it can be trusted.	• scientists adhere to the accepted methodologies of enquiry and answer different types of scientific questions.	• use different enquiry methods to answer scientific questions.
		• design and evaluate enquiries in order to maximise the trustworthiness of their data.

PCAG Knowledge Map: Biology

Understanding for global citizenship	The scientific knowledge children need by age 11...
• Biodiversity and its value. • The role of animals, plants, microorganisms and soils in healthy ecosystems. • The role of animals, plants, microorganisms and soils in human survival and health. • The interdependence of animals, plants, microbes and soil.	**Plants and Animals (including humans)** • Identification and classification. • Structure and function. • Life cycles and reproduction. • Conditions for survival and health. **Microbes** • Identification and classification of different types of microbes including fungi. • Conditions for survival, and growth. **Soil** • Composition and function. • Natural cycles of death and decay. **Interdependence** • Food chains and simple food webs. • Ecosystems and habitats. **Evolution** • Adaptations to environments. • Variation within species. • Inheritance through sexual and asexual reproduction. • Natural Selection. • Extinction. • Fossil formation and fossil records. **Interdependence** • Food chains and simple food webs. • Ecosystems and habitats. • Adaptations. • Cycling of nutrients.

Equity and inclusion: essential experiences that all children must have by age 11	The conceptual boundaries
• Grow different plants (including digging in soil) including flowers from bulbs and seeds. • Visit a garden centre and talk to people who work there. • Visit, observe and handle a wide range of living things in local habitats, using all their senses to explore them. • Visit, observe and handle living things in contrasting habitats beyond their locality, using all their senses to explore them. • Visit and compare different habitats across the seasons. • Find out about habitats that are local, national and global. • Encouraging wildlife into their own environment, e.g. placing or building bird boxes, bug hotels, bird tables, log piles, etc. • Find out about life cycles of different living things, including first-hand experience e.g. strawberries, tomatoes, butterflies, human babies. • Be involved in making healthy lifestyle choices. • Grow plants, prepare and eat them. • Visit a food grower and/or retailer and talk to the people who work there. • Observe the weather and its effects at different times of the year. • Visit a farm and talk to people who work there. • Handle rocks, minerals and fossils. • Take part in local and national campaigns promoting community engagement in growing things and celebrating green spaces.	**What to include** • Classification at level of observable physical or behavioural features. • Structure and function at the level of the organism and organ. • Carbon dioxide in the air is used to build plant mass and that plants produce oxygen. • Oxygen is required for all life processes and carbon dioxide is a waste product. • Characteristics are inherited by individuals from their parent(s.) • Food chains and food webs described as what is eaten by what. **What not to include** • Classification beyond observable physical or behavioural features. • Structure and function at the level of cells and tissues. • The term and process of photosynthesis. • The term and process of respiration. • Nutritional analysis beyond a balanced diet. • The terms DNA and genes. • The structure of microorganisms and the mechanism for how they cause disease. • Food chains and food webs as energy transfer.

PCAG Knowledge Map: Chemistry

Understanding for global citizenship	The scientific knowledge children need by age 11...

• How materials improve lives, including: food, warmth, shelter, aesthetics, tools, trading.
• Why materials are suitable for particular purposes.
• Materials as finite or renewable resources.
• Impact of the extraction, production, use and disposal of natural and human-made resources.
• Conservation of matter.
• Influence of changing temperatures on the causes of natural disasters, the water cycle, weather, and climate change.
	Materials
	• Types and names of everyday natural and manufactured materials.
	• Properties.
	• Sources.
	• Disposal.
	
	Temperature
	• Temperature as a measurement of how hot or cold something is.
	• Ways of raising the temperature.
	
	Changes to materials
	• Physical Changes.
	  ◦ Changing state (reversible) caused by heating and cooling.
	  ◦ Making and separating mixtures.
	• Chemical Changes - reactions (irreversible) caused by:
	  ◦ Cooking and burning.
	  ◦ Combining materials.
	  ◦ Decay.

