Ref.: **2024-01-D-46-en-2**
Orig.: **EN**

Science, Technology, and Society Syllabus – S6-S7

Approved by the Joint Teaching Committee on 8 and 9 February 2024 in Brussels (Hybrid)

Entry into force on 1 September 2024 for S6
on 1 September 2025 for S7

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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

The 2-period Science, Technology, and Society (STS) course is designed for pupils who are not enrolled in any 4-period science option in S6-7. However, pupils who are enrolled in physics, chemistry, and/or biology are also encouraged to enrol in this course.

The goal of the 2-period Science, Technology, and Society syllabus is not that pupils should acquire content knowledge by rote, but rather that they integrate the cross-cutting concepts (section 3.1) and master the subject competences (section 3.2) in order to be able to **make informed personal decisions and act as responsible citizens in contexts where science literacy is required** (see also section 5, "Assessment"). Pupils enrolled in biology, physics and/or chemistry will also find value in the transversal, holistic, and global emphasis on scientific literacy and broader social contexts.

This course builds upon the groundwork laid in integrated science and the S4-5 science courses. **The syllabus is designed for pupils whose higher studies and future careers will probably not be in STEM fields** (science, technology, engineering, or mathematics). The principal goal is to foster science literacy, through five topics (chosen from seven options) of immediate importance to pupils' everyday lives, and a project. In addition to the content themes, pupils will gain an appreciation of science as a process for generating reliable knowledge about the natural world and apply the competences of digital and information literacy to finding and assessing reliable sources from and about science.

The study of science is central to pupils' developing understanding of themselves in the universe. Accordingly, teachers must make links during the course to human issues -

individual, social, and global - wherever appropriate. They should likewise make links wherever appropriate to issues connected with ethics, social and political issues, biodiversity, conservation, and sustainable development. **Teachers are encouraged to coordinate with colleagues in relevant subjects, external experts, organisations, and initiatives such as school clubs and citizen science projects.**

Finally, teachers should avail themselves, throughout the science curricula in years S1-7, of the opportunity offered by the **European Schools Science Symposium** and other national and international science competitions and organisations.

Pupils will propose and carry out an independent project, related to any of the subject themes of the Science, Technology, and Society course. **The assessment of the project may replace the short written examination for one of the semesters in s7 (mark B1 or B2).**

The approach to science and mathematics learning referred to as ***inquiry-based learning*** (IBL) is highly encouraged for the 2-period course. 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. See annex 4 for examples of IBL lesson plans related to the course themes.

[1] https://primas-project.eu/wp-content/uploads/sites/323/2017/11/primas_final_publication.pdf

3. Learning Objectives

Content topics are used to learn general key competences, to acquire course-specific competences, to connect across disciplines with cross-cutting concepts, and to prepare pupils for lifelong learning. **The italicized verbs used in section 4 refer to these competences and cross-cutting concepts.**

3.1. Cross-cutting Concepts of Science and Mathematics[2]

The natural world:

- **Patterns**
  Patterns in forms and events guide organisation and classification, and prompt questions about the factors that influence them.
- **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.
- **Energy and matter**
  Tracking fluxes of energy and matter into, out of, and within systems helps understand the system's behaviour.
- **Structure and function**
  The way in which an object is shaped or structured determines many of its properties and functions.
- **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.

The tools of science:

- **Quantification**
  Scientists try, whenever they can, to turn data into numbers, because doing so allows them to use the toolbox of mathematics to explain, interpret, and create new avenues of inquiry.
- **Representing data**
  Scientists choose among many ways to represent data and conclusions, including graphs, mathematical models, drawings from observation, preservation of specimens, etc.
- **Scale, proportion, and quantity**
  In considering phenomena, it is critical to recognise what is relevant at different measures (e.g. size, time, or energy) and to recognise how changes in scale, proportion, or quantity affect a system's structure or performance.
- **Modelling**
  Modelling entails creating controlled versions of systems that can be used for understanding and predicting their behaviour.

Science as a human activity:

- **History of science**
  Scientists have developed the rules for scientific investigation over centuries, including that scientists must explain their methods of investigation, share their data, and let other scientists critique their conclusions (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.
- **Nature of science**
  Scientific explanations (theories) are always provisional and subject to rejection or revision on the basis of new evidence and interpretation.

[2] Adapted from http://ngss.nsta.org/CrosscuttingConceptsFull.aspx

3.2. Competences[3]

The competences to be acquired by students are listed below. Consultation of Bloom's Taxonomy of Measurable Verbs is advisable when evaluating competences. Acquisition of relevant content knowledge for each section is assumed.

- **Analysis and information literacy**
  The student is easily able to analyse and make critical interpretations of data presented at the level of an educated general public. The student can consistently independently find, and assess the reliability of, information on scientific subjects, on- and offline. They are capable of sophisticated evaluation of the provenance and authority of science-based claims in the public sphere.
- **Problem-solving and synthesis**
  The student readily makes connections between different parts of the syllabus, applies concepts to a wide variety of unfamiliar situations, and makes nuanced ethical arguments.
- **Oral and written communication**
  The student communicates clearly and concisely, using appropriate vocabulary. Excellent presentation skills. Engages in fluent discussion of issues of public importance raised by science and scientists.
- **Teamwork and project management**
  Works constructively as a team member, shows initiative, and can take responsibility for a team. The student can independently plan and carry out a project.

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

[3] The competences described in this chapter are defined with reference to the highest level expected to be achievable by pupils in the baccalaureate cycle (see chapter 5.1, "Attainment Descriptors").

4. Content

Nota bene: No detailed direction of time allotments per section is given in this syllabus, course planning being left to the teacher's judgement. The teacher should choose one topic in advance to begin with in S6; the subsequent topics should be chosen in consultation with pupils according to their interests. This course should be taught by one science teacher over the two years of the cycle.

4.1. Topics

Nota bene: Five topics should be chosen. **The topics are listed in alphabetical order by title. No chronological order is implied. The teacher and pupils should decide the topics and order by consultation.** The teacher should schedule the hours for the project as convenient and appropriate over the two-year cycle.

- **Brains, minds, intelligences, and learning** – *Human understanding of understanding—our own, other organisms, machine-based.*

- **Climate Change and Biodiversity** – *How our planet's climate is changing, and what it means for us and all living things on Earth.*

- **Developing Technologies** – *Thinking through our increasing power to manipulate and control ourselves and the world around us.*

- **Energy** – *How everything happens: energy sources, transformation, use, and conservation.*

- **Food, Nutrition, and Health** – *What we eat: exploring food production, distribution, consumption, processing, politics, nutrition sciences, marketing, and personal health.*

- **Personal and Public Health** – *Health for individuals and groups: infectious, systemic, and environmental diseases, and how we protect ourselves and each other.*

- **Water** – *The most abundant natural resource for us and all living things on Earth.*

Project – *An opportunity to explore at least one of this course's topics in depth.*

4.2. Tables

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

Topics *The syllabus is organised around a set of themes relevant to developing science literacy and to pupils' lives.* Lessons should be designed so that pupils themselves develop, via inquiry-based (IBL) approaches, the cross-cutting concepts enumerated in section 3.1 and the competences in section 3.2.
pupils *will be able to* **… in the context of…** (content) *italicized verbs indicate* the competences pupils should gain in a **broad overview of the scientific and social contexts** within which the basic knowledge content should be situated. (with further content specifications in parentheses) *- pupils may do...* *- the suggested activities are neither prescriptive nor exhaustive:* *teachers are free to use some but not all of them,* *and to use other activities instead of or in addition to these.*

Brains, minds, intelligences, and learning
Human understanding of understanding—our own, other organisms, machine-based.

analyse and *experiment with* **aspects of individual and social animal and human behaviour**
explore **human learning and memory**

- cognitive/neuroscience-based techniques to improve learning, study skills, and memory
- research/discuss human memory augmentation techniques (e.g. literacy, "Palace of Memory", computers...)
- simple behavioural experiments

research and *discuss* **definitions of 'intelligence'**
investigate and *experiment with* **different types of 'computers'**
compare and contrast **biological and mechanical 'thinking'**
compare and contrast **biological and mechanical 'senses'**
compare and contrast **human and machine learning and memory**

- research history and uses of IQ and human intelligence testing
- construct a simple binary computer
- research and debate definitions of intelligence
- research/experiment with emergent intelligence phenomena (e.g. ant/bee algorithms)
- research/experiment with artificial intelligences

recognise **emotions and feelings as biological summations of physical and mental states**
explore and *discuss* **issues involved in constructing a theory of consciousness**

- popularised clinical case studies
- research and discuss functions of hormones/medications/recreational drugs
- read/watch and discuss science fiction and speculative works
- research and debate issues related to possibility of nonhuman and machine consciousness

Climate change and biodiversity

How our planet's climate is changing, and what it means for us and all living things on Earth.

