Partnerships for Science Education

Project Number: 101006468

Project Acronym: PAFSE

Project title: Partnerships for Science Education

D2.3 DIGITAL EDUCATIONAL RESOURCES, LEARNING OBJECTS AND EDUCATIONAL SCENARIOS (PILOT VERSIONS)

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This document is the first version of D2.3 to be available in month 12 as PAFSE deliverable.

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Contents

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1. Specifications for Educational Scenario on the topic: Looking after myself and others – Healthy Eating

Main partner responsible
University of Cyprus, Nicosia, Cyprus

Element of the scenario

Subject: Biology classes

Grade: 8th grade (+/- 13-14 years old students)

Estimated duration: 9 lessons X 40 min

Classroom organization: Students' groups of 3-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).

PAFSE Topic: This Educational Scenario is an integrated learning module in Public Health Education related to the topic: Looking after myself and others- Healthy Eating.

- ✓ Fostering the Mediterranean diet: the underlying science.
- ✓ Physical activity and education for nourishment. Food Education and Physical Activity.

Overview

Obesity is one of the most serious global public health challenges of the 21st century, affecting every country in the world. In addition, it is not only a chronic disease in itself, but also a major risk factor for the world's leading causes of poor health and early death including cardiovascular disease, several common cancers and diabetes.

The main aim of this unit is to raise 8th grade students' awareness of rational nutrition and the health risks of unhealthy eating and not physical activity. Additionally, the unit aims to foster student's understanding about the role of socio-economic, political and cultural environment in the rising prevalence of childhood obesity worldwide and provide critical health literacy.

A socioscientific topic related to childhood obesity provides the scenario for the inquiry-based primary questions and of this unit related to the learning topic *Healthy Eating*:

Socioscientific topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions*

Georgia, Vasiliki, Anastasia and George are 13-15 years old, high school students. They, often, share their opinions, habits and experiences on health and nutrition issues on a google blog, which is often visited by their friends and classmates. Last week these students posted various statements related to health and nutrition issues. Specifically, in their posts they wrote the following:

Georgia: *For the last three years I have made tremendous efforts to lose weight, but I have not succeeded. Now I have decided to go vegan, hoping to succeed.*

Vasiliki: *I don't want to gain extra kilos, so I decided to avoid different types of food and to eat more frequent meals*.

Anastasia, reading the posts of her classmates, wrote the following on the blog: *I think that the issue of healthy eating and obesity is much more complicated. During a visit to my paediatrician, I heard that television advertising of unhealthy food is an important cause for childhood obesity.*

George also reacted to his classmates' posts by blogging the following: *On a scientific website on healthy eating, I read that the main causes of obesity are related to an individual's personal dietary choices and lifestyle, but also to the socio-economic and political conditions of the area where he/she lives.*

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Primary research questions:

- ✓ *What are the causes, health risks and solutions related to childhood obesity?*
- ✓ *What is individuals' and governments' responsibility for reducing childhood obesity?*
- ✓ *What are the community's perceptions and knowledge concerning childhood obesity?*

First, students will obtain a basic conceptual understanding about organic and inorganic nutrients essential to human functioning, about food pyramid and Mediterranean diet. Yet, they will identify the relationship between healthy eating and the concept obesity.

To answer the primary research questions of this unit, students are asked to formulate hypotheses and specific questions, to collect data from a variety of inquiry-based sources (e.g. such as texts, articles, pictures and videos, tables and diagrams, simulations and scientific measurements), in order to answer the socioscientific issue primary research questions related to childhood obesity.

Additionally, students organising and holding a forum for a discussion about childhood obesity and proposing solutions will act as knowledgeable social agents through citizenship education.

Glossary: didactical glossary (or content glossary) and pedagogical glossary

1. Didactical glossary (or content glossary)

Carbohydrates are organic nutrients, responsible for providing the most energy utilized by the animal kingdom. They are our body's first choice for fuel. Carbohydrates provide also structural materials to the living organism. They are also energy storage substances for plant cells. They come mainly from plant foods. Carbohydrates are often the sugar, fibres, and starches that are found in grains, fruits, vegetables, and some milk products (1g carbohydrates provides 4 Kcal or 17 KJ energy).

Complementary nutrients are those substances which, although they have neither a structural nor an energetic role in the body, are necessary for the normal functioning of the living organism.

Dietary fibre is mainly derived from the cell walls of plant cells. Their role in nutrition and health maintenance is very important. According to current scientific knowledge, fibre is divided into soluble and insoluble fibres. Insoluble fibre is not degraded in the colon, but passes through and excreted in the faeces. They are important for the good functioning of the digestive system, for the protection against colon cancer and constipation and for the increase of the feeling of satiety. The soluble fibre is degraded by the microbial flora (bacteria) of colon.

