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Integrated Science Syllabus – S1-S3

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1. General Objectives

The European Schools have the two objectives of providing formal education and of encouraging pupils' personal development in a wider social and cultural context. Formal education involves the acquisition of competences (knowledge, skills and attitudes) across a range of domains. Personal development takes place in a variety of spiritual, moral, social and cultural contexts. It involves an awareness of appropriate behaviour, an understanding of the environment in which pupils live, and a development of their individual identity.

These two objectives are nurtured in the context of an enhanced awareness of the richness of European culture. Awareness and experience of a shared European life should lead pupils towards a greater respect for the traditions of each individual country and region in Europe, while developing and preserving their own national identities.

The pupils of the European Schools are future citizens of Europe and the world. As such, they need a range of competences if they are to meet the challenges of a rapidly-changing world. In 2006 the European Council and European Parliament adopted a European Framework for Key Competences for Lifelong Learning. It identifies eight key competences which all individuals need for personal fulfilment and development, for active citizenship, for social inclusion and for employment:

1. Literacy competence
2. Multilingual competence
3. Mathematical competence and competence in science, technology and engineering
4. Digital competence
5. Personal, social and learning to learn competence
6. Civic competence
7. Entrepreneurship competence
8. Cultural awareness and expression competence

The European Schools syllabuses seek to develop all of these key competences in all pupils.

2. Didactic Principles

Integrated Science S1-S3 is compulsory for all pupils. The course builds upon the groundwork laid in the scientific and technological areas of Discovery of the World in the primary cycle. The objective is to equip secondary pupils with the toolbox of *concrete skills* (e.g., usage of basic instruments and equipment, dissection, drawing from observation), *subject content knowledge* (e.g., atoms as basic building blocks of matter, the basics of biological classification, the idea of an ecosystem, concepts of mass, energy, force, work, power), and *attitudes* (e.g., habits of scientific observation and experiment; acting as responsible citizens with respect to science) that they will need in the higher levels of science in S4-S7.

In years 4 and 5, science is taught in three of its constituent disciplines: biology, chemistry, and physics, all compulsory. In years 6 and 7, pupils have the choice of continuing any or all of these three disciplines at an advanced level. If they take no advanced science, they must take the biology 2 period option, providing a generalist overview for non-scientists.

The Integrated Science course is structured around a series of themes (see chapter 4), combining an introduction to scientific techniques and approaches with investigation of topics drawn from pupils' everyday experience.

Pupils should acquire the competences and concepts enumerated in section 3 for science and mathematics primarily by carrying out exploratory activities: observing, measuring, designing experiments and apparatuses, searching for explanations, discussing with peers and teachers, creating abstractions, models, hypotheses, and theories, and creating lab reports, presentations, and other work products. Under their teacher's active guidance, pupils should actively carry out a maximum of these activities themselves.

This approach to science and mathematics learning is referred to as ***inquiry-based learning*** (IBL). An overview of IBL can be found in the *PRIMAS* guide to inquiry-based learning in maths and science classes.[1] A useful and practical way to construct inquiry-based lessons is the "5E" lesson plan model.[2]

Pupils should carry out at least two substantial (≥10 class periods) inquiry-based learning units per year. While some possibilities are indicated in the syllabus content, IBL units may also be multidisciplinary and cover material drawn from across the year's syllabus or across the integrated science syllabus for all years; they may also be organised across subjects, by more than one teacher. Links to scientific competitions, the European Schools Science Symposium, for example, are also appropriate activities for IBL units.

3. Learning Objectives

Learning is not just acquiring more content knowledge. Content in a school context is used to give the pupils competences, to prepare them for society and work. This syllabus rests on a three-cornered foundation. Content topics are used to learn general key competences, to acquire specific scientific and mathematical competences, and to connect across disciplines with cross-cutting concepts, as modelled in the Next Generation Science Standards from the United States National Science Teachers Association.[3] The aim is to prepare pupils for lifelong learning. The boldface verbs used in the Learning Objectives column in section 4 refer to these competences and concepts.

3.1. Competences[4]

The competencies to be acquired by students are listed below. Consultation of Bloom's Taxonomy of Measurable Verbs is advisable when evaluating competences.

1. **Subject competences**
   The student is capable of critical analysis and use of scientific knowledge and vocabulary. The student has excellent graphing skills.

2. **Investigative work**
   The student can plan an investigation, selecting appropriate materials, equipment and techniques.

3. **Manipulation skills and safety**
   The student has developed excellent manipulation skills and considerable attention to safety concerns.

4. **Digital and information competences**
   The student can consistently independently find, and assess the reliability of, information on scientific subjects, on- and offline. S/he can independently use appropriate software for science tasks.

[1] https://primas-project.eu/wp-content/uploads/sites/323/2017/11/primas_final_publication.pdf
[2] The framework of 5E lesson plans is described at http://ngss.nsta.org/designing-units-and-lessons.aspx
[3] See http://ngss.nsta.org/About.aspx
[4] The competences described in this chapter are defined with reference to the highest level expected to be achievable by pupils in the first cycle (see chapter 5.1, "Attainment Descriptors").

5. **Communication (oral and written)**
   The student communicates clearly using scientific vocabulary correctly. S/he demonstrates excellent presentation skills.

6. **Teamwork**
   The student works constructively as a team member, shows initiative, and can act as a team leader.

Globally, students should develop awareness of the environment and learn to act as responsible citizens with respect to it.

3.2. Cross-cutting Concepts

This list of cross cutting concepts is shared by all science and mathematics syllabuses. This list is based on the U.S.A. “Next Generation Science Standards”.[5]

1. **Patterns**
   Patterns in forms and events guide organization and classification, and prompt questions about the factors that influence them.

2. **Cause and effect**
   Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. **Quantification**
   Scientists try, whenever they can, to turn data into numbers, because doing so allows them to use the great tool box of mathematics to explain, interpret, and create new avenues of inquiry.

4. **Representing data**
   Scientists choose among many ways to represent data and conclusions, including graphs, mathematical models, drawings from observation, preservation of specimens, etc.

5. **Scale, proportion, and quantity**
   In considering phenomena, it is critical to recognize what is relevant at different measures (e.g., size, time, or energy) and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

6. **Systems and system models**
   A system is an organized group of related objects or components, models can be used for understanding and predicting the behaviour.

7. **Energy and matter**
   Tracking fluxes of energy and matter into, out of, and within systems helps one understand the system's behaviour.

8. **Structure and function**
   The way in which an object is shaped or structured determines many of its properties and functions.

[5] See http://ngss.nsta.org/CrosscuttingConceptsFull.aspx

9. **Stability and change**
   For both designed and natural systems, conditions that affect stability factors that control rates of change are critical elements to consider and understand.

10. **History and nature of science**
    Scientists have developed the rules for scientific investigation over centuries, including: scientists must explain their methods of investigation, share their data, and let other scientists critique their conclusions (the principle of peer review). Scientists’ choices about what and how to investigate, how to explain results, and how to act on their understanding, are informed by their societal contexts. Scientific explanations (theories) are always provisional and subject to rejection or revision on the basis of new evidence and interpretation.

4. Content

4.1. Topics

S1: **1.1. Science Lab** - an introduction to the pleasures of scientific discovery, including: science as a set of rules and procedures to generate reliable knowledge about the natural world; the importance of a universal measurement system; the SI system of units; the contents of a scientific laboratory; lab safety precautions and procedures; the use of instruments; and the basics of experimental design and technique.

1.2. Food, Cooking, and Nutrition - the basic biology and chemistry of living organisms; the basic physics and chemistry of cooking using the techniques of heat, acid, salt, and fermentation; and a fundamental overview of nutrition science, including issues related to food labelling and marketing. The theme culminates in a capstone project: designing, and, if possible, cooking and eating a healthy and delicious meal with family and friends.

1.3. Sports - This section uses sports as an entry point to basic kinematics. Sports are also treated from the point of view of their effects on human health.

1.4. Puberty and Sexuality - An overview of the physical and emotional changes of puberty, followed by the anatomy of human reproductive systems; pregnancy and birth; understanding of contraception and protection against sexually transmitted infections; and the elements of healthy sexual relationships.

S2: **2.1. Our Place in the Universe** - An exploration of the universe, from intergalactic to atomic scales, including: our neighbourhood (the solar system); light and telescopes; the emergence of life on Earth and the possibility of it elsewhere; and atoms as building blocks of matter and the fundamental unit of chemistry.

2.2. *Mens Sana in Corpore Sano* (A Healthy Mind in a Healthy Body) - The elements of healthy living, including diet, exercise, and social aspects. The transmission of infectious diseases and means of preventing them. Environmental and systemic diseases. Dependency and addiction. Tobacco as an individual and social cause of death.

2.3. The Senses - An overview of the five human exteroceptic senses (vision, hearing, touch, taste, and smell), proprioception, and interoception, exploring issues in physics, chemistry, biology, and neuroscience. A final section treats animal senses not possessed by human beings.

S3: **3.1. Machines and How They Work** - The unit introduces the fundamentals of mechanics and the construction of idealised physics models, building from the basic concepts of force, work, and energy, through phenomena of electricity and magnetism, to offer an optional capstone project: building and programming a simple robot.