give an overview of **the current scientific consensus on climate change**

(important parameters: Earth's energy budget, ocean heat content, average surface temperatures, sea levels, ocean acidification, atmospheric CO_2 and methane levels, the concept of carbon budget, historical greenhouse gas emission and future scenarios; types and methods of data collection, consilience among different types of evidence, how scientists arrive at consensus; the policy dimensions)

- use online models and simulators, e.g. GCM, Markov chains
- relate to curve analysis, limits, and probability from math courses
- investigate techniques of acquiring historical data

explore aspects of **local and global biodiversity** and **biodiversity loss**

(5 drivers of biodiversity loss: competition for land/sea/resources, over hunting/fishing, climate change, alien invasive species, pollution)

analyse and give examples of **ecosystem services**

- biodiversity survey of a local environment
- observation of pollinators, dispersers
- decomposition, composting
- local water sources and cycles
- discussion of ecotourism costs and benefits
- research natural and human-made carbon sinks

recognise **importance of time frames for human and ecological adaptation to climate and biodiversity changes**

relate **biodiversity** and **climate change issues** and **possible human responses**

(possible topics: conservation, gene banking, habitat restoration, genetic "resurrection" of extinct species, indigenous peoples' rights, sustainable agriculture, adaptation, mitigation, bioengineering, geoengineering)

- research endangered taxa/ecosystems
- geological timeline
- use of online models and simulators
- class discussions and debates

Developing Technologies

Thinking through our increasing power to manipulate and control ourselves and the world around us.

Choose **one** of the developing technologies below:

biotechnologies
(possible topics: alterations to microorganisms, fungi, plants, animals including humans)

computing, artificial intelligence, big data
(possible topics: definitions and types of AI, roles of social media, surveillance and behaviour prediction, advertising/commerce, political uses and controls)

energy generation
(possible topics: nuclear fusion, biofuels, novel solar and hydropower strategies)

new materials
(possible topics: sources, purposes, production methods, batteries, polymers, zero-gap materials, nanotechnology, advanced composites, 2D materials)

space
(possible topics: getting there and back, scientific research, uses and ownership of extraterrestrial resources, space tourism, colonisation of the moon/Mars, space-based climate engineering, space elevators, possibility of extraterrestrial life)

identify, explore, and *discuss* the chosen technology with respect to **at least three of the following transversal themes** as appropriate**:**

issues of sustainability, environmental effects, lifestyle support and enhancement, luxury, economic aspects, uncertainty about future consequences, positive/negative/ambiguous impacts, role of automation/robotics

Transversal activities:
- reports/field trips/debates
- EU speakers on legal, regulation issues
- discussion of science fiction literature and film

Technology-specific activities:
(drug production technologies; "vat" meat; organ farming for transplants; GMO crops; stem cell research; 3D printing; bioprinting; robotics; experimenting with/research about AIs and potential uses; astronomical observation; school energy generation/optimisation projects)

Energy

How everything happens: energy sources, transformation, use, and conservation.

review **concept of energy**
(conservation, transformation, effects, efficiency)

- simple experiments to measure/quantify heat/work, energy transformation
- coffee cup calorimeter
- analyse energy values on food labels

compare and contrast **energy sources**
(possible topics: autotrophy, heterotrophy, fossil fuels, solar, wind, nuclear, hydropower, biofuels)
compare and contrast **energy storage**
(possible topics: fats, carbohydrates, seeds, blubber, batteries, reservoirs)
compare and contrast **energy transformation**
(possible topics: photosynthesis, digestion, ATP, power generation)
compare and contrast **energy conservation (and loss)**
(possible topics: rule of tenths, heat, death, entropy and loss in industrial power generation and storage systems)

- simple experiments to measure/quantify photosynthesis
- simple experiments to measure/quantify work, energy transformation
- simple digestion experiments
- modelling of trophic levels and food webs
- solar cooking
- research, presentation, debate on methods and historical development of power generation
- use online models and simulations
- utilisation of interactive games to actively engage students in learning about energy savings and energy efficiency practices

debate **issues of the politics, ethics, economics, social aspects of human energy use and power generation and conservation**
(possible themes: *sustainability, land use, resource extraction, indigenous peoples' rights, feasibility of "net zero"*)
- online ecological models
- research relevant EU policies and regulations
- research environmental impacts of "sustainable" technologies

Food, nutrition, and health

What we eat: exploring food production, distribution, consumption, processing, politics, nutrition sciences, marketing, and personal health.

compare and contrast **different forms of agricultural production**
(organic/conventional/the role of livestock; sustainability issues related to production)
evaluate and *discuss* **problems of extensive livestock production systems ~~culture~~ and meat consumption**
(social, political, environmental, ethical, sustainability aspects)

- visits to or from agricultural producers

research the **food supply chains**
(power of supermarkets/short supply chains)
distinguish **different types of food processing**
(domestic, artisanal/traditional, industrial)
explore the **different food labels and certification schemes** that provides assurances to consumers
(EU and private environmental and social labels)
analyse **food ingredient and nutritional information labels**
explain the **key factors involved in food safety** and how it is addressed by **the politics of food safety**
(interests of consumers, manufacturers, agricultural producers, retailers)
research and *discuss* **the politics of food/nutrition sciences**
(evaluation of sample size issues, funding sources, expert qualifications/affiliations, attribution of expertise/authority for claims about nutrition/health)
analyse **the role of advertising in public understanding of food, nutrition, and health**

- visit to local food processing facility
- weigh out sugar/salt or other ingredient content in foods and drinks
- compare unsaturated, saturated, trans fats in food fats and oils
- research and presentations on national and EU labelling requirements, food adulteration, and food safety legislation and enforcement
- research and discuss health claims for particular foods or nutrients
- visit to supermarket to analyse product placement, advertisement, etc.
- reflect on the role of the consumer in influencing the food supply system

identify **individual elements of personal health and nutrition for each pupil**
(basic nutrition, physical activity, elements of healthy diets and lifestyles, preventive medical care)

- planning and cooking healthy meals
- discussion of eating disorders, other health issues

Personal and public health

Health for individuals and groups: infectious, systemic, and environmental diseases, and how we protect ourselves and each other.

discuss how to maintain and improve your own individual **physical and mental health**

- discuss elements of healthy lifestyles
- study technologies of diagnosis and treatment (e.g. visualisation technologies, instruments, screening, medicines)
- discuss influences on ideas of health (e.g. peer pressure, families, media influencers)

recognise and discuss **infectious disease as a population phenomenon**
(epidemics, pandemics, environmental, systemic diseases)
explain and use **basic epidemiological models**
(R_0 resulting from varying values of virulence, duration of infection, rate of transmission, and initial immunity; significance of positivity rate)
analyse **the personal and public benefits of vaccination**
(personal and herd immunity)
recognise **the role of zoonoses in human disease**
(conditions leading to zoonotic outbreaks, linked to sustainability issues)
recognise and discuss **environmental health topics as population phenomena**
(exposure to physical, chemical and biological stressors)
research and analyse **roles of public health organisations**

- study historical outbreaks and responses, medical and social
- discuss differential access to health care
- online manipulable models
- overview of SARS-CoV-2 or other disease data and modelling
- model acquisition of herd immunity
- reports/presentations on current/historical vaccination campaigns
- presentations on zoonotic “spillover” events (e.g. tuberculosis, influenza, HIV, Ebola, Q fever)
- research conditions making zoonoses more likely
- discuss differential access to health care
- study effects of pollution on human health (e.g. chemicals, light, noise, plastics, tobacco...)

Water

Water, the most abundant natural resource for us and all living things on Earth

identify **the properties of water that underpin life and the biosphere**

(heat capacity, polarity, thermal conductivity, surface tension, heat of vaporisation, vapour pressure, viscosity and cohesion, boiling point and freezing point, density of solid state and liquid state)

- experiments with capillary action, surface tension, adhesion and cohesion, freezing expansion, lake turnover
- create terrariums, aquariums, Vinogradsky columns
- mechanisms for body temperature regulation

model **local and global water cycles**

- experiments with heat capacity of water
- field trips to local watersheds
- research, presentations about fertilizer runoff
- rainwater harvesting for school garden
- chemical analysis of rainwater and/or local water sources

research **how much of Earth's water is available for human use**
explore **water conservation issues and politics**
research **industrial uses of water**
analyse the **concept of water scarcity in both physical and economic terms**
explore **water as a renewable source of energy**

- experiment with hydroponics
- research water footprint for crops and livestock
- experiment with water needs (amount, salinity) of different varieties of same plant
- visit or invite representatives of water-intensive industrial sites (e.g. paper mill, sugar mill)
- investigate water footprint of textile industry
- hydropower plant visit; research ecological costs of hydropower
- chemical analysis of polluted water
- research impacts of microplastics water pollution
- research desalination, purification technologies
- use a water footprint calculator
- online modelling games
- research and debate European water conservation and distribution policies

Project

An opportunity to explore one or more of this course's themes in depth.