Equity and inclusion: essential experiences that all children must have by age 11	The conceptual boundaries
• Make things from different materials, including recycling. • Explore how materials float and sink. • Monitor and reduce waste within school. • Watch rubbish and recycling being collected. • Eat an ice lolly or ice cream, have an iced drink. • Play in puddles, handle ice and, if possible, snow. • Wash something (hair, clothes, other fabric, etc.) and dry it naturally and/or with a heat source. • Notice cooling water vapour in the air above hot water and draw pictures on a window/mirror with condensation. • Blow soap bubbles and bubbles through a straw and observe bubbles in fizzy drinks. • Explore materials that are a mixture of 2 states of matter e.g. shaving foam / squirty cream (liquid and gas) and sponges (solid and gas). • Handle different malleable solid materials e.g modelling clay, playdough, sticky tack, food doughs. • Handle powdery materials and other pourable solids e.g. flour, salt, rice, sand. • Explore liquids with different viscosities e.g. ketchup, water, treacle, shower gel. • Experience cooking and food preparation that involve change of state e.g. boiling something in water, melting and refreezing e.g. butter or chocolate, and irreversible changes, e.g. making a cake. • Take part in local and national campaigns promoting community engagement in repairing, reducing, recycling and reusing materials responsibly. • Get involved in local clean up initiatives in local parks, beaches, neighbourhoods etc. • Take part in improving local air quality and awareness through walk-to-school initiatives, cycling, and the use of public transport, etc.	**What to include** • Properties of materials: solid, liquid, gas, hardness, transparency, conductivity (electrical, thermal), magnetic, flexibility, elasticity, permeability, absorbency, porosity, mass in relation to size. • Terminology relating to measurement of temperature: what temperatures constitute "hot", "cold", "warm" in different circumstances. • Terminology relating to changing state: freezing, melting, boiling, condensing, evaporating. • Terminology relating to making and separating mixtures: dissolving, sieving, filtering. **What not to include** • Density, technical engineering language to describe properties, standard units for hardness, viscosity and conductivity. • Sublimation, other states of matter, particles and particle theory. • Terminology relating to measurement of energy: therm, joule, calorie. • Convection, radiation. • Energy or energy transfers.

PCAG Knowledge Map: Physics

Understanding for global citizenship	The scientific knowledge children need by age 11...	Equity and inclusion: essential experiences that all children must have by age 11
• Responsible uses of electricity. • Local and global consequences of using a particular source to generate electricity.	**Electricity** • Simple circuits- how they are constructed. • Different ways that electricity can be generated.	• Safely use electrical appliances and battery operated toys or objects. • Take part in 'switch off days' and energy saving campaigns.
• The importance of light for survival of life on earth. • The negative impact of light pollution. • The effects of UV light on humans.	**Light** • Sources - natural and artificial. • How we see objects. • Reflection and shadows.	• Experience complete darkness, and observe shiny and reflective objects in different light intensities. • Explore shadows and notice how they change during the day.
• The importance of sound for survival, communication and wellbeing. • The negative impact of sound pollution.	**Sound** • Vibrations and sources of sound. • Pitch and volume. • Sound insulation.	• Experience making sounds and music with different objects and instruments. • Listen to a musical performance, either live or on a video. • Listen to a range of sounds and music in different environments.

The conceptual boundaries

What to include

- Exploration of simple circuits, including multiple components.
- Terminology relating to electrical conductivity: conductor, insulator.
- Terminology relating to current and the need for a complete circuit: flow and charge.
- Terminology relating to voltage: push.

What not to include

- Measurement of current.
- Measurement of voltage.
- Terminology relating to naming series and parallel circuits.
- Resistance.
- Energy, energy transfers, or power, other than in everyday use.
- Electrons in relation to current.
- Standardised circuit diagrams.