Food pyramid is a visual representation and depicts the different food groups that are essential for the human body as well as the amounts of each group that should be eaten each day, based on nutritional recommendations.

Health is a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity

Health behaviour is any activity undertaken by an individual for the purpose of promoting, protecting, maintaining or regaining health, whether or not such behaviour is objectively effective towards that end.

Health education is any combination of learning experiences designed to help individuals and communities improve their health by increasing knowledge, influencing motivation and improving health literacy.

Health for All is the attainment by all the people of the world of a level of health that will permit them to lead a socially and economically productive life regardless of who they are or where they live.

Health outcomes is a change in the health status of an individual, group or population that is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status.

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Health policy refers to decisions, plans, and actions that are undertaken to achieve specific health care goals within a society.

Health promoting schools can be characterised as a school constantly strengthening its capacity as a healthy setting for living, learning and working.

Healthy life expectancy is a population-based measure of the proportion of expected life span estimated to be healthful and fulfilling, or free of illness, disease and disability according to social norms and perceptions and professional standards.

Health status is the state of health of a person or population assessed with reference to morbidity, impairments, anthropological measurements, mortality, and indicators of functional status and quality of life.

Inorganing nutrients refer to not carbon-containing substances derived from foods. Inorganic nutrients are divided into two groups: minerals and water. Some minerals are Sodium, Potassium, Calcium, Magnesium, Fluoride, Zinc and Iron.

Life expectancy is the average number of years an individual of a given age is expected to live if current age-specific mortality rates continue to apply.

Lipids are organic nutrients, responsible for providing structural materials, and energy to the cells of the living organisms. They are important energy-saving substances for animal organisms. They are the richest energy materials. They are also a thermal insulator for the body of animals (1g lipids provides 9 Kcal or 39 KJ energy).

Mediterranean diet is a diet inspired by the eating habits of people who live near the Mediterranean Sea. This diet is characterised of high intake of extra virgin olive oil, vegetables including leafy green vegetables, fruits, cereals, nuts and pulses/legumes, moderate intakes of fish and other meat, dairy products and red wine, and low intakes of eggs and sweets.

Minerals are inorganic complementary nutrients derived from the plant and animal foods, as well as from water. They play an important role in the body as key components of many biological structures (bones, teeth) and are involved in important functions in the body. Others are classified as macronutrients and are needed in large quantities in the body (e.g. calcium and magnesium salts) and others are classified as trace elements and are needed in small amounts in the body (e.g. iodine salts, iron salts, iron salts, calcium salts, etc.).

Nucleic acids are organic nutrients, mainly responsible for providing structural materials to the cells of the living organisms (genetic material) and determine and control the production of proteins. Through proteins, nucleic acids control all functions and hereditary characteristics of living organisms.

Nutrients are substances required by the living organism for survival, growth, and reproduction. In other words, nutrients are what give us energy and allow our bodies to perform their essential functions.

Obesity is a multifactorial disease caused by various factors like unhealthy eating reduced physical activity, psychological and hereditary factors (genes). Obesity isn't just a cosmetic problem. It's a medical problem that increases the risk of other diseases and health problems, such as heart disease, diabetes, high blood pressure and certain cancers.

Organic nutrients refer to carbon-containing substances derived from foods. Carbon represents an element essential to a majority of life forms on Earth. Organic nutrients are carbohydrates, lipids, proteins, nucleic acids, and vitamins.

Proteins are organic nutrients responsible for providing structural materials, and less energy to the cells of the living organisms. Much of our body is built from proteins. Proteins also carry out many essential functions in the body of the living organisms (e.g. transport of substances, defence of the organism, acceleration of chemical reactions, etc.). They mainly come from animal foods (1g proteins provides 4 Kcal or 17 KJ energy).

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Vegan diet contains only plants (such as vegetables, grains, nuts and fruits) and foods made from plants. Vegans do not eat foods that come from animals, including dairy products and eggs.

Vegetarian diet contains plants, foods made from plants, dairy products and eggs.

Vitamins are organic nutrients that our body cannot synthesize or it synthesizes them in amounts less than necessary. They are taken up through animal and plant foods. They are complementary nutrients necessary for the functioning of the body. There are 13 essential vitamins, each with its own unique functions that the body needs to stay healthy. The essential vitamins are: vitamins A, C, D, E, K and the B vitamins: B1, B2, B3, B5, B6, B7, B9 and B12.

Water belongs to the inorganic complementary nutrients. More than two thirds of the body of most organisms is made up of water. The water plays an important role in the body e.g. many chemicals can be dissolved in water and thus easily come into contact and react with each other. It's especially important for the circulatory system, because blood is primarily composed of water! So, water is essential for the transport of substances to all parts of the body. In addition, it helps organisms to keep their body temperature stable.