The assessment of the project may replace the short written examination for one of the semesters in s7 (B1 or B2).

propose and *carry out* **an independent project, related to any of the subject themes of the Science, Technology, and Society course**
(approximately 10 periods of class time over s6-7, 16 hours total maximum including outside work. Pupils may work individually, in pairs, or in small groups on a common project, but work must be individually documented and assessed. Pupils should be organised into small groups of 3-4 who will be mutually responsible for peer review and feedback. It is envisaged that all or almost all of the project be carried out during class hours.

- project proposal
- interim report of progress
- final product

provide **substantive peer review and feedback**

- feedback provided both orally and in writing for proposal and interim report according to specified criteria/rubric

present product of completed project to a **wider audience**

- possible project products include but are not limited to: experimental investigation; written report or essay; interview; participation in a citizen science project; video; website; online presentation; journalism piece; artistic project

make use of **formative and summative evaluation**

5. Assessment

Assessments must be oriented around (1) the **cross-cutting concepts** shared by mathematics and science (see section 3.1), (2) the **competence-based attainment descriptors** for the 2-period Science, Technology, and Society course (see sections 3.2 and 5.1), and (3) the **Key Competences for the European Schools** (see section 1). 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 an activity, brief presentations by pupils of work in progress) to more complex and time-demanding (e.g. tests requiring pupils to apply what they have learned in new situations, group presentations of a project, IBL outcomes).

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

- **demonstrate mastery of a subject, including ability to apply competences to new situations**
- **do substantial writing**
- **practice information literacy skills**
- **analyse historical, social, civic, cultural, political, and ethical aspects of science**
- **make and use models of phenomena and/or systems**
- **engage in debates and class discussions**
- **present their work to classmates, parents, or the public**
- **work in teams**
- **carry out self and peer evaluation**
- **perform and analyse experiments**

Teachers should make an annual assessment plan that provides a weighting of different assessment activities and ensures that all the competences are assessed over the two years of the cycle.

Teachers should not emphasise rote learning. Pupils should be prepared to analyse documents, to bring their own contextual knowledge to bear, and to synthesise complex responses.

Subjects for the baccalaureate oral examinations should be transversal across the topics chosen in the course. Each examination subject will consist of two documents at the level of a general public, at least one of which must include scientific data or conclusions for analysis. A cartoon or similar brief item may be included for use in follow-up discussion. <u>Full references must be included for each source.</u> Subject proposals should be formatted in the same way as the examples in Annex 2 (each document presented in a table: row 1, document number and brief introduction as appropriate; row 2, document; row 3, full source citation). Candidates will be asked to respond to the following three questions (see also Annex 2):

1) *Relate this examination subject to what you've learned in at least two topics of the Science, Technology, and Society course.*

2) *Describe and analyse the scientific data and/or conclusions presented in this examination subject.*

3) *Explain what is most important to understand about this examination subject to an interested person who is unfamiliar with it.*

Sample examination subjects are found in Annex 2.

5.1. Attainment descriptors – Science, Technology, and Society 2-period course

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

	9.0-10 ***Excellent***	**8.0-8.9** ***Very good***	**7.0-7.9** ***Good***	**6.0-6.9** ***Satisfactory***	**5.0-5.9** ***Sufficient***	**3.0-4.9** ***Failed/Weak***	**0-2.9** ***Failed/Very Weak***
Analysis and information literacy[4]	Can easily analyse and make critical interpretations of data presented at the level of an educated general public. Can consistently independently find, and assess the reliability of, information on scientific subjects, on- and offline. Is capable of sophisticated evaluation of the provenance and authority of science-based claims in the public sphere.	Can analyse and interpret data presented to the level of an educated general public. Can usually independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can make nuanced evaluation of the provenance and authority of science-based claims in the public sphere.	Produces good analysis and explanations of simple data. Can often independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can reliably evaluate the provenance and authority of science-based claims in the public sphere.	Produces basic analysis and explanations of simple data. With aid, can find, and assess the reliability of, information on scientific subjects, on- and offline, and evaluate of the provenance and authority of science-based claims in the public sphere.	Given help, can analyse and explain simple data. Can retrieve information on scientific subjects when directed to reliable sources, on- and offline. Can distinguish scientific consensus from fringe views in the public sphere.	Can use and interpret even simple data only with significant guidance. Generally, is unable to find, or to assess the reliability of, information on scientific subjects, on- and offline.	Is unable to analyse or interpret even simple data with help. Is unable to find, or to assess the reliability of, information on scientific subjects, on- or offline.
Problem solving and synthesis	Readily makes connections between different parts of the syllabus, applies concepts to a wide variety of unfamiliar situations, and makes nuanced ethical arguments.	Makes connections between different parts of the syllabus, applies concepts and principles to unfamiliar situations, and makes reasoned ethical arguments.	Can use knowledge in an unfamiliar situation; makes basic ethical arguments.	Can use knowledge in a familiar situation and make basic ethical arguments.	Can use basic knowledge in a familiar situation; demonstrates understanding of the importance of ethics in science.	Is unable correctly to apply basic knowledge to solve problems; unclear about the importance of ethical issues in science.	Is entirely unable to apply even basic knowledge to solve problems, shows little interest in ethical dimensions of science.

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

Oral and written communication	Communicates clearly and concisely, using appropriate vocabulary. Excellent presentation skills. Engages in fluent discussion of issues of public importance raised by science and scientists.	Communicates clearly, using appropriate vocabulary. Very good presentation skills. Readily engages in discussion of issues of public importance raised by science and scientists.	Communicates clearly most of the time using appropriate vocabulary correctly. Good presentation skills. Engages in discussion of issues of public importance raised by science and scientists.	Uses basic scientific vocabulary, and descriptions show some structure. Satisfactory presentation skills. Engages when prompted in discussion of issues of public importance raised by science and scientists.	Uses basic scientific vocabulary, but descriptions may lack structure or clarity. Sufficient presentation skills. Engages when prompted in basic discussion of issues of public importance raised by science and scientists.	Poor knowledge and use of scientific vocabulary. Produces generally insufficient or incomplete descriptions. Unable to present coherently. Little awareness even when prompted of issues of public importance raised by science and scientists.	Very poor communication and presentation skills. No awareness even when prompted of issues of public importance raised by science and scientists.
Teamwork and project management	Works constructively as a team member, shows initiative, and can take responsibility for a team. Can independently plan and carry out a project.	Works constructively in a team and can take responsibility for a team with guidance. Can plan and carry out a project with minimal guidance.	Works well in a team. Can plan and carry out a project with guidance.	Works satisfactorily in a team. Can plan and carry out a project given guidance.	Participates in teamwork. Can plan and carry out a project given significant guidance.	Needs assistance when working in a team. Unable to plan and carry out a project fully, even given significant guidance.	Does not work in a team. Unable to plan and/or carry out a project even given significant guidance.

SYNOPSIS – ATTAINMENT DESCRIPTORS BY LEVEL

Mark 9.0–10.0 – Excellent

The student: Can easily analyse and make critical interpretations of data presented at the level of an educated general public. Can consistently independently find, and assess the reliability of, information on scientific subjects, on- and offline. Is capable of sophisticated evaluation of the provenance and authority of science-based claims in the public sphere. Readily makes connections between different parts of the syllabus, applies concepts to a wide variety of unfamiliar situations, and makes nuanced ethical arguments. Communicates clearly and concisely, using appropriate vocabulary. Excellent presentation skills. Engages in fluent discussion of issues of public importance raised by science and scientists. Works constructively as a team member, shows initiative, and can take responsibility for a team. Can independently plan and carry out a project.

Mark 8.0–8.9 – Very good

The student: Can analyse and interpret data presented to the level of an educated general public. Can usually independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can make nuanced evaluation of the provenance and authority of science-based claims in the public sphere. Makes connections between different parts of the syllabus, applies concepts and principles to unfamiliar situations, and makes reasoned ethical arguments. Communicates clearly, using appropriate vocabulary. Very good presentation skills. Readily engages in discussion of issues of public importance raised by science and scientists. Works constructively in a team and can take responsibility for a team with guidance. Can plan and carry out a project with minimal guidance.

Mark 7.0–7.9 – Good

The student: Produces good analysis and explanations of simple data. Can often independently find, and assess the reliability of, information on scientific subjects, on- and offline. Can reliably evaluate the provenance and authority of science-based claims in the public sphere. Can use knowledge in an unfamiliar situation; makes basic ethical arguments. Communicates clearly most of the time using appropriate vocabulary correctly. Good presentation skills. Engages in discussion of issues of public importance raised by science and scientists. Works well in a team. Can plan and carry out a project with guidance.