What to include

- Terminology relating to objects and light: shadow, opacity, translucency, transparency.
- That we see when light enters our eyes.
- That we see an object when light from a source is reflected from the object into our eyes.
- Simple arrow drawings showing the direction of light from a source or an object to our eyes.

What not to include

- Complex light reflections and drawings of these.
- Refraction, prisms and white light splitting into a spectrum.
- Angles of incidence and reflection.
- Light waves.
- Energy or energy transfers.

What to include

- Terminology relating to production of sound: vibration, pitch, volume.

What not to include

- Terminology relating to production of sound: frequency, amplitude.
- Sound waves.
- Energy or energy transfers.

Understanding for global citizenship	The scientific knowledge children need by age 11...	Equity and inclusion: essential experiences that all children must have by age 11

• The importance of understanding forces for:
  • engineering;
  • impact of and mitigation of natural disasters.
	Forces
	• Types of force - push and pull.
	• Resistance forces - air, water and friction.
	• Contact and non-contact forces - gravity, magnetism and electrostatic.
		• Go to a playground and explore motion on swings, slides, roundabouts.
		• Play with a magnet and explore what is attracted to it.
		• Play with magnets or magnetic toys to feel attraction and repulsion.
		• Rub a balloon on their hair and stick it to a wall, or notice sparks when they take off a jumper.
		• Play with toy cars on a ramp and different surfaces.
		• Drop objects to explore how they fall in air and water.
		• Feel the resistance of air and water as they move their hands or bodies through it.
		• Play with objects in water, including pushing floating objects underwater.
		• Build things, using a range of materials, including making a lever and pulley.

• Understanding the Earth's place in the universe. • The importance of caring for our planet.	**Earth and the Universe** • The solar system within the universe. • Day and night. • Space exploration.	• Observe the Moon on different days/nights. • Notice the position of the Sun at different times of the day. • Use hand lenses and binoculars. • Watch videos of a space rocket taking off, moon landings and other space related film footage.

The conceptual boundaries

What to include

- Terminology relating to forces experienced in action: gravity, resistance, friction, buoyancy.

What not to include

- The difference between mass and weight.
- Explanations of balanced and unbalanced forces, e.g. how aeroplanes stay in the air.
- Explanations about the speed at which objects fall.
- Arrow diagrams to represent forces acting in different directions.

What to include

- The evidence for how we know that the Earth is rotating on its own axis.

What not to include

- Explanations for the phases of the Moon.
- An explanation for the seasons in relation to the tilt of the Earth.

8. Using the PCAG Curriculum Framework

PCAG Knowledge Map: Biology Appendix

Understanding for global citizenship	The scientific knowledge children need by age 11...	Equity and inclusion: essential experiences that all children must have by age 11
• Biodiversity and its value. • The role of animals, plants, microorganisms and soils in healthy ecosystems. • The role of animals, plants, microorganisms and soils in human survival and health. • The interdependence of animals, plants, microbes and soil.	**Plants and Animals (including humans)** • Identification and classification. • Structure and function. • Life cycles and reproduction. • Conditions for survival and health. **Microbes** • Identification and classification of different types of microbes including fungi. • Conditions for survival, and growth. **Soil** • Composition and function. • Natural cycles of death and decay. **Interdependence** • Food chains and simple food webs. • Ecosystems and habitats. **Evolution** • Adaptations to environment. • Variation within species. • Inheritance through sexual and asexual reproduction. • Natural Selection. • Extinction. • Fossil formation and fossil records. **Interdependence** • Food chains and simple food webs. • Ecosystems and habitats. • Adaptations. • Cycling of nutrients.	• Grow different plants (including digging in soil) including flowers from bulbs and seeds. • Visit a garden centre and talk to people who work there. • Visit, observe and handle a wide range of living things in local habitats, using all their senses to explore them. • Visit, observe and handle living things in contrasting habitats beyond their locality, using all their senses to explore them. • Visit and compare different habitats across the seasons. • Find out about habitats that are local, national and global. • Encouraging wildlife into their own environment, e.g. placing or building bird boxes, bug hotels, bird tables, log piles, etc. • Find out about life cycles of different living things, including first-hand experience e.g. strawberries, tomatoes, butterflies, human babies. • Be involved in making healthy lifestyle choices. • Grow plants, prepare and eat them. • Visit a food grower and/or retailer and talk to the people who work there. • Observe the weather and its effects at different times of the year. • Visit a farm and talk to people who work there. • Handle rocks, minerals and fossils. • Take part in local and national campaigns promoting community engagement in growing things and celebrating green spaces.