3.2. Our Living Earth - Beginning with the global effects of human production and consumption, students will analyse key parameters of ecosystems. They will be introduced to the principles of biological classification and explore issues related to biodiversity and sustainable development. An optional capstone project offers students the opportunity to carry out and write up autonomously a complete scientific investigation.

4.2. Tables

All parts in this syllabus are framed to put pupils at the center of the action, emphasized by the column headings:

Theme	***Subject content*** ***Pupils will learn about…***	***Learning objectives (and limits)*** ***Pupils will be able to…***	***Activities*** ***Pupils may do…***
The syllabus proposes organisation around a set of "Themes." This organization of themes should be understood as the default. *The subsections are to be understood as thematic rather than pedagogical. While being sure to introduce all learning objectives within a theme, teachers are free to follow the order of their choice.*	A broad overview of the scientific content belonging to the overall theme given in the first column. Content may be broken down into subsections as appropriate.	The roadmap for lesson planning, structured around the skills and subject knowledge that pupils should acquire as part of the syllabus. (Parentheses) indicate limits on the objectives, usually to specify the maximum level of technical knowledge required. Learning objectives are framed around verbs, in **bold**. Lessons should be designed so that pupils themselves carry out the action of these verbs.	"Suggested activities/*pupils may do*" provides a list of possible classroom activities the teacher may use to meet the learning objectives. Teachers are free to use some but not all of the activities, and to use other activities instead of or in addition to these. <u>Teachers must, however, always put hands-on student activity at the center of Integrated Science. Teaching should be through inquiry-based (IBL) approaches whenever possible.</u>

1.1. Science Lab *An introduction to the pleasures of scientific discovery, including: science as a set of rules and procedures to generate reliable knowledge about the natural world; the importance of a universal measurement system; the SI system of units; the contents of a scientific laboratory; lab safety precautions and procedures; the use of instruments; and the basics of experimental design and technique.*	**1.1.1. What is science?** …how science works to produce reliable information about the natural world	**deduce** and **discuss** the general rules scientists use to produce reliable information about the natural world: - scientists have to explain exactly how they do their investigations - scientists have to share all their data - scientists have to explain their data - scientists have to let other scientists critique their results - scientists have to be ready to change their ideas as a result of new data - the result is that scientific knowledge is constructed by scientists working together as a team, discussing and arguing until they come to solid agreement about how the natural world works	• discuss science and scientists: e.g., elicit pupils' ideas about what science is and isn't, what scientists do in their everyday lives, what makes scientific knowledge similar to and different from other kinds of knowledge, etc.
	1.1.2. Measurement and units. …decimal and duodecimal measuring systems …the need for a universal system of measurement in science …the principles of the SI measurement system …the most common SI prefixes and how to convert among them	**discuss** why scientists quantify whenever possible **model** the difficulties inherent in a situation in which different actors are measuring using different units **compare** and **contrast** the advantages of base-10 and base-12 measurement systems **construct** a measuring instrument (e.g., a thermometer) from scratch and decide on and **calibrate** a scale for it **distinguish** between accuracy and precision in measurement **deduce** that a universal system of measures is required for scientists to be able to share and compare data easily and transparently **understand** that scientists use the metric system/SI units (*Système international d'unités*) as a universal system for measurement **recognise** that larger and smaller units are created from a base SI unit using decimal prefixes (pupils should know the meaning of and be able to convert among *kilo-, hecto-, deca-, deci-, centi-, milli-, micro-*, and **know** how to find further prefixes and their meanings if necessary)	• assign pupils to represent different cities using different lengths under the same unit name, pre-metric system, then buy and sell e.g., cloth, to represent difficulties and opportunities of nonstandardised measures • discuss the elements of older measurement systems that still remain in common everyday use (e.g., *dozen*, *livre* (Fr), *Pfund* (De), *stone, tonne, teaspoon, knot*) or in scientific contexts (*calorie, astronomical unit*) • discuss who benefits and who loses from standardised measurement systems • research and present the history of the metric system • practice converting among decimal units, using names (e.g., meters-kilometers-centimeters-micrometers) • use objects (e.g., apples) to divide a dozen into 1/4, 1/3, 1/2, 2/3, 3/4 • use parts of the body (feet, forearms) to measure and compare lengths in and outside the classroom

	1.1.3. A science lab. …basic scientific instruments and techniques …safety issues in a laboratory …how to design a controlled experiment	**recognise** and **name** basic laboratory instruments (includes: thermometer, scale/balance, hand lens, microscope, telescope, beaker, Erlenmeyer flask, graduated cylinder, stopwatch, meter stick, protractor, funnel callipers, pipette, electric or Bunsen burner, etc.) **model** laboratory safety behaviour **explain** laboratory safety and warning icons **make use of** basic laboratory equipment as part of experiments to **measure** volume, time, mass, length, temperature, angles **design** and **carry out** one or more controlled experiments to investigate a simple question using some of the above equipment **recognise** sources of experimental error arising from measurement techniques **discuss** methods of compensating for experimental error (e.g., taking an average of many measurements) **carry out** experiments solo, in pairs, and in teams	• all equipment should be introduced in the context of simple IBL investigations (see section 2.2) • make posters explaining instruments, safety icons, and appropriate laboratory behaviour • make a map of the school using meter sticks, tape measures, and graph paper • make technical drawings of lab equipment including dimensions, mass, etc. • measure dry and soaked beans using calipers • design controlled experiments to, e.g., - test whether its temperature matters when measuring the volume of water - test whether its temperature matters when measuring the length of a metal rod - test whether all observers measure a runner's time with stopwatches the same way

1.2. Food, Cooking, and Nutrition *The basic biology and chemistry of living organisms; the basic physics and chemistry of cooking using the techniques of heat, acid, salt, and fermentation; and a fundamental overview of nutrition science, including issues related to food labelling and marketing. The theme culminates in a capstone project: designing, and, if possible, cooking and eating a healthy and delicious meal with family and friends.*	**1.2.1. Food** …why we need to eat …what we're made of …what we need to eat …how we know if something is food	**hypothesise** why animals need to eat (they need raw material to build themselves with and they need energy to run themselves) **compare** and **contrast** how animals and plants obtain energy and nutrients **know** that all living things are mostly made of water **name** the additional principal kinds of molecules organisms are made of (limited to: proteins, fats, carbohydrates [for plants]; no chemical or structural formulas) **recognise** that these three kinds of molecules comprise the three macronutrients we need to eat substantial amounts of every day **give examples of** foods containing large amounts of each of these three macronutrients **understand** that humans also need to eat two categories of micronutrients: minerals and vitamins **discover** the five basic flavours tasted by the human tongue (salt, sweet, sour, bitter, and umami) **explore** how humans—and all animals—use their senses (smell, taste, sight, and touch) to determine whether something is food **investigate** and **explain** conditions under which food spoils **design a controlled experiment** to test hypotheses about food preservation methods **recognise** that humans—unlike all other animals—process their food using cooking techniques (to make food tastier and to increase its nutritional value)	• design investigations to test how (nontoxic) alterations to food (e.g., colour, bitterness, consistency) change perceptions of its edibility • experiment with context-dependence of smells • experiment with detection of food spoilage by smell and sight • microscopic observation of spoiled/mouldy food: e.g., *Penicillium* and other moulds • controlled experiments on conditions leading to food spoilage (e.g., temperature, open vs. sealed, sterilisation/pasteurisation, salt/sugar concentration) • perform Francesco Redi's (1668) controlled experiment on spoilage

	1.2.2. Cooking – general …phase changes in water and other substances …heterogeneous and homogeneous mixtures …mixtures used in food	**design an experiment** to **describe** and **measure** the changes in water (volume, phase) when heated from ice to steam **recognise** and **name** the three phases of matter (solid, liquid, gas; no plasma) **describe** the principal characteristics of each phase **recognise** that foods consist of mixtures of substances **differentiate** between heterogeneous and homogeneous mixtures **prepare** and **identify** some mixtures used in foods **recognise** that the volume of a mixture may be different from the volume of its components **make** at least one liquid and one solid mixture	• experiment with phases of water • make popcorn to illustrate energy release and pressure from water turning to steam • design and build a thermometer (if not done in theme 1.1, “Science Lab”) • make macro mixtures such as trail mix/gorp (“Studentenfutter”) and separate them back into their components • compare freezing and boiling of salt water and distilled water • make an emulsion such as mayonnaise
	1.2.3. Basic cooking techniques – heat …the most basic cooking method …three ways of cooking food with heat: conduction, radiation, and convection …the differences resulting from cooking food with heat	**explore** and **measure** different types of heat transfer (conduction, radiation, convection—microwaving and induction not required) **experiment** with several methods of cooking making use of different types of heat transfer (e.g., grilling, baking, boiling, steaming, pan frying, deep frying) **compare** the flavours and other characteristics (e.g., colours, textures) of uncooked and cooked foods	• explore and measure different types of heat transfer using laboratory apparatuses • observe the Maillard reactions occurring when carbohydrates and proteins are cooked together at high temperatures (over about 115ºC) and analyse results in flavour, colour, texture, etc. • observe the caramelisation of sucrose and/or other sugars • cook egg white to observe changes to proteins (denaturing) when heated • cook one foodstuff (e.g., carrots or other suitable vegetable) using three or more of the principal methods of cooking using heat (grilling/broiling; baking; boiling/simmering; steaming; pan frying/sautéing; deep frying) to compare differences in flavour, texture, appearance, etc.