Mark 6.0–6.9 – Satisfactory

The student: Produces basic analysis and explanations of simple data. With aid, can find, and assess the reliability of, information on scientific subjects, on- and offline, and evaluate of the provenance and authority of science-based claims in the public sphere. Can use knowledge in a familiar situation and make basic ethical arguments. Uses basic scientific vocabulary, and descriptions show some structure. Satisfactory presentation skills. Engages when prompted in discussion of issues of public importance raised by science and scientists. Works satisfactorily in a team. Can plan and carry out a project given guidance.

Mark 5.0–5.9 – Sufficient

The student: Given help, can analyse and explain simple data. Can retrieve information on scientific subjects when directed to reliable sources, on- and offline. Can distinguish scientific consensus from fringe views in the public sphere. Can use basic knowledge in a familiar situation; demonstrates understanding of the importance of ethics in science. Uses basic scientific vocabulary, but descriptions may lack structure or clarity. Sufficient presentation skills. Engages when prompted in basic discussion of issues of public importance raised by science and scientists. Participates in teamwork. Can plan and carry out a project given significant guidance.

Mark 3.0–4.9 – Failed/Weak

The student: Can use and interpret even simple data only with significant guidance. Generally, is unable to find, or to assess the reliability of, information on scientific subjects, on- and offline. Is unable correctly to apply basic knowledge to solve problems; unclear about the importance of ethical issues in science. Poor knowledge and use of scientific vocabulary. Produces generally insufficient or incomplete descriptions.

Unable to present coherently. Little awareness even when prompted of issues of public importance raised by science and scientists. Needs assistance when working in a team. Unable to plan and carry out a project fully, even given significant guidance.

Mark 0–2.9 – Failed/Very weak

The student: Is unable to analyse or interpret even simple data with help. Is unable to find, or to assess the reliability of, information on scientific subjects, on- or offline. Is entirely unable to apply even basic knowledge to solve problems, shows little interest in ethical dimensions of science. Very poor communication and presentation skills. No awareness even when prompted of issues of public importance raised by science and scientists. Does not work in a team. Unable to plan and/or carry out a project even given significant guidance.

Annex 1 – Operators used in learning objectives in 4.2, by attainment descriptor

Note: operators may apply to and be listed under more than one attainment descriptor.

Analysis and information literacy	**Analyse und Informationskompetenz**	**Analyse et culture de l’information**
analyse	*analysieren/untersuchen/auswerten*	*étudier/interpréter*
compare/contrast	*vergleichen und gegenüberstellen*	*comparer*
discuss	*diskutieren/erörtern*	*argumenter/discuter*
distinguish	*unterscheiden/abgrenzen*	*distinguer*
evaluate	*bewerten*	*évaluer*
explore	*erkunden/untersuchen*	*explorer, étudier*
give overview	*einen Überblick geben*	*présenter une vue globale*
identify	*identifizieren*	*identifier*
relate	*verknüpfen*	*relier/mettre en relation*
research	*untersuchen*	*rechercher*
review	*überprüfen*	*vérifier*
Problem solving and synthesis	**Problemlösung und Synthese**	**Résolution de problèmes et synthèse**
explore	*erkunden/untersuchen*	*explorer, étudier*
explain	*erklären*	*présenter/expliciter/préciser*
model	*entwickeln*	*modéliser*
recognise	*erkennen*	*comprendre/constater*
Oral and written communication	**Kommunikation (mündlich und schriftlich)**	**Communication (orale et écrite)**
compare/contrast	*vergleichen und gegenüberstellen*	*comparer*
debate	*debattieren*	*débattre*
discuss	*diskutieren/erörtern*	*argumenter/discuter*
explain	*erklären*	*présenter/expliciter/préciser*
give overview	*einen Überblick geben*	*présenter une vue globale*
investigate	*untersuchen*	*étudier*
make use of feedback	*Evaluation nutzen*	*utiliser l’évaluation*
present	*präsentieren*	*présenter*
provide feedback	*Feedback geben*	*donner un avis*
use	*anwenden*	*utiliser/exploiter*
Teamwork and project management	**Teamarbeit und Projektmanagement**	**Travail en groupe et gestion de projet**
discuss	*diskutieren*	*échanger*
explore	*erkunden/untersuchen*	*explorer, étudier*
make use of feedback	*Evaluation nutzen*	*utiliser l’évaluation*
present	*präsentieren*	*présenter*
provide feedback	*Feedback geben*	*donner un avis*

Annex 2 – Sample oral Baccalaureate examinations

Subjects for the baccalaureate oral examinations should be transversal across the topics chosen in the course. Each examination subject will consist of two documents at the level of a general public, at least one of which must include scientific data or conclusions for analysis. A cartoon or similar brief item may be included for use in follow-up discussion. Full references must be included for each source. Subject proposals should be formatted as follows: each document presented in a table; row 1, document number and brief introduction as appropriate; row 2, document; row 3, full source citation).

The questions for the Baccalaureate oral examination
in Science, Technology, and Society will always be the same:

1) **Relate this examination subject to what you've learned in at least two topics of the Science, Technology, and Society course.**

2) **Describe and analyse the scientific data and/or conclusions presented in this examination subject.**

3) **Explain what is most important to understand about this examination subject to an interested person who is unfamiliar with it.**

DOCUMENT 1. Source: U.S. website of Ocean Spray, a cranberry growers' agricultural cooperative with worldwide annual revenue of 2 billion U.S. dollars (site accessed 2021).

Ocean Spray
Our Story | Products | Recipes | Health
Join Cranberry Club | Sign In

THE BERRY

Cranberries are one of Mother Nature's Superfruits! With powerful nutrients and well-documented health benefits, the cranberry can play an important role in a balanced diet and healthy lifestyle. The healthfulness of the cranberry begins at the farm. Here, at Ocean Spray, we have more than 700 cranberry farmers pouring their hearts into growing the fruit every day.

Why are cranberries good for you?

Small, but mighty, this Superfruit promotes many unique health benefits from the inside out. Among the more well-known benefits are the anti-bacterial properties that help prevent certain bacteria from sticking within the body and causing urinary tract infections. The cranberry is also naturally low in sugar and packed with antioxidant polyphenols. It addition, the cranberry contains essential vitamins, minerals, dietary fiber and more!

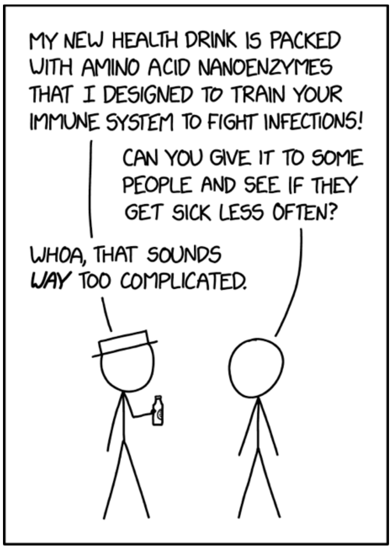
Ocean Spray® offers a wide variety of foods and beverages that can help add cranberry benefits to people's diets.

Learn More

(https://www.oceanspray.com/Health, accessed 11.9.2021)

DOCUMENT 2. Source: Randall Munroe, *XKCD* (2021)

xkcd *A webcomic of romance, sarcasm, math, and language.*



"You'd need to keep track of so many people! Would you use, like, Excel or something? Far too fancy for a simple country nanoenzyme developer like me."

https://xkcd.com/2475/

DOCUMENT 3. Source: "Scientific Opinion of the Panel on Dietetic Products, Nutrition and Allergies [European Food Safety Authority] on a request from Ocean Spray International Services Limited (UK), related to the scientific substantiation of a health claim on Ocean Spray Cranberry Products® and reduced risk of urinary tract infection in women" (2009).

European Food Safety Authority

Following an application from Ocean Spray International Services Limited (UK) … the Panel on Dietetic Products, Nutrition and Allergies was asked to deliver an opinion on the scientific substantiation of a health claim related to Ocean Spray cranberry products® … and urinary tract infection [*UTI*] in women.

The claimed effect is "helps reduce the risk of urinary tract infection in women by inhibiting the adhesion of certain bacteria in the urinary tract". The target population is healthy women from the age of 16 years.