This document has been written to inform the instigators and developers of new curricula. It is not a curriculum, nor is it designed to be translated directly into schemes of work. It is a framework to support curriculum developers in creating curricula that start with and embody the vision and aims. The biology, physics and chemistry knowledge maps deliberately begin with understanding for global citizenship to guide the developer in viewing the scientific knowledge through this lens and framing curriculum statements accordingly. The essential experiences plus additional information in the appendices further support this. They can be used to inform progression in curriculum statements and to create additional guidance to enable the writing of schemes of work that will also weave in a secure progression in knowledge of the nature and practices of science.

The conceptual boundaries	Human behaviour and its impacts

What to include
• Classification at level of observable physical or behavioural features.
• Structure and function at the level of the organism and organ.
• Carbon dioxide in the air is used to build plant mass and that plants produce oxygen.
• Oxygen is required for all life processes and carbon dioxide is a waste product.
• Characteristics are inherited by individuals from their parent(s).
• Food chains and food webs described as what is eaten by what.
 	
What not to include
• Classification beyond observable physical or behavioural features.
• Structure and function at the level of cells and tissues.
• The term and process of photosynthesis.
• The term and process of respiration.
• Nutritional analysis beyond a balanced diet.
• The terms DNA and genes.
• The structure of microorganisms and the mechanism for how they cause disease.
• Food chains and food webs as energy transfer.
	Humans
	• alter, degrade and destroy natural habitats e.g.
	  • obtain raw materials from the natural world
	  • burn plants and fossil fuels
	  • make changes to land use
	  • practise intensive farming, animal breeding and monoculture
	  • use pesticides and fertilisers to increase crop yields
	  • import new species into existing ecosystems.
	• use hormones and antibiotics to increase growth rates of animals for food.
	• overuse, or inappropriately use, medicines and drugs.
	• overcome negative adaptations, e.g. invent glasses to correct poor eyesight.
	
	Impacts include
	• humans are able to live in different environments.
	• depleted animal and plant populations and species extinction.
	• increase in carbon released into the atmosphere (and lower uptake of carbon from it due to deforestation) leading to climate change - in turn exacerbated by further use of fossil fuels to combat effects, e.g. use of fuel for central heating/air conditioning.
	• increase in soil degradation, erosion, compaction and water logging, flooding.
	• loss of biodiversity and habitats.
	• unequal global access to food and healthcare, and increased risk of global food shortages.
	• introduction of pesticides, fertilisers and antibiotics to the food chain.
	• changes to human diets, including change to gut microbes, reduction in diet variation and development of allergies.
	• increase in antibiotic resistant microbes.
	• invasion or proliferation of harmful species of plants or animals.
	• transmission of animal diseases across species.
	• perpetuation of negative adaptations, e.g poor eyesight.
	
	Negative impacts mitigated by
	• reduction in use of raw materials from the natural world, reuse and recycling.
	• reintroduction of native species and rewilding and re-establishment of smaller fields and hedgerows.
	• monitoring and protection of biodiversity - Sites of Special Scientific Interest, extinction watchlists, formal classification systems, documenting of the fossil record, seed banks.
	• agriculture and animal farming innovations, e.g. hydroponics, vertical farming, companion planting, crop rotation, organic approaches including biological pest control, selective breeding,technological management of animal health and wellbeing.
	• production and consumption of more plant-based foods.
	• advances in medicine and healthcare, including improved hygiene and health education, vaccination, antibiotics, antivirals, antifungals.
	• medical advances to mitigate inherited and acquired conditions.
	• scientists and society collaborating to improve global health, e.g. developing and distributing global vaccines.