	1.2.4. Basic cooking techniques – acid …acids, bases, and the pH scale …the use of pH indicators …acids as another method of “cooking” food and as a method of food preservation	**explore** the sensory experience of acidity and alkalinity in foods **discover** that humans like many kinds of acid flavours but that that few foods are alkaline, as humans find these flavours unpleasantly bitter and unpalatable **define** the pH scale as a means of measuring alkalinity and acidity (no chemical definitions of acids/bases required) **experiment** with pH indicators of various types **create** foods “cooked” using acids and **understand** that human appreciate such foods for their flavour and for the antimicrobial preservative properties of acids	• make and experiment with red cabbage pH indicator to test an array of substances (foods and others) and calibrate a pH scale • experiment with neutralization using red cabbage or other indicators • make acid-“cooked” foods such as directly acidified (non-fermented) pickles or escabeche • “cook” a whole egg in the shell in acid such as vinegar
	1.2.5. Basic cooking techniques – salt …salt as an essential mineral …chemical solutions, chemical concentration …crystallisation …salt as a flavour enhancer …salt as a food preservative	**recognise** that salt is the only inorganic mineral we regularly consume **understand** that salt is essential for our biochemistry, and that animals evolved specific taste receptors for it because it was rare and valuable **prepare** salt solutions of different concentrations and **measure** and **observe** their properties **observe** and **explain** the formation of salt crystals by evaporating brine **compare** flavours of a food when unsalted and salted **produce** foods depending on the chemical properties of salt (e.g., salt pickles, cured sausage, sauerkraut—see also 1.2.6, “Fermentation”)	• practice making solutions of different concentrations using salt • observe changes occurring in foods (e.g., vegetables) when placed in salt brines of different concentrations • crystallise salt from brine • taste different forms of salt (e.g., fine salt, coarse salt, refined salt and unrefined sea salts, fleur de sel, Maldon salt) and compare their flavours and the effects of crystal size on the palate • compare flavours of unsalted and salted foods (e.g., vegetables) • design a controlled experiment to demonstrate the antimicrobial properties of salt • prepare a food (e.g., salt pickles) whose results depend primarily on the properties of salt

	1.2.6. Basic cooking techniques – fermentation **This section is optional and may be used as an IBL unit** …fermentation as a process carried out by living microorganisms …alcoholic fermentation by yeast and its products …lactic acid fermentation by bacteria and its products	**know** that all types of fermentation are carried out by living microorganisms **deduce** that fermentation is a type of controlled or desirable spoilage **observe** alcoholic fermentation by yeast in a sugar solution **discover** that the by-products of yeast fermentation are alcohol and carbon dioxide (qualitative only, no molecular formulas) **make** a yeast-fermented food **know** that lactic acid fermentation is carried out by bacteria **discover** that the principal by-product of lactic acid fermentation is tangy lactic acid **observe** lactic acid fermentation by bacteria **make** a lactic acid fermented food	• observe yeast and/or lactic acid bacteria under the microscope • perform a controlled experiment to test whether yeast requires sugar and/or oxygen • use limewater to show both that we exhale carbon dioxide gas and that yeast produce it as a product of fermentation • make a yeast fermented food such as bread • observe lactic acid bacteria under the microscope (e.g., in yogurt or sauerkraut) • make a lactic acid fermented food such as yogurt or sauerkraut • test the pH of yogurt • for an extension, experiment also with acetic acid fermentation by bacteria to make vinegar
	1.2.7. Nutrition …what constitutes a healthy, balanced diet …dietary problems and disorders	**analyse** and **discuss** the components of a healthy diet and lifestyle **discuss** according to student interest at least two of the following issues related to healthy eating: - health consequences of unbalanced diets - dietary deficiency diseases - food allergies and intolerances - eating disorders - obesity as a public health issue linked to modern diets **understand** that food safety, including ingredient and nutrition labelling, is regulated by national and supranational agencies	• coordinate with school nurse or doctor and/or invite outside experts to discuss issues related to nutrition, healthy diets, and eating disorders

	…the reasons for ingredient and nutrition labelling of processed foods …how to read ingredient and nutrition labels …how to recognise "junk" foods …how to analyse food marketing and the competing interests of producers, retailers, and consumers	**analyse** and **discuss** the necessity for labelling laws **research** the history of food adulteration and food safety legislation **recognise** the distinction between processed and unprocessed foods for sale **recognise** the difference between mandated ingredient/nutrition information on food packaging and package advertising **analyse** the information provided on processed food ingredient labels **deduce** that ingredient lists must present components of food in order of percentage by weight **understand** what food additives are and the meaning and function of E-numbers on labels **recognise** the many forms of sugar and salt found on ingredient labels **analyse** mandated nutrition information on labels **understand** the concept of energy content of foods, measured in kilojoules or kilocalories **understand** the meaning of the Guideline Daily Amount (also known as the Recommended Daily Allowance and other names) on food labels **relate** GDAs to their individual nutritional needs taking into account age, size, sex, and activity levels **research** and **calculate** realistic daily amounts of nutrients for themselves, starting from the GDA **calculate** nutritional yields from a realistic serving size of a processed food given labelling information for a reference of 100g **recognise** the distinction in nutrition labels between "good" nutrients providing essential components of a healthy diet (protein, fats, carbohydrates, fibre) and "bad" nutrients to be limited or avoided in a healthy diet (sugars, saturated fat, salt) **analyse** food marketing tactics, both on packaging and globally	• research current and historical issues related to food safety and labelling • analyse ingredient and nutrition labels from a variety of processed foods, including both healthy and "junk" foods • analyse ingredient and nutrition labels and recognise "junk" foods having little nutritional value and/or high amounts of sugars, salt, and/or fats • learn to recognise the many names of sugar on labels (e.g., high fructose corn syrup, corn syrup, sucrose or other compounds ending in "-ose", apple or grape juice concentrate, honey, barley malt extract, and many others) • recognise that salt is now generally overconsumed in modern diets, with possible health consequences • weigh out the amounts of sugar and salt listed on "junk" food nutrition labels to give pupils a visual calibration of quantities (5g = 1 teaspoon; 15g = 1 tablespoon) • practice mathematical calculations of pupils' own daily nutritional requirements, serving sizes, and nutritional intakes on the basis of label data and their own research • field trip to a large supermarket to observe product placement and marketing, including: - the competing interests of manufacturers, supermarkets and consumers when it comes to purchasing decisions - strategies used by manufacturers and supermarkets for layout and product placement • field trip to a farm or farmer's market to observe and talk to local and artisanal food producers

	1.2.8. Capstone project—a healthy menu **This section is optional and may be used as an IBL unit** …how to put this entire theme's content to good use	**plan** (and, if possible, cook and eat) a complete meal **present** the work that went into planning/producing the meal, including: - information about nutritional considerations - aspects of physics, chemistry, and biology utilised in the menu's design and production - cooking techniques employed - cultural or historical aspects of particular dishes - the teamwork involved in its production	• research and home-test recipes • research nutritional information on ingredients and recipes • cook and eat a delicious meal, with family and friends

1.3. Sports *This section uses sports as an entry point to basic kinematics. Sports are also treated from the point of view of their effects on human health.*	**1.3.1. Movement** …measuring distance, time, and speed	**measure** lengths and time with the aid of simple instruments, using the IS units for time (second) and distance (metre) **determine** the average speed of a moving body using a tape measure and a stopwatch **know** the IS measure for speed (metre per second) and **convert** between metres per second and kilometres per hour **derive** the formula: v = d/t (speed = distance/time) **plot a graph** showing the distance in relation to time for different uniform movements	• measure lengths with the aid of simple instruments (rulers, tape measures, rangefinders etc.) • measure time with the aid of simple instruments (watches, phone clocks, chronometers etc.) • study the history of measuring instruments (hourglass, water clock, pendulum etc.) • design and build a water clock • determine the speed of pupils running a fixed distance • determine the speed of thrown balls or bodies in sports related contexts
	1.3.2 Forces …forces as interactions between two bodies …balance	**observe** effects of forces (change of motion or deformation) **identify** the effects of forces by observing real life examples **distinguish** between contact forces and distance forces (only gravitational pull) **understand** that a force can only be observed by the effect it produces (change of movement and/or deformation of a body) **understand** that a force is always applied by one body on another body (interaction) **explain** the role of bones and muscles in moving the arm: biceps (flexion) and triceps (extension) **measure** the intensity of a force (in newtons) using a spring balance **measure** the weight of objects with different masses using a spring balance **distinguish** between the weight and the mass of an object **know** that the weight of an object changes with the body that exerts the pull but mass does not **determine** the centre of gravity of different objects **analyse** situations of bodies in balance **understand** that a body does not move when the forces acting on it are in balance (two forces only)	• measure the intensity of a force (pull or push) in newtons using appropriate spring balances (with different scales and precision) • measure the weight of objects with different masses using a spring balance • study the friction of different surfaces using an inclined plane • discuss forces involved in weightlifting and other sports