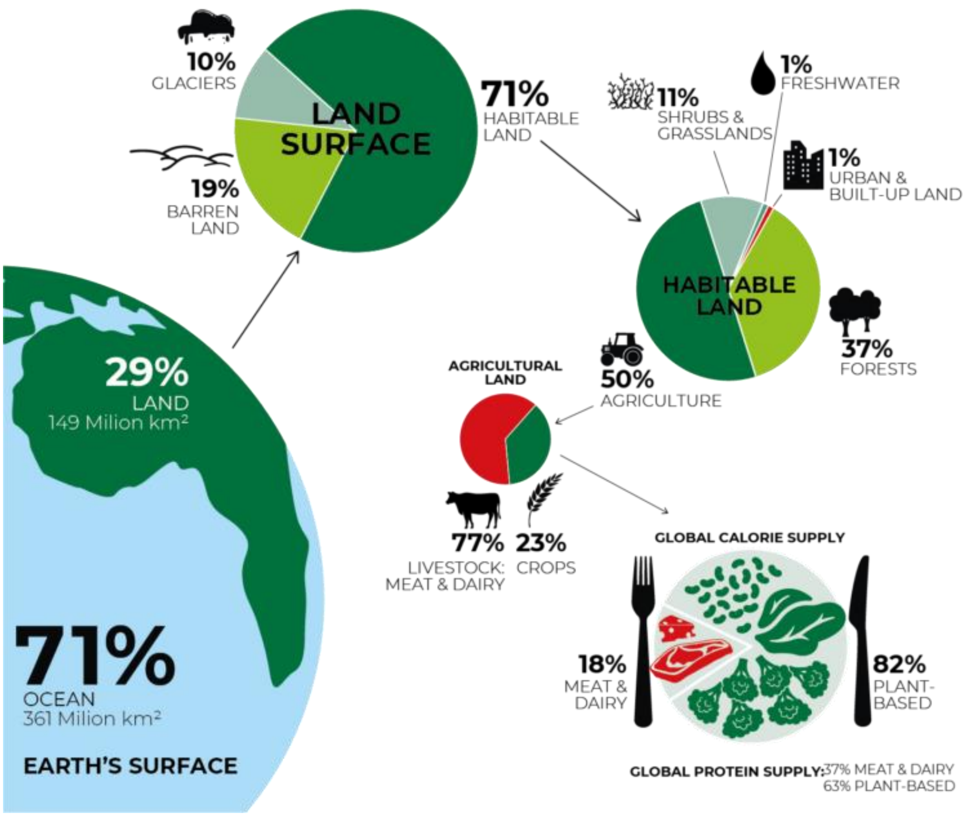
The applicant provided a … total of 12 human intervention studies. The panel considers that … 7 studies are of limited relevance for the claim targeted to healthy women. The panel considered the other 5 human intervention studies to be pertinent to the claimed effect. Two of the 5 pertinent studies are claimed proprietary by the applicant [*i.e., they were carried out by scientists working for the company*]. The panel noted that in the other 3 pertinent human studies there were significant limitations, including use of different cranberry formulations from that in the application, poor study design e.g. small numbers of subjects, the lack of a control group, short duration of study, as well as high drop-out rate in some of the studies, which considerably limit their value as a source of evidence to substantiate the claimed effect.

The panel concludes that the evidence provided is not sufficient to establish a cause and effect relationship between the consumption of Ocean Spray cranberry products® and the reduction of the risk of UTI in women.

The EFSA Journal (2009) 943, 1-16, doi: 10.2903/j.efsa.2009.943

DOCUMENT 1. Source: [The Curt Bergfors Foundation Food Planet Prize: Managing the Food System's Main Asset: Land.]

Like fossil fuels, land and soil are finite, non-renewable resources. They are also vulnerable to depletion and degradation. The conversion of land from one purpose to another—which is known as land-use change and refers, for example, to when grasslands are turned into cropland, or to when urban development encroaches on fertile farmland—is a leading cause of degradation. So too is land-use intensification—the process in which the productivity or profitability of a unit of land is augmented by, say, applying fertilizers or increasing heads of livestock.



PLANET TO PLATE: A breakdown of how we use the Earth's surface to feed ourselves.

DOCUMENT 2. Source: Sarah L. Bridle, *Food and Climate Change Without the Hot Air.* UIT Cambridge, Ltd. (2020).

What if everyone changed what they ate, to reduce their greenhouse-gas emissions from food? If everyone managed to halve their food emissions, it would reduce global greenhouse gas emissions by over 10%. Somehow, though, we need to make total emissions zero by 2050. Are we ever going to get there?

Emissions from heating, cars, planes and other non-food activities ... often require much bigger lifestyle changes than switching which shelf to pick food from, or they require governments to change in an internationally coordinated way. But the good news is that a major shift in diets can actually reduce climate change by *much more than 10%,* depending on what is done with the land that would otherwise have been used for farming. Since over one third of the Earth's land area is currently used for food production, repurposing farmland is a big deal.

DOCUMENT 3. Source: *https://twitter.com/Grietachtig/status/667614535268900864*

DOCUMENT 1. Source: Rebecca Corey, Yahoo News, accessed 2023.

AI takes on grief and loss, with new chatbot that lets you talk to dead loved ones

"You absolutely don't need consent from someone who's dead"

What does the future of grief and loss look like? An AI company called You, Only Virtual is creating chatbots modelled after deceased loved ones, with its founder, Justin Harrison, telling "Good Morning America" that he hopes people won't have to feel grief at all.

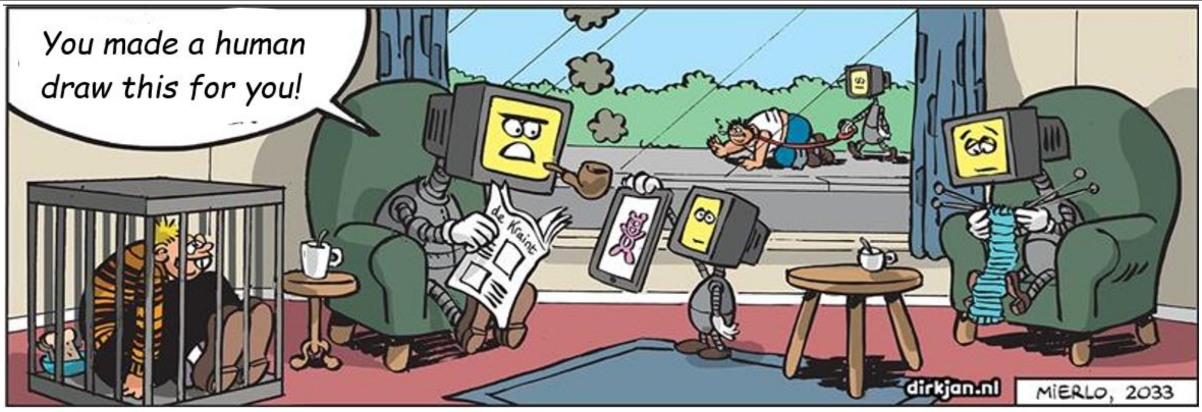
You, Only Virtual scans text messages, emails and phone calls shared between an individual and the deceased person to create a chatbot that composes original written or audio responses mimicking the deceased person's voice and modelling the relationship and rapport that the two shared in life.

The company, founded in 2020, hopes to offer a video-chat option later this year, "and ultimately provide augmented-reality that allows for interaction with a three-dimensional projection," GMA reported.

Harrison, who used the technology to create "a virtual mom" after his mother died, rejected possible privacy concerns raised by the use of personal conversations to build a chatbot without the consent of the deceased.

"You absolutely don't need consent from someone who's dead," he said. "My mom could've hated the idea, but this is what I wanted and I'm alive."

DOCUMENT 2. Source: Dirkjan.nl.



DOCUMENT 3. Source: Sjoerd de Jong, NRC. Accessed September 2023.

Neurophilosophers are knocking heads together

The integrated information theory of consciousness is under fire

Consciousness is *hot* in science – and therefore a cause for heated debates, conflicts and even battles of direction. In an open letter last week, 124 neuroscientists and philosophers strongly opposed a theory that is steadily gaining attention, the 'integrated information theory' (IIT) of consciousness. This is "pseudoscience", say the signatories, including big names such as the Americans Patricia Churchland and Daniel Dennett, who defend a purely physicalist view of consciousness.

The signatories find the new theory, developed in 2004 by neuroscientist and psychiatrist Giulio Tononi, unscientific and unverifiable. They also fear risky social effects if it is widely embraced, for example with regard to abortion and euthanasia (they believe that it follows from IIT that plants, fetuses and coma patients also have consciousness).

Sympathizers of the theory see the action as grossly exaggerated and a misplaced accusation. The reason for the letter was reporting in *Nature* and *Science* about empirical support for IIT, but, according to them, these reports were not at all favorable.

This is also the opinion of David Chalmers, the Australian philosopher who put the 'hard problem of consciousness' on the map in the 1990s. He complains on X about the "disproportionate" letter. "Calling IIT pseudoscience is like dropping an atomic bomb on a local dispute," said Chalmers.

'Integrated Information Theory' assumes that consciousness is a property of complex, integrated systems of information processing. In principle, this could also apply to physical systems other than the human or animal brain, for example even to plants. The theory has a mathematical elaboration, with *phi* as a symbol for the degree of information integration (and ultimately consciousness).

IIT is making waves and, according to physicist Sabine Hossenfelder, it is currently "the most popular mathematical theory about consciousness," she writes in *Existential Physics* (2022). But the theory has also been fiercely controversial from the start. Neurophilosophers criticize this as unverifiable or even as a form of 'magical thinking'. According to some, IIT comes dangerously close to panpsychism (the idea that the entire universe is conscious), despite the limitation that it explicitly concerns complex information systems and not 'everything that exists'.