2. Pedagogical glossary

a. Brainstorming

Brainstorming is an instructional technique with several variations that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

b. Socio-scientific inquiry-based teaching and learning approach

Socio-scientific inquiry-based teaching and learning is a pedagogical approach which connects science and society in the classroom through the use of socio-scientific issues. Socio-scientific issues (SSIs) are complex and contentious societal issues with substantive connections to science ideas and principles.

Socio-scientific inquiry-based teaching and learning has three main stages:

i. Use of SSI for raising inquiry-based authentic questions.

ii. For exploring these questions, social and scientific inquiry is used (e.g. planning, searching and evaluating information, using a variety of evidence sources, such as research, expert knowledge, practice experience and data to capture the complexity of a problem-, analysing, negotiating the social and scientific dimensions of the SSI, making inferences, synthesising and drawing conclusions, constructing arguments, etc.).

iii. Students are stimulated to form opinions and formulate solutions related to the SSI – questions.

The main inquiry phases and sub-phases are described below (Pedaste et al., 2015)

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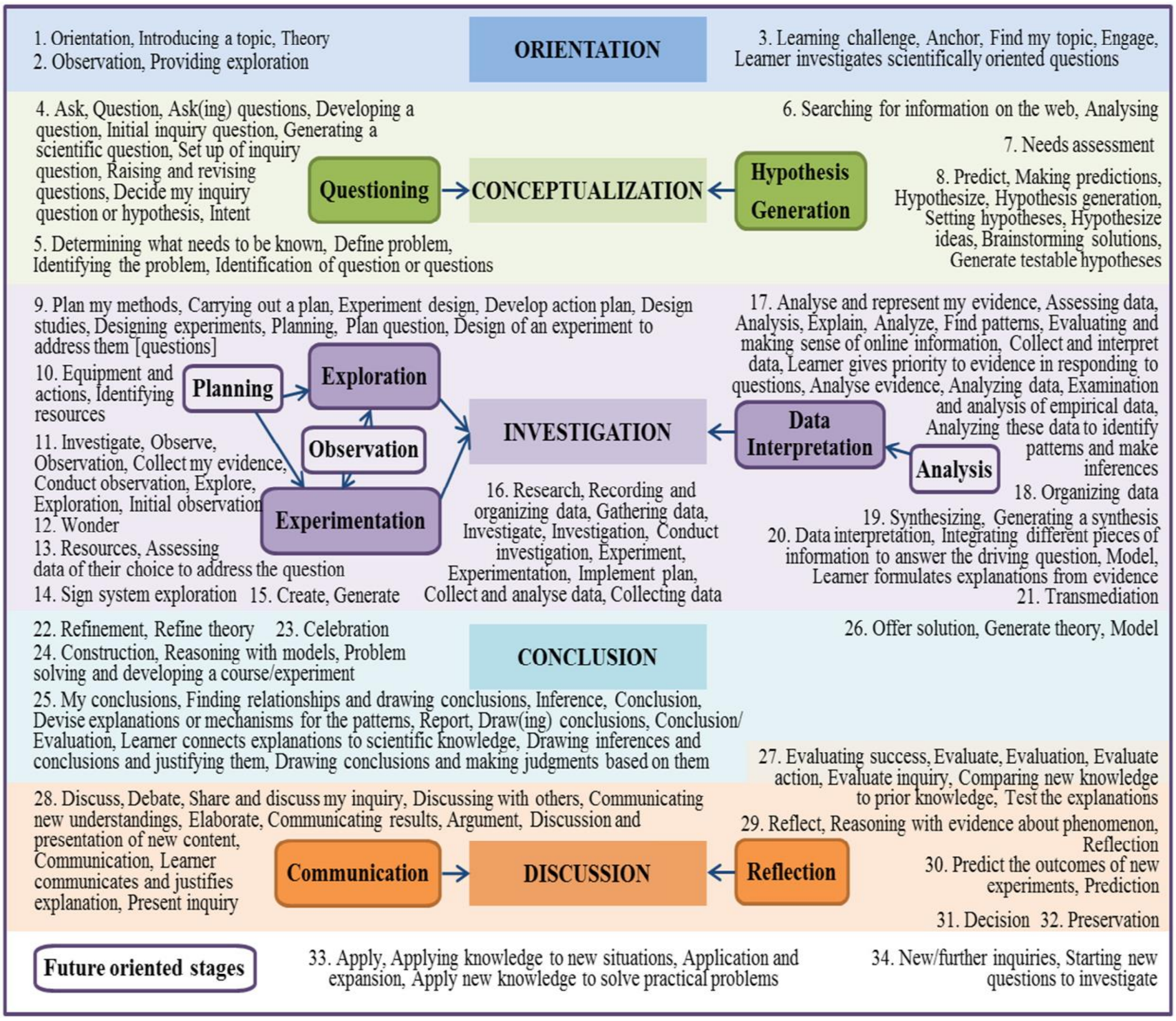

Fig. 1. The main inquiry phases sub-phases are described below (Pedaste et al., 2015).

c. Collaborative learning

Collaborative learning is a pedagogical method, using group (3-5 students) teaching -learning activities (except those activities which require an individual reflection on one's own learning or those that require whole-class discussions).