	1.3.3 Breathing …composition of air …breathing …heart and blood system and its role in transporting oxygen and carbon dioxide …scuba diving: breathing under difficult conditions …increase in pressure under water with depth	**distinguish** between the different gases of the air (oxygen, carbon dioxide, nitrogen) **perform experiments** to determine the properties of the gases of the air **design experiments** to see the difference between inhaled and exhaled air **understand** the difference between respiration and combustion **measure** breathing rate under different physical activity conditions **measure** how long it takes for breathing to return to normal and **observe** that this time is shorter for people who are fit **understand** that the heart is a pump **measure** pulse rate and **understand** the relation between activity and pulse rate **understand** that the oxygen is carried from the lungs to the cells by the red blood cells **observe** red blood cells under the microscope **observe** that the pressure under water increases with depth **understand** why scuba divers must return to the surface slowly to avoid “the bends”	• the properties of the main gases of the air can be discovered through simple experiments, which can then be used to distinguish between the gases of inhaled air and exhaled air • through discussion the pupils can then model what happens inside the body • measure breathing rate under different conditions • make a model with a balloon to show how the lungs work • measure pulse rate under different conditions • observe a block of wood floating in fresh water and salt water and explain why divers need to use more weights in salt water • observe what happens when a bottle of sparkling water or soda is opened in terms of gas production and how the “squishiness” of the bottle changes • measure the pressure under water in a cylinder using a manometer connected to a funnel by a flexible tube and show that the pressure increases with depth

	1.3.4 Sports and health …bones and muscles used in sports …injuries and how to treat them …drugs and cheating …water balance	**name** the major bones of the human skeleton **observe** at least two types of joints (ball and socket, hinge, pivot, saddle) and **understand** the type of movement associated with each joint **understand** how antagonistic muscles work to bring about movement **observe** x-rays of a broken bone and **understand** why broken bones need to be set **discuss** ways of treating a cut to prevent infection **understand** how to protect the skin from the u*ltraviolet* rays of the sun and **discuss** why this is extra important for mountain and water sports **research** the action of anabolic steroids and stimulants and the harm produced by overuse **research** which painkillers are legal in sport competitions **compare** heat loss from a thermometer with the bulb covered by dry or wet cotton wool **discover** the role of sweating to cool the body when doing exercise **research** minerals lost in sweating and how to replace them	• observe a skeleton and see how some of the joints work. • dissect a chicken leg with foot to show anatomy and function of joints, muscles, *ligaments,* and tendons • draw and label some of the bones and joints • do some exercises such as push-ups or squats to see how antagonistic muscles work • a meeting with the school nurse would be a good way to look at first aid • observe x-rays of broken bones • research the effects of steroids and pain killers • evaporative cooling experiments to demonstrate how sweating works • make an isotonic sports beverage in class

<table>
<tr>
<td rowspan="2">1.4. Puberty and Sexuality

An overview of the physical and emotional changes of puberty, followed by the anatomy of human reproductive systems; pregnancy and birth; understanding of contraception and protection against sexually transmitted infections; and the elements of healthy sexual relationships</td>
<td>1.4.1. Puberty and sexual maturity

…the physical and emotional changes of puberty

…the hormonal causes of puberty</td>
<td>know that human beings reach sexual maturity and can have children beginning at puberty
describe the principal changes of puberty common to both sexes, the principal changes for girls, and principal changes for boys

understand that the changes of puberty are caused by changes in hormone levels (no specific hormonal pathways included; hormones defined simply as chemical messengers causing the changes of puberty and adulthood)</td>
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<td>1.4.2. Human reproductive anatomy

…the anatomy of male and female reproductive organs

…the function of the principal structures of these organs

…that women produce egg cells and men produce sperm

…that an egg and a sperm must meet to begin the development of a baby

…the experience of the menstrual cycle</td>
<td>know and explain the functions of the important components of human female and male reproductive and urinary anatomy (no technical details required)

know that an egg (produced by a woman) and a sperm cell (produced by a man) have to unite (fertilization) to begin the development of a pregnancy and a baby

know and describe the basic phases of the menstrual cycle (no hormonal pathways required)
discuss the physical and emotional experience of the menstrual cycle</td>
<td>• label diagrams including:
- male: penis, scrotum, testes, seminal vesicles, urethra, bladder
- female: vulva, labia majora, labia minora, clitoris, urethra, bladder, vagina, cervix, uterus, Fallopian tubes, ovaries
• at several points during this unit, pupils should have the opportunity to pose questions anonymously using a suggestion box or online portal
• it is helpful at some point during this unit to have class sessions separated by girls and boys
• outside presenters and facilitators may be invited for parts of this theme</td>
</tr>
</table>

	1.4.3. Human sexuality …the cause of pregnancy …a brief overview of fetal development and childbirth …contraception …protection against sexually transmitted infections …sexual orientation …the central place of communication and consent in sexual relationships	**understand** the basic mechanics of heterosexual intercourse and how it can lead to pregnancy **describe**, in simple fashion, the development of a pregnancy from fertilised egg to birth **understand** the principles of barrier and hormonal contraceptives **understand** that contraceptive measures should always be taken when pregnancy is not wished for **know** that certain diseases (sexually transmitted infections) can be transmitted by sexual contact **understand** that hormonal contraceptives protect only against pregnancy, not STIs **know** that only condoms provide the most reliable protection against STIs **understand** that sexual identity is complex and personal **know** that people may be sexually attracted to members of the opposite sex, the same sex, or both sexes **understand** that sexual desires differ from person to person **understand** that pleasurable and healthy sexual relationships always require mutual negotiation, ongoing communication, and consent between partners	• show examples of each category of contraceptive and describe their use • discuss realism of media depictions of sexual activities and relationships

2.1. Our Place in the Universe *An exploration of the universe, from intergalactic to atomic scales, including: our neighbourhood (the solar system); light and telescopes; the emergence of life on Earth and the possibility of it elsewhere; and atoms as building blocks of matter and the fundamental unit of chemistry*	**2.1.1. The solar system and the universe** …the system of the sun, Earth, and moon …the solar system as a whole …our galaxy and the universe	**model** the planet Earth and **explain** its motion around the sun (revolution and rotation) **explain** how the seasons occur as a result of the axial tilt of the earth **model** the moon and **explain** its motion around the earth (revolution and rotation) **explain** why we always see the same side of the moon **calculate,** using the method of Eratosthenes, the radius and circumference of the Earth, given observational data **understand** that radiation from the sun is the Earth's primary source of energy **know** that the eight planets in our solar system revolve around the sun **distinguish** among stars, planets, moons (planetary satellites), asteroids, and comets **make a model** of the solar system and **compare** the sizes of the sun, the planets, and the moons **know** that the solar system is part of the Milky Way galaxy, which contains billions of stars **know** the approximate size and age of the solar system and the approximate age of the universe **know** that the universe is expanding	• build a model of the sun-Earth-moon system to understand the seasons on Earth • research the demonstrations of a spherical earth known in classical antiquity • compare and contrast the evidence for geocentric and heliocentric theories of the solar system available to direct observation by students • on a football field or other suitable outdoor space, measure out to scale the relative sizes of the orbits of the planets of the solar system • research recent discoveries of exoplanets using space telescopes • research Edmond Halley's prediction that the comet now bearing his name would reappear in 1758 • for an IBL unit: research how Johannes Kepler calculated the shapes, speeds, and relative sizes of the orbits of the planets of the solar system • for an IBL unit: research how observations of the 1769 transit of Venus led to the first measurements of the actual size of the solar system • convert units of distance of different magnitudes • make a timeline for the universe from the Big Bang to today • visit an observatory and/or a planetarium • observe the moon, planets, and stars using a telescope • make a pinhole projector to observe the sun (especially partial eclipses)

	2.1.2. Light …propagation of light …the production of shadows …the phases of the moon …eclipses of the moon and sun …reflection and refraction …how telescopes and microscopes work	**show** that light travels in a straight line in a homogeneous medium **know** the approximate speed of light (300 000 km/sec) **know** that nothing else in the universe can go as fast as light **calculate** a light year in kilometers and the distances between celestial objects (nearest stars and galaxies) **understand** and **represent visually** the production of shadows **model** and **explain** the phases of the moon **model** and **explain** solar and lunar eclipses **experiment** with reflection and refraction **demonstrate** using prisms that white light is composed of all the colours of the rainbow **explain** why we see rainbows **experiment** with convergent and divergent lenses **explain** how a telescope works **explain** how a microscope works **measure** the diameter and **calculate** the area of the microscope field of view at various magnifications	• design experiments to show that light travels in a straight line in a homogeneous medium and how shadows form • experiment with refraction of light between different media • experiment with prisms • build a telescope as an IBL unit • build a microscope as an IBL unit • research Galileo's telescopic observations starting in 1609 (mountains on the moon, moons of Jupiter, phases of Venus, etc.) • use the sun-earth-moon system model built in 2.1.1 to study the phases of the moon and solar and lunar eclipses • calculate the time taken for light to reach Earth from the moon, the sun, and the nearest galaxy (given average distances) • analyse the phrase "looking far away is looking into the past"
	2.1.3. Life on earth (and elsewhere?) …the conditions necessary for current life on Earth …the challenges for humans trying to leave Earth	**discuss** conditions necessary for life on Earth **discuss** the challenges facing human beings in travelling to and living on other planets	• research and discuss the conditions and elements on Earth necessary for life • research current theories about LUCA and the conditions on Earth when life first appeared • imagine life on other planets and present it in drawings, stories, etc. • discuss what conditions might be necessary for life to have evolved elsewhere in the universe • build a model rocket as an IBL extension project