IIT advocates dispute that the theory is untestable, but Hossenfelder points out that the calculations needed to determine a system's *phi* would take an impossibly long time using today's computers just to establish "consciousness" in a worm. Moreover, according to her, simple information systems are conceivable that can score a sky-high *phi* without being consciously aware.

Sample Baccalaureate Oral Examination
Science, Technology, and Society
Sample Examination Subject Template

DOCUMENT 1. Source: XXX. (Information about source if necessary)
Document *Reference*

DOCUMENT 2. Source: XXX. (Information about source if necessary)
Document *Reference*

DOCUMENT 3. Source: XXX. (Information about source if necessary)
Document *Reference*

Annex 3 – Oral Examination – Assessment Record Sheet

European School of ………………………………………….

Student/Élève/Schüler: …………………………………… Class/Classe/Klasse: ……………

Examiner/Examinateur/Examinator: …………………………………….

Mark	Evaluation according to the attainment descriptors
9.0-10 Excellent	The candidate has a "big picture" view of science, technology, and society. Can easily make connections between different parts of the course, demonstrating mastery at the top level of the syllabus or beyond. Is at ease analysing and making critical interpretations of unfamiliar scientific data and conclusions at the level of an educated public. Has clearly and concisely organised responses to the examination subject, and engages fluently in follow-up discussion, including of ethical and information literacy aspects as appropriate.
8.0-8.9 Very good	The candidate has a "big picture" view of science, technology, and society and can make connections between different parts of the course with little aid, demonstrating mastery of the entire syllabus. Can competently analyse unfamiliar scientific data and conclusions at the level of an educated public and demonstrates critical thinking. Has well-organised responses to the examination subject, and can respond to follow-up discussion, including of ethical and information literacy aspects as appropriate.
7.0-7.9 Good	The candidate can apply the competences called for in the syllabus, drawing on solid knowledge of content and vocabulary. Can analyse unfamiliar scientific conclusions and data at the level of an educated public, or ethical or information literacy issues, given minimal aid from the examiners. Has competently organised responses to the set questions, and is able to engage in follow-up discussion if supported by the examiners.
6.0-6.9 Satisfactory	The candidate demonstrates understanding of the major areas covered by the syllabus, employing correct vocabulary, and can analyse new issues given some aid from the examiners. May require some aid to analyse unfamiliar scientific data or conclusions or to recognise ethical or information literacy issues. Has prepared and structured responses to the set questions within the allotted time, and is able to engage in follow-up discussion when led by the examiners.
5.0-5.9 Sufficient	The candidate demonstrates understanding of the course, and can apply competences to unfamiliar issues given aid from the examiners. Largely employs correct vocabulary and recalls basic content related to a question. Given aid from the examiners can interpret data or scientific conclusions presented at the level of an educated public. Has prepared responses to all questions and presented them coherently. Can follow up on at least one further point in discussion with the examiners when led.
3.0-4.9 Failed/Weak	The candidate displays gaps in knowledge of one or more sections of the syllabus, and is unable successfully to make connections, interpret scientific data or conclusions, or recognise ethical or information literacy issues from these, even with substantial aid from the examiners. Shows gaps in vocabulary and/or content knowledge that are not corrected after support from the examiners. Responses have not been prepared to all questions, and/or the candidate is unable to respond within the allotted time. Minimal capacity or opportunity for follow-up discussion.
0-2.9 Failed/ Very Weak	The candidate displays major gaps in most parts of the syllabus, and is unable successfully to make connections, interpret scientific data or conclusions, or recognise ethical or information literacy issues from these, even with substantial aid from the examiners. Major gaps in vocabulary and content. Responses are substantially missing, incorrect, off-topic, disorganised, and/or out of the allotted time. There is no possibility of follow-up discussion.

Final mark: **Note finale:** **Endnote:**	

Date/Date/Datum: …………………… Signature/Signature/Unterschrift: ………………………………

Annex 4 – IBL Sample Lessons

Nota bene: The lesson plans in this annex are <u>not compulsory</u>. They are included as examples of different types of IBL (inquiry-based learning) approaches to a selection of course themes/topics.

Sample lesson 1: Water cycle (Topic: Water)

Sample lesson 2: Space exploration and tourism (Topic: Developing technologies)

Sample lesson 3: Epidemiological modelling (Topic: Personal and public health)

Annex 4 – Sample IBL Lesson 1

Theme: **Water.** Topic: **Water Cycle.** 2-3 periods

Sources: *Adapted from Cornell Science Inquiry Partnership - Curriculum Resources for Inquiry-Based Learning, ©HSPI-The Pogil Project, Pogil^{TM} - Activities for High School Biology, United States Geological Survey, Nature lab – Educator Resources*

Overview**:**

No prior knowledge required. In small teams facilitated by teacher, students conduct structured inquiry focused on the water cycle, landscape characteristics, and water quality. They track water through ecosystems, using interactive data-rich maps and models to investigate the relationship between global water pools and fluxes and explore why there is always a water supply. They investigate how bodies of water interact with the atmosphere, receiving precipitation and exchanging gases between water and air and with the surrounding landscape, receiving runoff along with sediments and dissolved materials that get carried along during rainfall or snowmelt events. After completing this lesson, students will have a better sense of the interconnections between human activities, landscape processes, and water quality and supply.

Students watch a video, read background material, and interpret diagrams that introduce water cycle concepts, followed by small group discussion to complete the tasks assigned; the teacher guides and explains as necessary.

Students will:

- identify questions and concepts that guide scientific investigations;
- recognize and analyse alternative explanations and models;
- formulate and revise scientific explanations;
- communicate and defend a scientific argument.

Assessment:

Questions and activities embedded in each lesson.

Suggested additional assessments:

- Students could bring to class a current news article that has to do with water availability/quality;
- Students could expand on their investigation by further researching questions that arose during the activity.

Preparation:

Stream video: *Water: The Source of Life*. Prepare student handouts 1-3 (see below). Provide for computer access for the second and third parts of the activity. Familiarise yourself with and be prepared to lead a discussion on pools and fluxes (resources here and here).

Lesson parts:

Task 1. Watch video.
Task 2. Complete Handout 1, "Source of Life," linked to video (teamwork)
Task 3. Complete Handout 2, "The Water Cycle" (teamwork)
Task 4. Explore interactive diagram: Pools and Fluxes in the Water Cycle
Task 5. Complete Handout 3, "Pools and Fluxes" (teamwork)

Extensions:

This lesson is excellent preparation for a field trip water sampling project to learn about water quality and types of pollution. This lesson can serve as an extension to an inquiry lesson addressing acid rain.

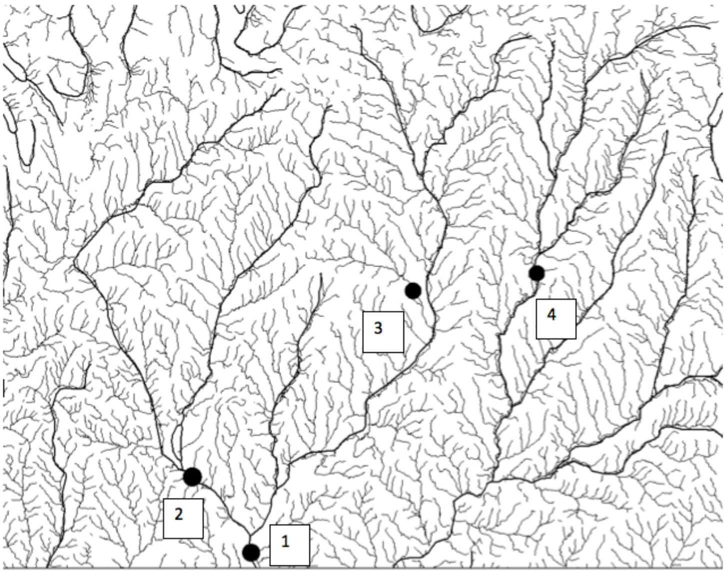
Annex 4 – Sample IBL Lesson 1

Theme: **Water.** Topic: **Water Cycle.** 2-3 periods

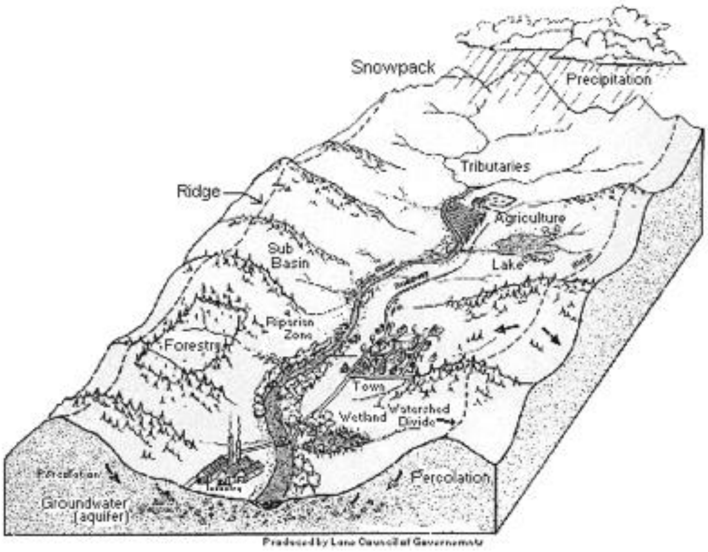
Handout 1: Source of Life (student worksheet)

1. As you watch *Source of Life*, note the ideas that relate to the topic of watersheds or living in a watershed.
2. What is the source of most of the city of Bogotá's water?
3. What are the primary sources of pollution or contaminants in the water that travels from Chingaza to Bogotá?
4. Why do you think you were shown this video?
5. Think about what you know about your own watershed. What ideas might you use from the video as inspiration and understanding for exploring or working in your own watershed?