PCAG Knowledge Map: Chemistry Appendix

Understanding for global citizenship	The scientific knowledge children need by age 11...	Equity and inclusion: essential experiences that all children must have by age 11

• Why materials are suitable for particular purposes.
• How materials improve lives, including: food, warmth, shelter, aesthetics, tools, trading.
• Materials as finite or renewable resources.
• Impact of the extraction, production, use and disposal of natural and human-made resources.
• Conservation of matter.
• Influence of changing temperatures on the causes of natural disasters, the water cycle, weather, and climate change.
	Materials
	• Types and names of everyday natural and manufactured materials.
	• Properties.
	• Sources.
	• Disposal.
	
	Temperature
	• Temperature as a measurement of hot or cold something is.
	• Ways of raising the temperature.
	
	Changes to materials
	• Physical Changes.
	  ◦ Changing state (reversible) caused by heating and cooling.
	  ◦ Making and separating mixtures.
	• Chemical Changes - reactions (irreversible) caused by:
	  ◦ Cooking and burning.
	  ◦ Combining materials.
	  ◦ Decay.
		• Make things from different materials, including recycling.
		• Explore how materials float and sink.
		• Monitor and reduce waste within school.
		• Watch rubbish and recycling being collected.
		• Eat an ice lolly or ice cream, have an iced drink.
		• Play in puddles, handle ice and, if possible, snow.
		• Wash something (hair, clothes, other fabric, etc.) and dry it naturally and/or with a heat source.
		• Notice water vapour cooling in the air above hot water and draw pictures on a window/mirror with condensation.
		• Blow soap bubbles and bubbles through a straw and observe bubbles in fizzy drinks.
		• Explore materials that are a mixture of 2 states of matter e.g. shaving foam / squirty cream (liquid and gas) and sponges (solid and gas).
		• Handle different malleable solid materials e.g modelling clay, playdough, sticky tack, food doughs.
		• Handle powdery materials and other pourable solids e.g. flour, salt, rice, sand.
		• Explore liquids with different viscosities e.g. ketchup, water, treacle, shower gel.
		• Experience cooking and food preparation that involve change of state e.g. boiling something in water, melting and refreezing e.g. butter or chocolate, and irreversible changes, e.g. making a cake.
		• Take part in local and national campaigns promoting community engagement in repairing, reducing, recycling and reusing materials responsibly.
		• Get involved in local clean up initiatives in local parks, beaches, neighbourhoods etc.
		• Take part in improving local air quality and awareness through walk-to-school initiatives, cycling, and the use of public transport, etc.

The conceptual boundaries	Human behaviour and its impacts
What to include • Properties of materials: hardness, transparency, conductivity (electrical, thermal), magnetic, flexibility, elasticity, permeability, absorbency, porosity, mass in relation to size. • Terminology relating to measurement of temperature: what temperatures constitute "hot", "cold", "warm" in different circumstances. • Terminology relating to changing state: solid, liquid, gas, freezing, melting, boiling, condensing, evaporating. • Terminology relating to making and separating mixtures: dissolving, sieving, filtering. **What not to include** • Density, technical engineering language to describe properties, standard units for hardness, viscosity and conductivity. • Sublimation, other states of matter, particles and particle theory.	**Humans** • obtain raw materials from the natural world (plants, animals and minerals) e.g. by farming, logging, mining, oil drilling, fracking. • compete for finite natural resources. • manufacture new materials. • manufacture objects from raw materials, chosen for suitability, including single use objects. • burn fossil fuels. • dispose of or export waste for burning or landfill. • use technology to invent new materials that are fit for purpose, e.g. smart materials such as graphene, thermochromic and photochromic materials, hydrogels. **Impacts include** • humans are able to live in different environments. • habitat destruction. • depletion of renewable and non-renewable natural materials. • air, water, light and sound pollution. • increase in carbon in the atmosphere leading to climate change. **Negative impacts mitigated by** • systems for reducing waste and pollution, recycling and reusing materials and products. • use of sustainable sources for new materials, e.g. cellulose-based plastics. • making processes of obtaining raw materials more efficient and less wasteful and polluting. • developing materials as alternative energy sources to fossil fuels, e.g. biofuels. • scientists and society collaborating to prevent further climate change and mitigate the effects of changes that have happened or will continue to happen.