	2.1.4. Atoms, elements, and molecules …the particle model of matter …chemical elements as the smallest particles with differentiated properties …molecules as bonded atoms …chemical reactions as rearrangements of molecules	**understand** that matter is made of submicroscopic particles (limited to atoms and molecules) **understand** states of matter and changes of state in terms of the particle model of matter (limited to solids, liquids, and gases) **know** that the chemical elements found on the periodic table of elements are the smallest differentiated particles of matter **identify** the abbreviations for elements on the periodic table and **learn** some of the most common (e.g., H, He, O, N, C, Fe, K, etc.) **know** that molecules are made of atoms bonded together **understand** chemical reactions in terms of rearrangements of atoms and molecules **create** word equations to describe chemical reactions seen in class	• many chemistry demonstrations and experiments possible, including: - separating water into hydrogen and oxygen - burning hydrogen to water - production of carbon dioxide (test with limewater) - burning magnesium, weighing reactants and product - rusting of iron in combination with atmospheric oxygen - reaction of metals with water and acids • research and present elements from the periodic table

2.2. *Mens Sana in Corpore Sano* **(A Healthy Body and a Healthy Mind)** *The elements of healthy living, including diet, exercise, and social aspects. The transmission of infectious diseases and means of preventing them. Environmental and systemic diseases. Dependency and addiction. Tobacco as an individual and social cause of death.*	**2.2.1. Healthy living** …components of a healthy lifestyle …the relationship of diet and exercise to physical and mental health …the human microbiome and its role in maintaining health …the importance of social relationships in health …the role of management of screen time in maintaining health	**explain** and **discuss** elements of healthy diets (reference to syllabus content section 1.2) **explain** and **discuss** the relationship between physical activity and good health (reference to syllabus content section 1.3) **know** that healthy human bodies contain myriads of microorganisms growing on and in them (the microbiome) **describe** the main areas of the body colonized by our microbiome **calculate** amount of students' body mass made up of microorganisms **research** common microbiome organisms **explain** some roles of the microbiome **recognise** the characteristics of healthy social and familial relationships **discuss** the impact of good social relationships on physical and mental health **research** and **present** the effects of screen time on physical and mental wellbeing **discuss** strategies for limiting screen time, individually and socially	• possible to coordinate with school nurse and/or psychologist for this and other subtopics in 2.2 • grow bacteria from pupil skin samples (following appropriate safety procedures) • research on human microbiome • make usage diaries of digital devices • discuss issues related to social media

	2.2.2. Diseases and disorders—infectious diseases …the basic model of infection by microorganisms or viruses …the main modes of infectious disease transmission …how vaccination protects against infectious disease …the importance of herd immunity due to vaccination …the effects of antibiotic overuse …the importance of individual and public health measures to prevent the spread of infections	**explain** basic model of infection (microorganisms or viruses attack the body to use its resources to reproduce themselves and transmit themselves to subsequent hosts) **know** that bacteria are living cells, while viruses are infectious molecular agents that take over cells to produce more viruses **explain** the main modes of infectious disease transmission **explain** basic model of vaccination (no details of immune system necessary) **model** spread of infection in a population, given parameters: virulence, duration of infection, rate of transmission, initial immunity due to previous infection or vaccination (qualitatively or using computer models only) **model** herd immunity due to vaccination in a population **explain** why diseases once eradicated in high-income countries have been making a comeback due to failures to vaccinate children **predict** methods of curing infections in an individual and/or stopping transmission in a population (qualitatively only) **explain** that antibiotics are effective only against bacterial infections and are useless against viruses **predict** effects of antibiotic overuse on microbiome in humans and animals **experiment** with the antimicrobial properties of soap and hand sanitizers **deduce** how hand washing with soap and water and the use of hand sanitizers help to prevent the spread of infections **compare** the role of sanitation in spread of disease in high- and low-income countries	• research and present pathogenic microorganisms • research lab safety techniques for culturing bacteria • experiment with antibiotics and antibiotic resistance in bacterial cultures • model disease transmission using classroom population and/or online tools • verify pupils' own vaccination records • research and present particular diseases covered by vaccines (e.g., measles, rubella, human papillomavirus…) and individual and public health consequences if vaccination rates fall • research and present public health and epidemiology professions • use historical cases in epidemiology (e.g., John Snow and 1854 London cholera outbreak; worldwide eradication of smallpox in 1970s) as basis of lessons • controlled experiments with the antimicrobial properties of soap and hand sanitizer • school information campaign to reduce spread of respiratory and gastrointestinal infections • research and present the history of sanitation systems • research how coughing or sneezing into the elbow rather than the hand or the open air helps prevent the spread of respiratory diseases like colds or flu

	2.2.3. Diseases and disorders—noninfectious diseases (environmental and systemic) …other causes of disease and disorder than infections …systemic diseases …dietary deficiency diseases …environmental diseases caused by human pollution of the environment …occupational diseases …psychological and brain disorders	**recognise** that not all illnesses are caused by infectious agents **deduce** that diseases may also be caused by conditions in the environment, or by disorders arising within the body **recognise** that some diseases, such as most cancers, or inherited type 1 diabetes, occur as the result of errors within the body itself rather than as a result of infectious agents **deduce** using knowledge of nutrition that lack of essential vitamins or minerals can cause dietary deficiency diseases (if not discussed in 1.2) **explain** the symptoms and both the dietary and social causes of one or two deficiency diseases (e.g., scurvy, pellagra, beri-beri, goiter, or rickets) **deduce** that exposure to environmental pollution can cause diseases **research** the symptoms and medical and social causes of one or two pollution-caused diseases (e.g., lead poisoning, Minamata disease, or pesticide exposure in farmworkers) **discuss** the symptoms and medical and social causes of one or two occupational diseases (e.g., silicosis, black lung, or green tobacco sickness) **understand** that depression, anxiety disorder, eating disorders, schizophrenia, and other mental illnesses have complex causes in mind, brain, and body **know** the resources available to pupils who are suffering from depression, anxiety, eating disorders, or other psychological issues	• research and present the biological and social causes of present and historical dietary deficiency diseases • research and present the biological and social causes of present and historical diseases caused by pollution • research and present the biological and social causes of present and historical occupational diseases • coordinate with school nurse, doctor, and/or psychologist to discuss mental illnesses and the avenues available for their treatment, in and outside school • invite outside experts to discuss mental and physical health issues with students

	2.2.4. Pleasure, dependence, and addiction …drugs of use and abuse …technologies and behaviours of use and abuse …consequences of dependence and addiction …help for students facing dependence issues	**understand** that people sometimes seek pleasure through the use of mind-altering substances **recognise** that such behaviours carry risks **know** the main risks of different drugs of use and abuse **analyse** and **discuss** the social situations leading to drug use and abuse **recognise** that technologies and behaviours may also induce dependence (e.g., smartphones, social media, gambling) **discuss** the personal, familial, and social consequences of dependence and addiction **know** the options available to students having trouble managing substance or behaviour dependence or addiction	• role-playing activities • invited outside experts or facilitators
	2.2.5. Tobacco and smoking …the link between tobacco use and death …the addictive nature of nicotine …tobacco industry tactics to maximise smoking …the risks of vaping or e-cigarette use	**know** that tobacco kills up to half its users **know** that tobacco use is the single greatest worldwide preventable cause of death **know** that tobacco causes more than one in ten deaths worldwide (over six million people per year as of 2015) **understand** that cigarettes are highly addictive due to the nicotine they contain **understand** that the younger someone starts smoking, the harder it is to quit as an adult **understand** the reasons that tobacco companies target children **research** and **discuss** the risks of vaping or use of e-cigarettes	• research the evidence that makes it clear that tobacco use, especially cigarette smoking, causes death by cancer, heart disease, lung disease, and other diseases • research the history of tobacco advertising • informational school campaign about the risks of tobacco use • informational campaign about the risks of vaping • research whether the tobacco industry deliberately manipulates nicotine levels in its products to maximise addiction in users • research the hundreds of chemicals found in cigarette smoke that cause cancer and other diseases • build a smoking machine