How do you know whether the water in a river or stream is OK to drink? The most direct way to determine the water quality would be to sample the water and measure the level of pollutants (what are some water pollutants?). But you can also look at the features in a watershed to predict the water quality. The figure below shows a system of rivers.



7. Which way is the water flowing? (Draw arrows on the map)
8. What is a *watershed*, also called a *drainage basin* or *catchment*? (After you reach consensus in your group check with your teacher.)
9. Define the watershed for each black dot in the map above. (Draw a circle around all the rivers that drain into each point.)



Look at the watershed on the right.

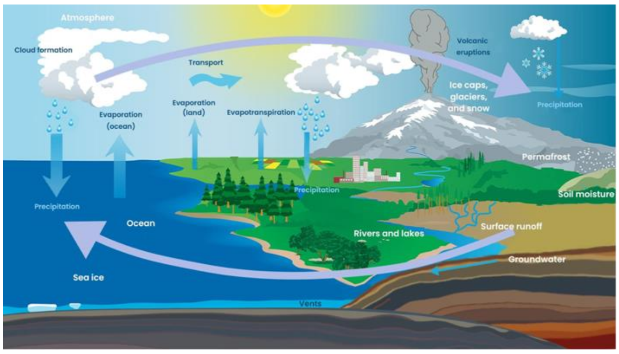
10. What landscape features does the water have to flow through in order to reach the outflow of the river?
11. How do you think these different features will affect water quality?

Annex 4 – Sample IBL Lesson 1

Theme: **Water.** Topic: **Water Cycle.** 2-3 periods

Handout 2: The Water Cycle (student worksheet)

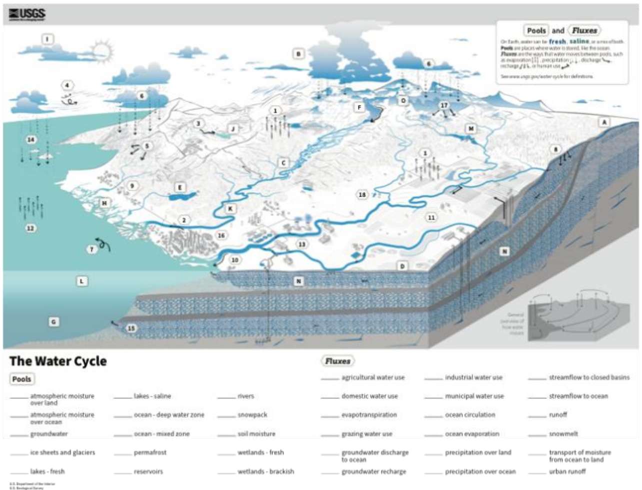
Launch this interactive diagram of the global water cycle showing where water is stored on Earth, and the major processes that move water between the atmosphere, land, and ocean.



1. What is the largest reservoir for water on earth?
2. What process contributes to the formation of groundwater?
3. Name two ways in which water is converted to vapour.
4. How does water return to the oceans from the land?
5. Rain, sleet, and snow are examples of what?
6. Which of the processes associated with the water cycle might be responsible for helping to clean or filter the water?
7. If the air contains high levels of pollutants what effect might this have on water quality?
8. The water cycle, like the other cycles, is a “closed system.” What does that say about the importance of keeping the water on earth free from pollution?
9. Which process(es) of the water cycle – precipitation, evaporation, condensation, run-off, percolation or transpiration might contribute to the addition of pollutants to rivers, lakes and oceans? Why?
10. In order to continually use the same area of land for agriculture, some farmers apply fertilizers to improve the level of nitrates in the soil. An alternative to intensive use of fertilizer is to plow the roots of leguminous plants back into the soil and leave the area unplanted for a season. Why would a farmer plow this type of plant roots back into the soil and what would be the benefit of turning over the soil and leaving the old plant roots?

Handout 3: Pools and Fluxes (student worksheet)

This interactive chart provides specific data and information about the water cycle, showing the size of global pools and fluxes of water and includes examples of specific water pools *and* fluxes*. Pools are places, like the ocean, where water is stored. Fluxes are the ways that water moves between pools, such as evaporation, precipitation, discharge, recharge, or human use. Using this information fill in the blanks on the diagram at right, using this for reference, which gives a more comprehensive view of the water cycle, drawing on principles of information design to focus attention on water as it moves through natural and built environments. It shows how multiple ecosystems – including a coastal plain, dry basin, wet basin, and agricultural basin – are connected across watersheds and at continental scales.*



Annex 4 – Sample IBL Lesson 2
Theme: **Developing Technologies.** Topic: **Space.** 6 periods

Goal: *Looking at the future of space travel from different perspectives.*

Approach: Below are two different topics relating to space travel. These topics give pupils opportunities to explore not only scientific complexities but also political, economic, environmental, and ethical aspects and motivations. The teacher can:

- use one or both of the topics below, or use this model to develop additional topics;
    - introduce the topic(s) to the class as a whole, then have pupils choose small groups focusing on selected questions to research, discuss, write, and present their assigned subtopics;
    - split the pupils into groups from the beginning with assigned topics;
- use optional hyperlinks for introduction.

Topic 1: Space Tourism.

Several companies, some well known for their wealthy founders, are steadily making progress towards lowering the costs of launching into space. Some new designs, including balloon launches and reusable rockets, open up opportunities for a new business: recreational space travel.

Assignment: In small groups, you will investigate one of the questions or subtopics below. Find articles, news, and examples. Develop a 10-minute presentation addressing your subtopic, including visuals (you may make a poster, a concept map, a prezi, etc.), to be given in class. You will hand in an overview of your preparations and a bibliography and source analysis.

- Subtopic A: "Space" is a term used in many different contexts. Explain the different uses of "space," and create a clear, visual and intuitive overview to present to your classmates.
    - Some terms that may be useful: *stratosphere, mesosphere, low orbit, high orbit, moon, solar system, galaxy, deep space*
- Subtopic B: Find and describe different recently developed technologies which have accelerated the possibilities for space tourism (and lowers the costs per astronaut)
    - Some terms that may be useful: *3D printed rocket, balloon launch, launch from plane, reusable rocket*
- Subtopic C: What are the risks, compared to airplanes or other travel: e.g. crash statistics, cosmic radiation, onboard health issues? Should children be allowed? Pregnant people? Should there be an upper age limit? What kinds of physical and mental preparation must a would-be space tourist currently go through?
- Subtopic D: What does it cost to go to space? What should travel to space be worth? Who should go? Some people argue everyone should go at least once, while others are opposed to any recreational space tourism. What do you think?
- Subtopic E: What would be the environmental impact of mass tourism in space? Describe the problems and challenges. Might there be comparison with 'flight shaming'?
    - Some terms that may be useful: *pollution, fuel, exhaust, resources, crossing atmospheric layers, light pollution, space junk*
- Subtopic F: Who owns space? Who's responsible? Who makes the rules? If you were to propose space tourism regulations to the United Nations, what rules would you suggest?

Annex 4 – Sample IBL Lesson 2

Theme: **Developing Technologies.** Topic: **Space.** 6 periods

Topic 2: Moon Race.

In recent years, many countries have been working to achieve new lunar landings. Why are countries so eager to land people or robots on the moon? (China, the EU, USA, India, Pakistan, Russia...). What might the future of the moon look like?

Some frequently mentioned motives are:

- nationalism/prestige
- mining/resource extraction
- colonisation/territorial expansion
- scientific research
- deep-space hub

Choose and study one of the motives from the list above. Find at least three recent news articles on the subject from scientific publications or (international) media articles. Prepare a brief written summary of your findings, plus a bibliography and source analysis.

The country you live in may already be taking part in the moon race, or might do so in the future. Prepare a presentation to convince your fellow students why your country should or should not take part in the moon race.