PCAG Knowledge Map: Physics Appendix

Understanding for global citizenship	The scientific knowledge children need by age 11...	Equity and inclusion: essential experiences that all children must have by age 11
• Responsible uses of electricity. • Local and global consequences of using a particular source to generate electricity.	**Electricity** • Simple circuits- how they are constructed. • Different ways that electricity can be generated. • How electricity is used.	• Safely use electrical appliances and battery operated toys or objects. • Take part in 'switch off days' and energy saving campaigns.
• The importance of light for survival of life on earth. • The negative impact of light pollution. • The effects of UV light on humans.	**Light** • Sources - natural and artificial. • How we see objects. • Reflection and shadows.	• Experience complete darkness, and observe shiny and reflective objects in different light intensities. • Explore shadows and notice how they change during the day.

The conceptual boundaries	Human behaviour and its impacts
What to include • Exploration of simple circuits, including multiple components. • Terminology relating to electrical conductivity: conductor, insulator. • Terminology relating to current and the need for a complete circuit: flow and charge. • Terminology relating to voltage: push. **What not to include** • Measurement of current. • Measurement of voltage. • Terminology relating to naming series and parallel circuits. • Resistance. • Energy, energy transfers, or power, other than in everyday use. • Electrons in relation to current. • Standardised circuit diagrams.	**Humans** • use natural resources to generate electricity. • change the natural environment through building, e.g. dams, power; stations, wind farms. • compete for natural resources. **Impacts include** • depletion of non-renewable energy sources. • air, water, sound and light pollution. • habitat destruction. • increase in carbon in the atmosphere leading to climate change. • unequal global access to electricity. **Negative impacts mitigated by** • technologies to generate electricity from renewable energy sources and to reduce dependency on non-renewable sources. • technologies to reduce pollution caused by generation of electricity. • making and using more efficient devices and reducing individual use of electricity. • international agreements on energy use and emissions.
What to include • Terminology relating to objects and light: shadow, opacity, translucency, transparency. • That we see when light enters our eyes. • That we see an object when light from a source is reflected from the object into our eyes. • Simple arrow drawings showing the direction of light from a source or an object to our eyes. **What not to include** • Complex light reflections and drawings of these. • Refraction, prisms and white light splitting into a spectrum. • Angles of incidence and reflection. • Light waves. • Energy or energy transfers.	**Humans** • use electricity for producing light, and to manufacture objects to provide light, e.g. candles, lamps, torches. • use artificial light to grow crops and rear animals. • Invent optical devices e.g. glasses, telescopes, microscopes, periscopes. • develop methods of UV protection. **Impacts include** • light pollution. • correction of vision defects and improved scientific observation. • see electricity section. **Negative impacts mitigated by** • use of blackout blinds and shaded streetlights; designated dark sky places. • see electricity section.

Understanding for global citizenship	The scientific knowledge children need by age 11...	Equity and inclusion: essential experiences that all children must have by age 11
• The importance of sound for survival, communication and wellbeing. • The negative impact of sound pollution.	**Sound** • Vibrations and sources of sound. • Pitch and volume. • Sound insulation.	• Experience making sounds and music with different objects and instruments. • Listen to a musical performance, either live or on a video. • Listen to a range of sounds in different environments, including sounds of nature and consider their responses.