2.3. The Senses *An overview of the five human exteroceptic senses (vision, hearing, touch, taste, and smell), proprioception, and interoception, exploring issues in physics, chemistry, biology, and neuroscience. A final section treats animal senses not possessed by human beings.* ***The teacher should choose three of the eight sections for in-depth treatment, and may use more sections as IBL units.***	**2.3.1. Vision** …the anatomy of the human eye …the principle of stereo vision …the complex interplay in visual perception between the optics of the eye and processing in the brain	**construct a model** of the human eye, including basic structures and function **know** that the cornea and lens of the eye act as convergent lenses (reference to syllabus content section 2.1.2) **understand** simple cases of near- and farsightedness in terms of eyeball shape and their correction with eyeglasses **investigate** stereo vision **deduce** from the effects of various illusions that the brain has a large role in determining what is perceived visually	• dissect cow/sheep eyeball • experiment with additive and subtractive colours • find and map blind spot in field of vision of each eye • use a vibrating light source to view image of shadow of blood vessels cast on the retina • experiment with optical/perceptual illusions • construct a pinhole magnifier • construct a zoetrope • experiment with retinal saturation effects
	2.3.2. Hearing …the anatomy of the human ear …the basic physics of acoustics …the principle of stereo hearing …the complex interplay in auditory perception between the physics of the ear and processing in the brain	**construct a model** of the human ear, including basic structures and function **demonstrate** that sound is vibration propagated through a medium **investigate** stereo hearing **experiment** with auditory illusions	• show that sound does not travel in a vacuum • experiments to show sound vibrations: - tin can telephones - tuning fork in water - flame in front of loudspeaker - beans on drum - etc. • model sound propagation using springs • experiment with stereo hearing and localization of sounds • construct prosthetic “ears” to change perception of sound • investigate how hearing aids function • measure the speed of sound

	2.3.3. Touch …the different types of touch sensors in the skin …the differing densities of touch sensors in different parts of the body	**identify** the types of sensory nerves in the skin (shallow and deep pressure, thermoreceptors, pain receptors, itch receptors, chemoreceptors) **survey** the density of touch-sensitive nerves in different parts of the body	• use calipers or a compass to measure the distance at which two touches are felt separately in different areas of the body (e.g., front and back of hand, upper arm, sole and top of foot, etc.) • John Locke's 1689 experiment (*Essay Concerning Human Understanding*) demonstrating that our perceptions of heat and cold are relative rather than absolute
	2.3.4. Smell …the many different types of olfactory receptors …the interconnection of smell and taste …the context-dependence of smell perception	**know** that humans possess thousands of olfactory receptors **explore, describe,** and **categorise** a variety of smells **explore** relationship between taste and smell **investigate** the context-dependence of perception of smells	• create perfumes using basic techniques: maceration, expression, enfleurage, distillation • design a controlled experiment to test differing reactions to particular smells in particular contexts (e.g., isovaleric acid, present in both cheeses and sweat)
	2.3.5. Taste …the five basic tastes …the relationship between taste and smell	**discover** the five types of flavour receptors in the tongue and mouth (sour, sweet, salty, umami, bitter) **explore** relationship between taste and smell	• analyse perception when tasting one flavour but smelling another • analyse connection between colours and perceived flavours
	2.3.6. Proprioception …how we know where our body is without looking …how our ears help us balance	**investigate** how we know where our body and its parts are in space **experiment** with the sense of balance and tie its principal organ (the semi-circular canals) to investigation of the ear	• experiment with proprioception unreinforced by vision (walking, writing, touching fingertips, etc.) • compare proprioceptive skills between pupils who are trained in their use (e.g., dancers) and those who are not

	2.3.7. Interoception …how we know whether we're well or sick, hungry or full	**interpret** feelings of the state of their bodies in terms of interoceptive messages between body and brain	• discuss perception of feelings of wellness, illness, etc. How do you know that you're well or sick?
	2.3.8. Nonhuman senses …the many ways animals may perceive the world that we cannot	**research** senses possessed by animals that humans do not have, e.g., - ultraviolet vision - infrared vision - polarised light sensing - infrared sensing - electromagnetic sensing - echolocation - ultralow frequency hearing - different taste and smell receptors **experiment** with apparatuses and equipment giving humans access to information other animals have through their senses	• research and present other types of animal eyes (e.g., insects, cephalopods…) and visual capabilities (infrared, ultraviolet…) • research and present hearing in other organisms (e.g., echolocation in bats, dolphins; low-frequency perception by elephants, high-frequency perception by dogs) • research how taste receptors differ among species (e.g., rats can taste starch; cats cannot taste sugar) • look through polarised filters • use a black light to reveal ultraviolet colours through fluorescence • experiment with elementary echolocation (e.g., snapping fingers to navigate in a completely dark room)

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<tr>
<td rowspan="2">3.1. Machines and How They Work

The unit introduces the fundamentals of mechanics and the construction of idealised physics models, building from the basic concepts of force, work, and energy, through phenomena of electricity and magnetism, to offer an optional capstone project: building and programming a simple robot.</td>
<td>3.1.1. Force and work

…the concept of force

…the use of idealised models in physics

…simple machines

…the concept of work

…the joule as unit of work

…“work” in its physics and everyday senses</td>
<td>analyse the characteristics of a force (point of application, magnitude, line of action, sense)
represent forces using vector arrows

discuss how physicists simplify analysis by making idealised models (e.g., by neglecting friction or other forces, assuming that forces act at a single point, etc.)

plan, construct, and test simple machines (e.g., inclined planes, wedges, levers, pulleys, gears)
deduce the equilibrium conditions of a lever (only the forces perpendicular to the lever)
define torque (forces perpendicular to a lever only)
analyse the advantages and disadvantages of a simple machine (trading force for distance)
experiment with the principle of the transmissibility of forces (cases where transmission is parallel to the force only)
deduce that in an ideal situation, the product of forces’ magnitudes remains unchanged (idealised cases only: no consideration of friction or the weight of the machine itself)

derive the concept of mechanical work (limited to the result of a constant force along a straight path parallel to the force, $W = F \cdot d$)
derive the SI unit for work (the joule, J)

discuss the difference between a physicist’s concept of work and the everyday meanings of the word</td>
<td>• make force diagrams to analyse examples drawn from everyday situations
• research, and bring to class when practical, everyday examples of simple machines (levers, pulleys, inclined planes, etc.)
• observe and analyse a piano action mechanism
• experiment with and measure the trade-off of force for distance with various machines
• analyse and experiment with levers in the human body
• experiment to discover whether a simple machine can reduce the total work required for a task
• for an IBL extension, design and build Rube Goldberg machines</td>
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<td>3.1.2. Energy

…the concept of energy

…the distinction between force, work, and energy</td>
<td>explain the idea of energy in mechanics

differentiate between force, work, and energy
understand that work is the result of a transformation or transfer of energy
distinguish different forms of energy

experiment with various types of energy transformation</td>
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	…forms of energy …transfer and transformation of energy …energy loss in transfer or transformation …energy sources for animal bodies and industrial societies …renewable energy sources	**observe** for particular cases and **deduce** as a generality that energy transformations and transfers are always accompanied by energy losses **recognise** that the chemical combustion of food is the source of energy for human (and all animal) bodies (reference to syllabus content section 1.2.1) **analyse** the energy use of a household appliance and **discuss** possible ways to reduce its energy use **research** the principal industrial energy sources employed by modern humans (e.g., fossil fuels, wind, sunlight, nuclear fission, hydroelectric, etc.) **discuss** the undesirable effects of human energy consumption (e.g., air pollution, greenhouse gases, heat waste, noise and light pollution, etc.) **research** and **discuss** renewable sources of energy for human societies	• discuss the concept of energy in physics • experiment with energy transformation and measurement of its effects • represent energy flows using Sankey diagrams (e.g., using online tools) • research, present, and model various types of large-scale energy transformation (e.g., wind turbines, solar panels, hydroelectric plants, car batteries, combustion engines) • compare and contrast renewable and non-renewable energy sources for industrial societies • school informational campaign for everyday energy conservation measures
	3.1.3. Electrostatics …electrostatic effects …the existence of two types of charge …lightning …an atomic model for charge	**experiment** with electrostatic effects arising from friction and contact **observe** electrostatic attraction and repulsion effects **observe** and **explain** the spark and snap of transfer of electric charge **interpret** transfers of electric charge by contact or induction **observe** and **interpret** grounding of an electrically charged body **deduce** the existence of two types of electric charges **describe** their interactions (qualitatively only) **research** and **discuss** examples of electrostatic effects in everyday life **construct a simple model** to explain lightning **explain** the function of a lightning conductor **explain** electrostatic phenomena in terms of a simple atomic model	• simple electrostatics experiments to show the existence of opposite charges and the transfer of charge • use electrified balloons to charge lightweight insulators (e.g., bits of packing peanuts, breakfast cereal) suspended by threads to show attraction, repulsion, and transfer of charge • use laboratory apparatuses to demonstrate electrical effects (e.g., pith ball or gold leaf electroscopes, Van de Graaff generator, Wimshurst machine, Kelvin water dropper) • build and use a Leyden jar

	3.1.4. Electric circuits …how to build and represent a circuit …conductors and insulators …a particle model for current …the uses of electric current …current and voltage …how to use electricity safely	**devise, construct,** and **test** various types of electric circuits (series and parallel) **demonstrate** that a current only runs through a closed circuit **represent** simple circuits using correct symbolic notation and **describe** the conventional direction of the current in various circuits **experiment** with electrical insulators and conductors **interpret** electric current through a metallic conductor in terms of moving electrons **explore** the use of electrical energy to create other effects (e.g., magnetism, heat, light, chemical energy) and **discuss** their applications **measure** circuits using ammeters and voltmeters (qualitative description only of amperage and voltage) **observe** the effects on amperage and voltage in circuits in series and parallel **analyse** whether current is used up in a closed circuit **research** and **explain** the dangers to living organisms of electric shocks and the misuse of electric current **explain** the dangers of a short circuit **explain** the importance of grounding household circuits **discuss** safety measures in the use of electricity at home	• build and diagram simple circuits in series and parallel, using bulbs, switches, multiway switching • make an elementary circuit map of a classroom or science lab • test the conducting and insulating properties of different materials (e.g., distilled water, tap water, graphite, glass, ceramics, plastic, wood etc.) • experiment with small electrical devices and appliances (e.g., incandescent and gas-discharge lightbulbs, electric motors, electromagnets, doorbells) • use ammeters and voltmeters to measure current and potential in different types of circuits • model electric current and various types of circuits using pupils passing small objects representing electrons

