Sciences:
Concept development in the sciences

This material is for teachers to use alongside the experiences and outcomes as they plan for the development of learners' scientific knowledge, understanding and skills.

It describes progression in the development of knowledge and understanding of some of the scientific concepts which are contained within the experiences and outcomes as children and young people learn within a level and then move on to the next.

Line of development 01

The biodiversity and interdependence line of development (01) deals with survival of the species and adaptation to the environment. This is complemented by the inheritance line of development (14), which develops an understanding of how organisms develop and pass on genetic information to the next generation.

Evolution is introduced at the second level (**SCN 2-01a**), where learners relate the physical and behavioural characteristics of living things to their survival and extinction. They develop their understanding of the diversity of plants and animals by exploring a range of resources, including the local environment. They can explore simple adaptations which have taken place in plants and animals, such as features that allow flight and swimming, feeding mechanisms, and plant adaptations for drought or living on water. The concept of evolution can be introduced by studying the evidence of fossil records to develop an appreciation of organisms which have become extinct. Learners could study features which did not allow these organisms to survive in the changing environment e.g. flightless birds such as the dodo; and dinosaurs. Examples of living things under threat due to environmental changes can also be discussed.

The concepts of species diversity, distribution and adaptation for survival are further developed at third and fourth levels (**SCN 3-01a** and **4-01a**).

Line of development 02

At first level (**SCN 1-02a**), teachers can introduce simple food chains to show the feeding relationships between plants and animals. Learners begin to explore the importance of the sun as a provider of energy for plant survival at this stage.

At second level (**SCN 2-02a** and **2-02b**), learners develop an understanding of interactions and energy transfer between living things in food webs (i.e. interconnected food chains) and ecosystems.

They can consider the diverse variety of ways that plants have benefited society including as sources of energy (e.g. peat, fossil fuels), staple forms of food (e.g. rice, potato, wheat), useful materials from plants (e.g. wood, paper, rubber), uses in medicine, and in supporting diversity of life. At this stage, learners develop their awareness that plants are essential for oxygen production, as preparation for study of photosynthesis at third level.

The process of photosynthesis is introduced at third level (**SCN 3-02a**) and includes the production of carbohydrates as an energy source for animals as illustrated by practical activities.

Line of development 03

At second level (**SCN 2-03a**), learners can explore the role of fertilisers through practical activities involving, for example, house plant nutrient fertilisers. The effect of factors such as dilution of the fertiliser or use of different fertilisers can be investigated.

At third level (**SCN 3-03a**), learners grow plants using a variety of growth promoters and inhibitors to investigate ways in which plant growth can be altered. Learners could undertake research into the use of these and of alternatives, including the growth of genetically-modified (GM) plants. They can explore the role of pesticides, herbicides and fungicides. They could consider organic farming methods and compare these with the use of artificial chemicals and GM crops, enabling learners to develop informed views on the use of each.

At fourth level (**SCN 4-03a**), learners design an artificial fertiliser taking account of the major nutrients that are required by a plant for healthy growth i.e. nitrogen, phosphorus and potassium in appropriate proportions. They can consider the solubility of salts containing the major nutrients, and potential problems associated with their overuse. There are useful opportunities to develop numeracy skills, for example in the calculation of percentage compositions of simple fertilisers.

Line of development 04

At the early stage (**SCN 0-04a**), learners develop an awareness of different ways of supplying energy to 'make things go' through exploring a variety of battery-operated, wind-up and push-along toys. At first level (**SCN 1-04a**), they extend their understanding of forms and sources of energy, for example by considering heat and light from the sun, chemical energy in food and fuels, electrical energy from batteries and the electricity supply, and sound energy from musical instruments and audio devices.

At second level (**SCN 2-04a**), learners develop the idea of energy conversion through investigating simple devices which might include torch, electric motor, kettle and electric buzzer. Comparing different types of items, e.g. light bulbs, washing machines and televisions, could provide a practical context for examining wasted energy in the form of heat and how this might be reduced.

At third level (**SCN 3-04a**), learners investigate heat transfer in solids, liquids and gases – by conduction, convection and radiation – and have opportunities for designing energy-efficient systems such as those which might be used in the construction industry.

Line of development 05

The concept of the changing states of water can be developed progressively throughout the early and first levels (**SCN 0-05a** and **1-05a**), including the use of terms such as melting, freezing, boiling, evaporation and condensation.