• The importance of understanding forces for:
  • engineering;
  • impact of and mitigation of natural disasters.
	Forces
	• Forces are pushes and pulls.
	• The effects of forces.
	• Contact and non-contact forces - gravity, magnetism and electrostatic.
	• Resistance forces - air, water and friction.
		• Go to a playground and explore motion on swings, slides, roundabouts.
		• Play with a magnet and explore what is attracted to it.
		• Play with magnets or magnetic toys to feel attraction and repulsion.
		• Rub a balloon on their hair and stick it to a wall, or notice sparks when they take off a jumper.
		• Play with toy cars on a ramp and different surfaces.
		• Drop objects to explore how they fall in air and water.
		• Feel the resistance of air and water as they move their hands or bodies through it.
		• Play with objects in water, including pushing floating objects underwater.
		• Build things, using a range of materials, including making a lever and pulley.

• Understanding the Earth's place in the universe • The importance of caring for our planet.	**Earth and the Universe** • The solar system within the universe. • Day and night. • Space exploration.	• Observe the Moon on different days/nights. • Notice the position of the Sun at different times of the day. • Use hand lenses and binoculars. • Watch videos of a space rocket taking off, moon landings and other space related film footage.

The conceptual boundaries	Human behaviour and its impacts

What to include
• Terminology relating to production of sound: vibration, pitch, volume.
 	
What not to include
• Terminology relating to production of sound: frequency, amplitude.
• Sound waves.
• Energy or energy transfers.
	Humans:
	• use electricity for producing sound, and to manufacture objects to provide sound, e.g. radio, mobile phone, musical instruments.
	• compose, play, record and listen to music.
	• develop audible warning systems.
	• use ultrasound technologies in medicine and health.
	• use hearing aids and implants.
	
	Impacts include:
	• improved global and person to person human communication.
	• improved medical diagnosis and treatment.
	• sound pollution:
	  • disruption to animal communication and marine animals' echo-location systems
	  • human health and well-being: deafness due to exposure to loud sounds, loss of sounds of nature.
	• see electricity section.
	
	Negative impacts mitigated by:
	• use of sound insulation.
	• see electricity section.

What to include • Terminology relating to forces experienced in action: gravity, resistance, friction, buoyancy. **What not to include** • The difference between mass and weight. • Explanations of balanced and unbalanced forces, e.g. how aeroplanes stay in the air. • Explanations about the speed at which objects fall. • Arrow diagrams to represent forces acting in different directions.	**Humans:** • create the built environment. • invent and use tools and machines, e.g. levers and pulleys, aeroplanes, boats. • develop medical advances: MRI scans, wheelchairs, artificial limbs with moving parts to mimic human movement. • disrupt the climate. **Impacts include:** • improved medical diagnosis and treatment. • increase in accidents and disasters caused by humans. • potential increase in the frequency and severity of natural disasters - storms, tornadoes, hurricanes, earthquakes, tsunamis. • use of materials and fuels to support modern transport systems. **Negative impacts mitigated by:** • development of engineering technology to construct the built environment safely. • harnessing natural forces to generate electricity, e.g. wind turbines. • creation of defences and early warning systems for e.g. floods, earthquakes.
What to include • The evidence for how we know that the Earth is rotating on its own axis. **What not to include** • Explanations for the phases of the Moon. • Explanation for the seasons in relation to the tilt of the Earth.	**Humans:** • develop technologies for exploring space e.g. telescopes, rockets, space probes, satellites. • use natural resources to manufacture spacecraft and to send them into space. • use information from space probes and satellites to build knowledge of the universe. **Impacts include:** • depletion of non-renewable energy sources. • increase in carbon in the atmosphere leading to climate change. • space pollution. **Negative impacts mitigated by:** • invention of protective clothing for astronauts. • creation and launch of the International Space Station to provide data about the Earth and its climate, and about the effects of being in space on humans. • use of solar panels to generate electricity for satellites and the International Space Station. • international collaboration and treaties.

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