	3.1.5. Magnetism …magnetic attraction and repulsion …magnetic polarity …magnetic, magnetisable, and nonmagnetic materials …modelling magnetism and magnetic fields …the earth as a magnet …electromagnetism	**observe** the attraction and repulsion between permanent magnets **deduce** the existence of two opposite magnetic poles **observe** that magnetic poles always appear in pairs **investigate** examples of permanent magnets **investigate** magnetisable materials (ferromagnetic only) **investigate** examples of nonmagnetic materials **represent** a permanent magnet using an elementary magnet model **analyse** a phenomenon of temporary magnetisation (e.g., iron filings) using an elementary magnet model **observe** and **draw from observation** the magnetic fields created by permanent magnets of different shapes **model** the earth's magnetic field **understand** how a magnetic compass works **experiment** with the effect of magnets on an electric current in a metallic conductor **explain** how an electromagnet works	• experiments to identify what materials can and cannot be attracted by magnets • find everyday examples of household magnets and their uses • experiment with permanent magnets to show - polarities and their attraction/repulsion - that magnets always have two poles • experiments to compare and contrast magnetism and other forms of action at a distance (e.g., electric interactions, gravitation,) • experiments with magnetisation of ferromagnetic materials such as iron filings, needles, etc. • use iron filings to visualise and draw magnetic fields of magnets of a variety of shapes • make a simple model of the earth's magnetic field • learn to orient and navigate using a compass • research organisms capable of magnetotaxis (sensing magnetic fields)
	3.1.6. Capstone project—robotics **This section is optional and may be used as an IBL unit** …how to put this entire theme's content to use to build a functioning robot	**plan** and **construct** a robot to carry out a specified task objective, using simple construction elements and programming techniques, incorporating - simple machines (e.g., gears, springs, levers, wheel and axle) - electromagnetic elements (e.g., electric motors) - electronics (programmable elements, including core software code syntax language components, e.g., setup, loops, comments, start and end brackets, data types, arithmetic operators)	• design and build a programmable robot to carry out an agreed-upon task objective • possible coordination with ITC teacher for programming elements

3.2 Our Living Earth *Beginning with the global effects of human production and consumption, students will analyse key parameters of ecosystems. They will be introduced to the principles of biological classification and explore issues related to biodiversity and sustainable development. An optional capstone project offers students the opportunity to carry out and write up autonomously a complete scientific investigation.*	**3.2.1. Human nutrition and its effects on our environment** …anthropogenic climate change …production, processing, distribution, and disposal of food products …the relationship between human food production and greenhouse gas emissions …the environmental effects of human land use	**identify** the principal gases of the atmosphere (nitrogen, oxygen, argon, water vapour, carbon dioxide) **research** and **discuss** the causes of anthropogenic climate change **diagram** or **model** the production, processing, distribution, and waste disposal of at least one plant and at least one animal food product **analyse** the consequences of human food consumption for climate change **research** and **present** the carbon footprint of several foods **analyse** the environmental consequences of human land use patterns	• keep a food diary to analyse the origins and environmental footprint of a pupil’s own food consumption • possible coordination with human sciences teachers • research project to track several products (e.g., apples, processed snack foods, meat, or fish) from a local supermarket through production and transport chains to waste disposal • write a class cookbook with environment-friendly recipes • determine and compare personal CO_2 balance sheets for a menu entailing low emissions (e.g., vegetarian, local products) and a menu entailing high emissions (e.g., meat-based, highly processed, long transport chains)
	3.2.2. Ecosystems …matter and energy flows …decomposers	**define** an ecosystem **analyse** an ecosystem in terms of energy flows **analyse** global water and carbon cycles **review** how animals and plants obtain energy and nutrients (reference to syllabus content section 1.2.1) **observe** the action of decomposers and **relate** their role to those of producers and consumers in an ecosystem	• observe decomposers in an aquarium or terrarium • experiments to analyse photosynthesis (show that carbon dioxide, water and light are necessary; oxygen and carbohydrates are produced) • make posters and/or presentations of food chains, food webs and food pyramids based on materials and data

	…photosynthesis …trophic levels and relationships	**design experiments** to discover the reactants, the products, and the necessary conditions for photosynthesis **derive** a simplified word equation for photosynthesis **relate** the reactants and products of photosynthesis in plants to the reactants and products of respiration in both plants and animals **explain** and **analyse** the relations of different trophic levels **create a model** of an ecosystem and **discuss** the advantages and limits of models **illustrate** the most important trophic relationships of living organisms in a particular ecosystem	
	3.2.3 Ecosystem survey …abiotic factors …biotic factors …water survey …soil survey	**discover, deduce,** and **measure** some of the principal abiotic factors controlling ecosystem characteristics **predict** the consequences for lifestyles of animals with different methods of heat regulation **investigate** the types of animals active during the day, at night, and in twilight **observe** microorganisms in water and **draw** them **from observation** **do field study** of soil composition and water retention, and **survey** soil organisms at different depths **identify** common soil organisms using a dichotomous key	• measure some of the principal abiotic factors (e.g., temperature, light intensity, humidity, pH) • research/present heat regulation in various animals • research/present species of diurnal, nocturnal, and crepuscular animals • collect and observe soil organisms from a 10 cm^3 volume with naked eye, hand lens, and dissecting microscope, distinguishing between organisms found at different depths

	3.2.4. Classification …working definitions of “life” and “species” …constructing a classification …constructing and using a dichotomous key …scientific classification of organisms …biodiversity …sustainable development	**employ** a working definition of life that includes plants, animals, fungi, and bacteria **employ** a working definition of species as a recognisable group of organisms distinct from other groups **create** a classification of and a *dichotomous key* for a given set of objects **understand** that the scientific system of classification is only one of many ways to organize and understand the diversity of living things **practice** classification of a given set of organisms using taxonomic ranks: species, genus, family, order, class, phylum, kingdom, domain **identify** a given set of related biological specimens using a dichotomous key **collect, preserve,** and **label** specimens with relevant scientific information (e.g., herbarium specimens, insect collection) **understand** that scientific classifications of organisms represent scientists’ understanding of their common descent and evolutionary relationships **research** some major taxonomic groups of organisms (e.g., flowering plants, arthropods, basilomycetes, vertebrates) and **identify** the key characteristics that lead scientists to group them together **define** biodiversity **predict** the effects of biodiversity loss due to natural and human causes **research** and **discuss** proposals for sustainable development to protect biodiversity as economic, ethical, aesthetic, and/or biological imperatives for human beings	• research Carolus Linnaeus and the history of biological classification systems • visit a natural history collection (e.g., herbarium, zoology collection) • create a class or personal herbarium and/or other natural history collection • observe, draw, and try to identify aquatic microorganisms in water (e.g., hay infusion, pond water) • awareness campaigns for biodiversity, sustainable development, etc.

	3.2.5. Capstone project: an ecological field study **This section is optional and may be used as an IBL unit** …how to define an ecological unit for study …how to record data for a sustained study …information skills for scientific research …how to write a scientific paper	**define** an ecological unit in space and time to study, taking into account any relevant bioethical issues **measure** and **record** the unit's abiotic parameters at appropriate intervals using appropriate scientific techniques **identify** key species using appropriate techniques and resources **observe** and **record** changes to abiotic factors and biota for the length of the study **research** aspects relevant to the study, using scientific resources on- and offline, evaluating them for provenance and reliability **write a scientific study** of the ecological unit studied, using the format abstract-methods-results-conclusions	Possible ecological units for study: - terrestrial meter or larger plots - an agricultural plot - a treetop - a pond or stretch of river - a Winogradsky column - an aquarium - a terrarium

5. Assessment

Assessments must be oriented around the **Key Competences for the European Schools** (see section 1), the **attainment descriptors** for Integrated Science (see sections 3.1 and 5.1), and the **cross-cutting concepts** shared by all the mathematics and science syllabuses (see section 3.2). Teachers must incorporate assessment of all of these in each year's teaching. Assignment of semester grades must likewise be based on the descriptors.

Pupils must be assessed in a broad variety of ways throughout the year, to give a wide-ranging picture of each pupil's attainments, strengths, and areas for further work. Both formative and summative assessments must be used, ranging from quick and simple (e.g., short quizzes, oral assessments by teacher during the course of an activity, brief presentations by pupils of work in progress) to more complex and time-demanding (e.g., laboratory reports, tests requiring pupils to apply learned content in new situations, group presentations of a project). **In the S1-3 cycle, it is expected that assessment will be holistic rather than numerical, in accordance with the marking system.**

As per section 2, pupils should carry out at least two more substantial (at least 10 class periods) inquiry-based learning units per year. Inquiry-based units may be multidisciplinary and cover material drawn from across the year's syllabus or across the integrated science syllabus for all years; they may be organised across subjects, by more than one teacher. Inquiry-based units will generally include several formative assessments as well as a final, summative product. They will cover a substantial number of the Key Competences, the attainment descriptors for Integrated Science, the cross-cutting concepts enumerated in section 3.2, and the guidelines given here.