At second level (**SCN 2-05a**), learners explore the water cycle in nature by applying their knowledge and understanding of changing states of water. They are introduced to the concept of matter existing in three major states (solid, liquid and gas) and should be able to describe some observable physical properties of each.

At third level (**SCN 3-05b**), learners investigate the main components of air and their relative abundance. They learn about and use tests for oxygen and carbon dioxide. They explore the production of carbon dioxide by the combustion of carbon-based fuels and the resulting impact on climate change. The process of respiration provides a basis for progression to **SCN 4-05b**.

Learners begin to develop an awareness of the importance of maintaining the balance of gases in the air at fourth level (**SCN 4-05b**), taking account of their learning of respiration and photosynthesis, and an appreciation of the effects of burning carbon-based fuels.

Line of development 06

At the first level (**SCN 1-06a**), learners will be able to link their observations of the apparent daily movement of the sun and moon, the phases of the moon over a lunar month and seasonal changes over a year, to the actual motions of the Earth's rotation about its axis and its orbital motion about the sun and the rotation of the moon about the Earth.

At fourth level (**SCN 4-06a**), learners explore how the advances in techniques for observing space, such as radio and optical telescopes, and optical and infra-red spectroscopy, have enabled astronomers to greatly extend knowledge of the Universe, leading to theories of its origins in the Big Bang, and the formation of elements in stars. They learn how space exploration has provided detailed information about the planets of our own Solar System.

Line of development 07

At the early and first levels (**SCN 0-07a** and **SCN 1-07a**), learners experience and explore the way objects move and use this to develop their vocabulary to describe forces, e.g. pushing, pulling, kicking, stretching, squashing and twisting. Through play, they can see and learn about the effect of forces on objects e.g. changing the shape of a spring or an elastic band, and changing the motion of a ball by speeding it up, slowing it down or changing its direction.

At second level (**SCN 2-07a**), learners can develop an understanding of friction through exploring different textures of surfaces and the force of pushing the surfaces together. They can develop their understanding of air resistance by studying objects which travel at high speeds (e.g. a racing cyclist or a downhill skier) or objects with large surface areas, such as a parachute. They can investigate methods of improving efficiency in moving objects, such as streamlining, and explore the effects of increasing or decreasing friction as a means of enhancing performance, for example in sports activities.

At third level (**SCN 3-07a**), learners further develop their knowledge and understanding of how surfaces and forces interact. Investigations of energy loss due to friction can lead to the exploration of methods that can be used to improve efficiency of moving systems.

At fourth level (**SCN 4-07b**), learners use accurate and appropriate methods for measuring speed – for example using light gates and electronic timers, ultra-sonic sensors, speed guns, videos of motion – extending to calculations of acceleration in situations where speed changes, e.g. motion down a slope, or under the action of an unbalanced force. They can then apply this knowledge to aspects of transport safety such as the braking distances of vehicles under different road and tyre conditions, and design features of cars to reduce the impact of forces on drivers and passengers in crash situations.

Line of development 08a

At first and second levels (**SCN 1-08a** and **SCN 2-08a**), playing with magnets introduces learners to forces which can act over a distance and helps them identify magnetic materials (most commonly iron, but also nickel and cobalt) and non-magnetic materials (e.g. aluminium, copper and brass, and all non-metals). At second level they develop their understanding of forces by exploring magnetic, electrostatic and gravitational forces as examples of forces which can act over a distance (i.e. the objects do not need to touch). An important distinction for learners is that they recognise that magnetic and electrostatic forces can attract or repel, while gravitational forces always attract. They learn that the force of gravity between two objects is normally only observed when one object has a very large mass e.g. the Earth or the sun.

At the third level (**SCN 3-08a**), learners investigate the relationship between the Earth's gravitational force on an object and its distance from the centre of the Earth, leading to predictions about, for example, changes in the weight of an object at different altitudes, the forces acting on a rocket launched into space, or on an orbiting satellite.

At fourth level (**SCN 4-08a**), learners develop an understanding of the factors affecting the strength of electromagnets, e.g. the number of coils, size of current, material and dimensions of core, and can use this understanding to compare their designs with electromagnets used in real-life applications.