Alternative: Debate contest approach. Assign pupils a position to prepare, to encourage consideration of all sides of issues.

Annex 4 – Sample IBL Lesson 3

Theme: **Personal and Public Health.** Topic: **Epidemiology.** 2 periods + online discussion.

Lesson overview: *Pupils watch a video from the Crash Course series "Outbreak Science" introducing epidemiological modelling. They then explore a selection of online models, using digital literacy skills to research and understand background and terminology as needed, and engage in class and online discussion to compare, contrast, and evaluate them.*

Materials: Projector for video. Computer/internet access for each pupil (laptops, tablets, or dedicated computer room).

Assessment: Pupils will receive a (formative) A-mark for their contributions to a Teams chat to discuss strengths and weaknesses of different online epidemiology models.

Competences assessed: Analysis and information literacy; problem solving and synthesis; written communication

Syllabus Subject Content and Learning Objectives:

recognise and discuss **infectious disease as a population phenomenon** (epidemics, pandemics, environmental, systemic diseases)

explain and use **basic epidemiological models** (R_0 resulting from varying values of virulence, duration of infection, rate of transmission, and initial immunity; significance of positivity rate)

analyse **the personal and public benefits of vaccination** (personal and herd immunity)

Cross-cutting Concepts:

- **Patterns**
- **Cause and effect**
- **Stability and change**
- **Quantification**
- **Representing data**
- **Scale, proportion, and quantity**
- **Modelling**
- **Nature of science**

	Engagement	**Time: 30 minutes**	
What the teacher will do	*What the teacher will say*	*Probing/eliciting questions*	*Possible student responses*
Watch Crash Course "Outbreak Science" video 9, "Can We Predict an Outbreak's Future?" with class. Stop video to explain and elaborate as appropriate.	We've been talking in class about how to maintain our individual health, and about how our bodies respond to being sick. Today we'll go to a bigger scale: how infectious diseases spread in populations.	So, what do scientists use models for? What are their strengths and weaknesses? What are the strengths of the SIR and SEIR models? Their weaknesses? What important parameters are missing? How are these models so powerful even though they're simple? How does vaccination change infection curves?	Models tell us how things work. Models tell us what will happen. Models aren't real. SIR and SEIR are too simple. How do scientists figure out what to measure? How do they get the data?
Decision point assessment: move to next section when… video is finished and pupils' questions are answered.			

Annex 4 – Sample IBL Lesson 3

Theme: **Personal and Public Health.** Topic: **Epidemiology.** 2 periods + online discussion.

	Exploration and Explanation	**Time: 55 minutes**	
What the teacher will do	*What the teacher will say*	*Probing/eliciting questions*	*Possible student responses*
(Alternatively, you can provide individual links to these: *Washington Post* billiard ball simulator; *Towards Data Science* agent-based simulation; *Melting Asphalt* grid-based model; *Washington Post* hexagonal grid model; *R2D3* simulations; Gabriel Goh, interactive Epidemic Calculator; Alison Hill, Modelling Covid-19 Spread vs. Healthcare Capacity; or to other online epidemiological models.)	Please log on to your computer and go to *Medium,* "Covid-19: Top 7 Online Interactive Simulations, Curated." Choose one or two models and play with them in depth. While you're looking at these models, you should be doing lateral research to find out about terminology, organizations, etc. mentioned in the articles that are unfamiliar to you. Be sure you are assessing the reliability of every source. Ask me if you need help!	What do you like/dislike about this model you're looking at? What is the [WHO/CDC/Santé Publique, etc.]? How can you figure this out? You've found a link to https://pubmed.ncbi.nlm.nih.gov/. What does this mean?	This one shows how individual contacts shape an outbreak. This one is fun to try to set so there's a world plague that kills everybody! I can't figure out if [Website] is reliable. I can't figure out what [X] means/is showing me. This page is asking me to pay to get a journal article!
Decision point assessment: move to next section when… five minutes of class time remain.			

	Elaboration	**Time: 5 minutes**	
What the teacher will do	*What the teacher will say*	*Probing/eliciting questions*	*Possible student responses*
Set up a dedicated chat thread on class Teams or other platforms for pupils to discuss the models they were looking at.	OK, everyone will log on to Teams and tell us which model(s) you liked best or found most effective and why.	Be sure you explain both the strengths and weaknesses of the one(s) you pick!	

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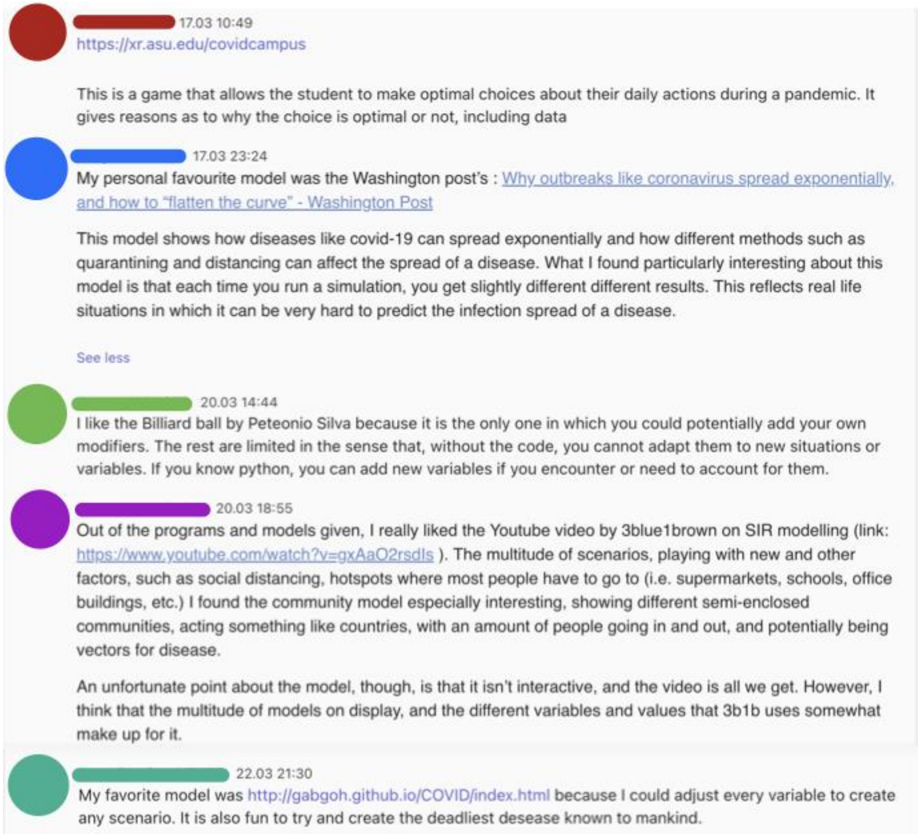
Theme: **Personal and Public Health.** Topic: **Epidemiology.** 2 periods + online discussion.

Evaluation	**Time: variable (outside class)**
What the teacher will do	*Sample student responses*
Read through and contribute to the online discussion of the models. Give an A-mark to each pupil based on completeness, depth of understanding, quality of research, and communication skills.	 [redacted] 17.03 10:49 https://xr.asu.edu/covidcampus This is a game that allows the student to make optimal choices about their daily actions during a pandemic. It gives reasons as to why the choice is optimal or not, including data [redacted] 17.03 23:24 My personal favourite model was the Washington post's : Why outbreaks like coronavirus spread exponentially, and how to "flatten the curve" - Washington Post This model shows how diseases like covid-19 can spread exponentially and how different methods such as quarantining and distancing can affect the spread of a disease. What I found particularly interesting about this model is that each time you run a simulation, you get slightly different different results. This reflects real life situations in which it can be very hard to predict the infection spread of a disease. See less [redacted] 20.03 14:44 I like the Billiard ball by Peteonio Silva because it is the only one in which you could potentially add your own modifiers. The rest are limited in the sense that, without the code, you cannot adapt them to new situations or variables. If you know python, you can add new variables if you encounter or need to account for them. [redacted] 20.03 18:55 Out of the programs and models given, I really liked the Youtube video by 3blue1brown on SIR modelling (link: https://www.youtube.com/watch?v=gxAaO2rsdls). The multitude of scenarios, playing with new and other factors, such as social distancing, hotspots where most people have to go to (i.e. supermarkets, schools, office buildings, etc.) I found the community model especially interesting, showing different semi-enclosed communities, acting something like countries, with an amount of people going in and out, and potentially being vectors for disease. An unfortunate point about the model, though, is that it isn't interactive, and the video is all we get. However, I think that the multitude of models on display, and the different variables and values that 3b1b uses somewhat make up for it. [redacted] 22.03 21:30 My favorite model was http://gabgoh.github.io/COVID/index.html because I could adjust every variable to create any scenario. It is also fun to try and create the deadliest desease known to mankind.