Pupils should be given guidance and structured support to work towards autonomy in complex assessments; pupils in the beginning of S1 will require help at every step to design an experiment, while pupils in S3 should be able to do much of the work themselves.

Assessments over the course of a year must include tasks requiring pupils to:

- **design and carry out their own investigation**
- **design and carry out an experiment using a control**
- **write a laboratory report including abstract/methods/results/conclusions**
- **use mathematical techniques**
- **include a design/engineering component**
- **make and use models of phenomena and/or systems**
- **do substantial writing**
- **practice digital literacy skills**
- **integrate historical, social, civic, cultural, and/or ethical aspects of science**
- **present their work to classmates, parents, or the public**
- **practice skills and content in structured exercises (e.g., worksheets, problem sets)**
- **demonstrate mastery of subject content, including ability to apply content to new situations**
- **demonstrate mastery of practical skills (e.g., wiring a circuit, making a microscope mount and bringing it into focus)**
- **work in teams**
- **carry out self and peer evaluation**
- **produce creative work (e.g., videos, comics, posters, perfumes, musical compositions, letters to scientists)**

Teachers should make an annual assessment plan that provides a weighting of different assessment activities and ensures that all the competences are assessed within each school year of the cycle.

5.1. Attainment descriptors – Integrated Science S1-S3

Globally, students should develop awareness of the environment and learn to act as responsible citizens with respect to it.

Attainment Descriptors: Comprehensive Table

	A *Excellent*	B *Very good*	C *Good*	D *Satisfactory*	E *Sufficient*	F *Failed/Weak*	Fx *Failed/ Very Weak*
Subject Competences	Is capable of critical analysis and use of scientific knowledge and vocabulary. Excellent graphing skills.	Can use scientific knowledge to analyse unfamiliar problems. Is able to draw, describe and analyse different kinds of graphs.	Can use scientific knowledge to analyse familiar problems. Is able to draw, describe and analyse simple graphs.	Shows satisfactory understanding of scientific knowledge but has difficulties applying it. Is able to draw, describe and read simple graphs.	Recalls basic scientific knowledge (names, facts and definitions) correctly. Is able to draw and describe simple graphs.	Shows little recall of basic scientific knowledge. Has difficulty drawing and describing simple graphs.	Shows very little recall of basic scientific knowledge. Has difficulty drawing and describing simple graphs without assistance.
Investigative Work	Can plan an investigation, selecting appropriate materials, equipment, and techniques. Can plan and write a detailed and structured report.	Can plan an investigation with assistance and write a detailed and structured report.	Follows the procedure for an investigation and writes a detailed report following guidelines.	Follows the procedure for an investigation and writes a basic lab report following guidelines.	Follows a procedure for an investigation and writes a basic lab report by completing given work sheets.	Rarely completes investigations. Written reports insufficient.	Rarely follows the procedure or completes written work for investigations.
Manipulation Skills and Safety	Has developed excellent manipulation skills and considerable attention to safety concerns.	Very good progress in developing new manipulation skills and is very aware of safety concerns.	Good progress in developing new manipulation skills and pays attention to safety concerns.	Satisfactory progress in developing new manipulation skills pays attention to safety concerns.	Sufficient progress in developing new manipulation skills pays attention to safety concerns.	Insufficient progress in developing new manipulation skills and insufficient attention to safety concerns.	Has made no progress in developing new manipulation skills and generally pays no attention to safety.

Digital and Information Competences[6]	Can consistently independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can independently use appropriate software for science tasks.	Can usually independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can use appropriate software for science tasks with some assistance.	Can often independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can use appropriate software for science tasks with assistance.	With aid, can find, and assess the reliability of, information on scientific subjects, on- and offline. Can use appropriate software for science tasks given structured assistance.	Can retrieve information on scientific subjects when directed to reliable sources, on- and offline. Can follow structured instructions to use appropriate software for science tasks.	Generally unable to find, or to assess the reliability of, information on scientific subjects, on- and offline. Has great difficulties using appropriate software for science tasks even with assistance.	Unable to find, or to assess the reliability of, information on scientific subjects, on- or offline. Unable to use appropriate software for science tasks even with assistance.
Communication (oral and written)	Communicates clearly using scientific vocabulary correctly. Demonstrates excellent presentation skills.	Communicates clearly using scientific vocabulary correctly. Demonstrates very good presentation skills.	Communicates clearly most of the time using scientific vocabulary correctly. Demonstrates good presentation skills.	Uses basic scientific vocabulary, and descriptions show some structure. Demonstrates satisfactory presentation skills.	Uses basic scientific vocabulary, but descriptions may lack structure or clarity. Demonstrates satisfactory presentation skills	Generally produces descriptions that are insufficient or incomplete with a poor use of scientific vocabulary. Lacks acceptable presentation skills.	Has very poor communication and presentation skills.
Teamwork	Works constructively as a team member, shows initiative, and can act as a team leader.	Works constructively in a team.	Works well in a team.	Works satisfactorily in a team.	Participates in teamwork.	Needs assistance when working in a team.	Does not work in a team.

[6] *This competence is part of the European Digital Competence Framework (https://ec.europa.eu/jrc/en/digcomp).

Attainment Descriptors: Synopsis

Grade A (Excellent)

The student: is capable of critical analysis and use of scientific knowledge and vocabulary. Has excellent graphing skills. Can plan an investigation selecting appropriate materials, equipment, and techniques. Has developed excellent manipulation skills and shows considerable attention to safety concerns; can plan and write a detailed and structured report. Communicates clearly using scientific vocabulary correctly. Can consistently independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can independently use appropriate software for science tasks. Demonstrates excellent presentation skills. Works constructively as a team member, shows initiative, and can act as a team leader.

Grade B (Very good)

The student: can use scientific knowledge to analyse unfamiliar problems. Can plan an investigation with assistance and write a detailed and structured report. Has made very good progress in developing new manipulation skills and is very aware of safety concerns. Communicates clearly using scientific vocabulary correctly. Can usually independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can use appropriate software for science tasks with some assistance. Demonstrates very good presentation skills. Is able to draw, describe and analyse different kinds of graphs. Works constructively in a team.

Grade C (Good)

The student: can use scientific knowledge to analyse familiar problems. Can follow a procedure and write a detailed report following guidelines. Has made good progress in developing new manipulation skills and pays attention to safety concerns. Communicates clearly most of the time using scientific vocabulary correctly. Can often independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can use appropriate software for science tasks with assistance. Demonstrates good presentation skills. Is able to draw, describe and analyse simple graphs. Works well in a team.

Grade D (Satisfactory)

The student: shows satisfactory understanding of scientific knowledge but has difficulty applying it. Can follow a procedure and write a basic lab report following guidelines. Has made satisfactory progress in developing new manipulation skills and pays attention to safety concerns. Uses basic scientific vocabulary, and descriptions show some structure. With aid, can find, and assess the reliability of, information on scientific subjects, on- and offline. Can use appropriate software for science tasks given structured assistance. Demonstrates satisfactory presentation skills. Is able to draw, describe and read simple graphs. Works satisfactorily in a team.

Grade E (Sufficient)

The student: recalls basic scientific knowledge (names, facts and definitions) correctly. Can follow a procedure and write a basic lab report by completing given work sheets. Has made sufficient progress in developing new manipulation skills and pays attention to safety concerns. Uses basic scientific vocabulary, but descriptions may lack structure or clarity. Can retrieve information on scientific subjects when directed to reliable sources, on- and offline. Can follow structured instructions to use appropriate software for science tasks. Demonstrates satisfactory presentation skills. Is able to draw and describe simple graphs. Participates in teamwork.

Grade F (Failed/Weak)

The student: shows little recall of basic scientific knowledge. Rarely completes experimental work. Has made insufficient progress in developing new manipulation skills and pays insufficient attention to safety concerns. Generally produces descriptions that are insufficient or incomplete with poor use of scientific vocabulary. Is generally unable to find, or to assess the reliability of, information on scientific subjects, on- and offline. Has great difficulties using appropriate software for science tasks even with assistance. Lacks acceptable presentation skills. Has difficulty drawing and describing simple graphs. Needs assistance when working in a team.

Grade FX (Failed/Very weak)

The student: shows very little recall of basic scientific knowledge. Has problems following a procedure or completing written work. Has made no progress in developing new manipulation skills and generally pays no attention to safety. Is unable to find, or to assess the reliability of, information on scientific subjects, on- or offline. Is unable to use appropriate software for science tasks even with assistance. Has very poor communication and presentation skills. Has difficulty drawing and describing simple graphs without assistance. Does not work in a team.

6. Annex 1 – Organisational conditions

- **The Integrated Science course should be scheduled with at least one double period per week, to facilitate practical work.**

- **In order to assure an integrated approach, each year of Integrated Science should be taught by one teacher only.**