Line of development 08b

At second level (**SCN 2-08b**), experiments on floating and sinking allow learners to identify materials which are lighter (less dense) or heavier (more dense) than water. They can carry out a practical challenge to design, construct and test objects made from more dense materials but which will float.

Line of development 09

From the outset and throughout this line of development, the need to work only with safe sources of electricity, e.g. low voltage batteries, is emphasised.

At first level (**SCN 1-09a**), learners construct circuits using very simple components, e.g. batteries, bulbs, connectors and switches, to appreciate that a complete conducting loop is necessary for circuits to work. They gain an understanding that a conductor is something that allows electricity to flow through it. At second level (**SCN 2-09a**), they further develop their understanding by exploring and constructing increasingly complex circuits using a wider range of components such as motors and buzzers. This begins to establish the concept of energy transfer (i.e. movement of electrical energy) round a circuit, and the conversion of electrical energy into other forms of energy in different components e.g. electrical energy into heat and light in a bulb.

At third level (**SCN 3-09a**), learners investigate the basic properties of series and parallel circuits and of electrical components to develop their understanding of everyday applications, such as the parallel wiring of domestic lighting systems. At fourth level (**SCN 4-09a/4-09b/4-09c**), learners develop an awareness of the interrelationship between current, voltage and resistance, understanding the part each plays. They will understand the properties of input devices such as variable and light-dependent resistors, thermistors and switches, output devices e.g. bulbs and LEDs, motors, relays, and processing devices such as transistor switching circuits. This enables exploration of electronic systems and their application in real-life situations.

Line of development 10

At second level (**SCN 2-10a**), learners develop the idea that some chemical reactions can produce an electric current (for example by using two different strips of metal and lemons/limes/potatoes), leading to an awareness that the electricity generated can be used to power an appliance such as a light bulb or potato clock.

At third level (**SCN 3-10a**), learners explore factors which affect the voltage (e.g. type of metal electrode, concentration of solution, type of solution, depth and distance between electrodes) and can investigate and compare ways of increasing the output voltage.

At fourth level (**4-10a and 4-10b**), learners explore the position of metals in the electrochemical series and their use to predict the size of voltage and direction of current in chemical cells. Prediction of displacement reaction results is also possible at this level. Learners could undertake research to develop an awareness of the latest developments in cell technology, such as fuel cells.

Line of development 11a and 11b

The concept of sound as waves is developed progressively from early to second levels.

At early level (**SCN 0-11a**), learners will initially investigate different sources of sound and begin to recognise some differences in the sounds produced, leading to them observing that all sounds originate from vibrations in **SCN 1-11a**, e.g. by 'twanging' a tuning fork or ruler, plucking a guitar string and beating a drum. This is less obvious with instruments such as a recorder, where air is made to vibrate in the mouthpiece. The link between changes in pitch and vibrations can be explored by changing the tension or the vibrating length of a guitar string.

At second level (**SCN 2-11a**), learners will understand the concept of the transmission of sound by waves in air, or other media such as water. This is probably best illustrated using a 'slinky' spring, where regular compressions and extensions of the coils can be seen to travel longitudinally along the length of the spring. This will help learners develop an understanding of the communication systems used by whales and dolphins and echo-sounding by bats.

At fourth level (**SCN 4-11a**), learners develop an appreciation that the appearance of wave patterns observed on an oscilloscope can be linked to changes in the pitch, volume and tone of sounds from different sources. ICT, especially in the form of digital audio editors, can be used to enhance the learner's experience.

Throughout **SCN 2-11b, SCN 3-11a, SCN 3-11b** and **SCN 4-11b** learners will progressively develop their understanding of light and other forms of electromagnetic radiation.

At second level (**SCN 2-11b**), learners can use, for example, coloured torches or stage lighting systems to illustrate practical applications of the properties of reflection and colour-mixing of light. This leads to learners using familiar optical devices such as spectacles, cameras, binoculars and microscopes to demonstrate applications of the use of lenses to bend the path of light rays in **SCN 3-11a**. They extend this understanding to consider forms of radiation beyond the visible, e.g. ultraviolet, infrared and x-rays, and how they impact on everyday life (**SCN 3-11b**).

At fourth level (**SCN 4-11b**), learners can develop their knowledge further by investigating other forms of electromagnetic radiation, leading to an understanding of differences and common properties, and to an awareness of the wide range of applications in medicine, telecommunications, astronomy, and industrial processes.

Line of development 12

Throughout this line of development, learners progressively develop their knowledge of the structure and function of organs of the body, including the senses.

At second level (**SCN 2-12a**), learners develop an understanding of cells as the basic units of life and their organisation to form familiar body systems. They study different body systems, their structure and function, e.g. the lungs, liver, heart and kidneys, and consider the factors which cause damage to these organs, for example too much fat or sugar in the diet or the effects of alcohol on the liver.

Also at second level (**SCN 2-12b**), learners develop an understanding of the way in which each sense organ works (for example, in the eye a lens focuses the light, in the ear the external part of the ear channels the sound into the ear) and can relate this to its structure. They can look at the ways in which the sense organs adapt to changing conditions e.g. what the iris of the eye does if the light is very bright or how people who are blind use braille. They can discuss their own memories of past smells and tastes and why this is so important to an animal's survival.

At third level (**SCN 3-12a**), they further extend their knowledge of the structure and functions of main organs and systems of the body, e.g. the exchange of gases in the circulatory system. Within the study of the digestive system, for example, the function of enzymes can be explored. In **SCN 3-12b**, learners explore ways in which technology can be used to monitor health, e.g. blood pressure and cholesterol levels, or screening for conditions such as diabetes or cancers. They can explore the implications of DNA analysis which could reveal information about predisposition to particular conditions. They can consider how the information might be used to give indications of how treatments or lifestyle changes might help to improve the future quality of life.

At fourth level (**SCN 4-12a** and **SCN 4-12b**), the principle of homeostasis can be studied using specific examples relating to, for example, maintaining stable body temperature and regulating blood glucose levels. Learners can consider the physiological mechanisms which maintain conditions within tolerable limits. Behavioural adaptations in animals might include interesting examples from local and extreme habitats e.g. woodlice, worms, birds, snakes, salmon, bears.

Line of development 13

At second level (**SCN 2-13a**), through practical activities carried out in a safe environment, learners can explore examples of microorganisms that are beneficial and harmful e.g. the use of yeast in bread making and the importance of bacteria and fungus in the breakdown of waste in compost columns. This can be further developed at third level (**SCN 3-13b**) to include practical activities to safely test for the presence of microorganisms in the local environment. The effects on growth of microorganisms of a variety of factors, such as temperature and disinfectants, can also be investigated. This leads on to the exploration of the use of microorganisms and enzymes in industry at fourth level (**SCN 4-13b**).

At fourth level (**SCN 4-13a** and **4-13c**), learners can develop an informed view on issues associated with, for example, in vitro fertilisation (IVF), pre-implantation genetic screening, transferring living cells, tissues or organs from one species to another (xenotransplantation), gene therapy, GM technology and stem cell therapy, considering why such procedures may be seen to be controversial and exploring people's opinions and concerns.

Line of development 14

At third level (**SCN 3-14b**), learners should consider the ethical implications associated with the collection, processing, storage, security and ownership of genetic information. They can investigate current and future uses of DNA profiling, along with surrounding controversies.

Line of development 15

Throughout this line of development, learners gradually develop their understanding of the connection between the structure and properties of materials.

At early level (**SCN 0-15a**), learners can choose materials for different uses based on their physical properties (e.g. strength, hardness, resistance to water). This is further developed in **SCN 1-15a**, where learners explore a more extensive range of materials and their physical properties (e.g. colour, hardness, texture, smell, shape, weight/mass). The basic properties of metals can be explored and related to their uses e.g. conduction of heat and electricity, hardness, shiny appearance, can be moulded. The sources of some of the Earth's resources can be explored e.g. wood, soil, water, minerals, fuels, metals.

Practical challenges might include building structures, such as towers or bridges, that will support the weight of an object.

At second level (**SCN 2-15a**), learners explore familiar changes in substances to produce other substances with different characteristics e.g. decaying of animal or plant matter, burning, cooking, rusting.

At third level (**SCN 3-15a** and **SCN 3-15b**), learners develop their understanding of the characteristic properties of metals and non-metals. By exploring elements of Group 1, 7 and 0, learners gain an introduction to the organisation of the elements in the Periodic Table. Common examples of compounds with properties that are different from their constituent elements provide further illustration of properties being changed. The correct use of symbols, formulae and equations should be introduced at this level.

At fourth level (**SCN 4-15a**), learners develop their understanding of the concepts of covalent and ionic bonding and resulting structures. They begin to understand how observation of properties can lead to models of possible structures at the atomic level.

Line of development 16a

At second level (**SCN 2-16a**), learners explore mixtures of substances and methods used to separate them into their constituent parts on the basis of their observable properties e.g. particle size, shape, magnetic attraction. This is developed further at third level (**SCN 3-16a**), where learners explore the difference between pure substances (elements and compounds) and mixtures. The selection of physical methods for separation of mixtures on the basis of physical properties is extended to include, for example, distillation and dissolution.

Line of development 16b

At second level (**SCN 2-16b**), learners participate in practical investigations involving dissolving and gain an appreciation of the importance of changing one variable at a time, e.g. temperature of water, physically changing the particle size, volume of water, stirring, to make the comparison fair. By third level (**SCN 3-16b**), learners can use the terms of solute, solvent and solution correctly in context, and understand the relationship between concentration and the relative amounts of solute or solvent.

At fourth level (**SCN 4-16b**), learners are introduced to the concept that mass is conserved during chemical change through practical and other activities such as the use of calculations involving balanced chemical equations.

Line of development 17

At second level and third level (**SCN 2-17a** and **SCN 3-17a**), learners progressively develop their understanding of the formation, characteristics and uses of rocks, minerals, sand and soil. Through practical activities in **SCN 3-17b**, learners can extract useful substances from natural resources e.g. metals from ores, dyes from plants or other materials, essential oils from plant material.

At fourth level (**SCN 4-17a**), learners explore common fractions from crude oil and their uses. They gain an appreciation of the importance of carbon compounds from crude oil to our lives.

Line of development 18

At second level (**SCN 2-18a**), learners explore common uses of water, for example as a solvent, coolant, heat source. They can participate in practical activities to clean different water samples, using a range of methods such as filtering, evaporating, use of filter beds.

At third level (**SCN 3-18a**), learners compare the properties of common acids and bases (for example, acids have a sour taste; bases have a bitter taste and slippery feel; strong acids and bases are corrosive; both acids and bases dissolve in water and react with indicators to produce different colour changes; acids and bases neutralise each other). Knowledge of the formation and naming of simple salts underpins this outcome. The implication of situations in which pH levels cannot be returned to normal levels can be discussed. Learners have opportunities to further develop the use of both word and formula equations based on their developing knowledge of chemical formulae.

Learners can collect and analyse samples collected from the environment (e.g. soil, air, water samples) in **SCN 4-18a**. They can use the results of analysis to present findings about the levels of pollution in the environment and present informed views about causes and effects. The use of data from a variety of sources can be incorporated into the learner's experience.

Line of development 19a

At second level (**SCN 2-19a**), learners safely carry out practical activities using readily-available chemicals e.g. household chemicals; they investigate chemical reactions leading to an understanding that a new substance is always made when a chemical reaction takes place.

At third level (**SCN 3-19a**), learners investigate the factors that can affect the rate of chemical reactions e.g. temperature, concentration, particle size and the use of catalysts and enzymes. Everyday examples can be used as context here.

At fourth level (**SCN 4-19a**), learners investigate further examples of chemical reactions and begin to explore where the extra energy comes from in exothermic reactions or where it goes in endothermic reactions. The practical application of such reactions should also be explored.

Line of development 19b

At third level (**SCN 3-19b**), learners explore the reaction of acids and carbonate rocks, and its consequences can be considered. Corrosion in general, and rusting in particular, should also be investigated. Simple physical methods of preventing rusting, environmental factors which increase the rate of rusting and the consequences of rusting should also be explored. Learners have opportunities to develop the use of both word and formula equations based on their developing knowledge of chemical formulae.

At fourth level (**SCN 4-19b**), learners establish an order of reactivity from the results of experiments involving metals and oxygen, water and acid. The use of certain metals to protect iron from rusting can be explored and related to their position relative to iron in the electrochemical series. Learners investigate methods of extracting metals from ores in relation to their positions in the reactivity series. The test for hydrogen gas can be introduced when exploring the reaction between metals and acid. Learners have opportunities to further develop the use of both word and formula equations based on their developing knowledge of chemical formulae and reactions.