The role of the teacher is to guide students, stating explicitly the aims of each task or reformulating and adapting new key questions in order to help them to find their own learning path. This teacher's role as a facilitator is necessary to promote a gradual development of students' learning autonomy, when questioning, thinking, planning, reflecting, interacting, discussing, and gradually developing conceptual frameworks through the active participation in tasks.

d. Learning Science by Constructing Models

Modelling-based Learning approach is an approach for teaching and learning in science whereby learning takes place via student construction of models as representations of physical phenomena that include representations of physical objects and their characteristics, physical entities and physical processes involved in the physical phenomena. This leads to an externalized representation of the underlying mechanism of a physical phenomenon and helps students build an understanding of that mechanism.

Particularly, models help us to visualize a system and specify its structure or behaviour. Moreover, the modelling process usually simplifies a phenomenon thereby revealing its more fundamental concepts

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and downgrading any secondary information that is not directly relevant to those aspects of the system that are of interest for investigation purposes. Models have a representative, interpretive and predictive power.

e. Learning Science by Constructing Concept map

Concept maps are a kind of graphic organizers similar to mind maps. They include concepts in frames interconnected with arrows. A verb is written above each arrow which determines the kind of the semantic connection, in a way that the two interconnected concepts and the arrow (mainly verb) form a semantically independent sentence. In addition, concept maps are a direct method of looking at the organization and structure of an individual's knowledge within a particular domain and at the fluency and efficiency with which the knowledge can be used.

f. Learning Science by Using Infographic

An infographic (information graphic) is a kind of multimodal representation of facts and information. It usually forms a broad graphic composition combining short texts, numerical data, graphs, diagrams, sketches, colors, and shapes. The aim of the infographic is to present a big load of information on a topic in a visual way, making it comprehensible immediately.

g. Open Schooling

Open Schooling is an educational perspective in which schools become open to society by bidirectional collaborating with different institutions with the aim to:

i. Improve community well-being by raising awareness and co-creating solutions to both personal and socially relevant problems that have a direct impact at a local level.

ii. Enrich the curricula and pedagogical repertoire of schools, by sharing different views and expertise from both educational and non-educational agents and institutions with the aim to promote students' meaningful learning and competence development.

iii. Give epistemic authority to all agents from within and outside the school, specifically to the students and their families, by engaging them in sustained inquiry, knowledge creation, creative action, and dissemination on issues of relevance to the local community and beyond.

To do so, projects and initiatives on Open Schooling take advantage of the knowledge, practices, visions, attitudes, resources, and values of all involved agents, empowering them to collectively transform society from a reflective and critical standpoint that focuses on sustainability, equity, social justice, and inclusion.

Open Schooling emerges as a new term first in the report Science Education for Responsible Citizenship and in EU's Work Programme 2016-2017 and continues to be a priority in the Work Programme 2018-2020. However, despite the term not being explicitly there, we can identify the Open Schooling idea already in the Work Programme 2014-2015.

The EU WPs from 2016 to 2020 followed up on the report Science Education for Responsible Citizenship to explicitly promote the concept of Open Schooling in their strategy of Science with and for Society, which revolves around the concept of Responsible Research and Innovation (RRI) and its pillar on Science Education.

h. Critical Health Literacy

Critical health literacy is an important dimension of health literacy beyond fundamental literacy and comprehension skills in health contexts. It includes quite useful notions and skills for a health literate citizen in modern society. Critical health literacy mainly consists of the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular the notion of social determinants of health), and the participation in civic collective actions for the promotion of health.

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i. One Health Approach

The One Health approach is a transdisciplinary approach that considers human health under a broad context highlighting the direct interconnections with animal health and the environment.

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STEM Content

1. Fundamental concepts of biological sciences (e.g., childhood obesity, food pyramid, healthy eating, Mediterranean diet, nutrients, etc.).

2. Promotion of the interconnection among science, technology, society, and environment (STSE).

3. Promotion of critical STEM literacy, critical health literacy and critical scientific literacy aspects in

STEM instruction with a view to promoting active citizenship.

4. Highlight of the role of science for the establishment of public health.

5. Conduction of authentic socio-scientific research by students.

6. Research data collection, analyse, make inferences, synthesize, draw conclusions, and appropriate research project presentation by students.

7. Construction, use and nature of scientific models.

8. Promoting understanding of nature of science and epistemological beliefs.

General Learning Objectives

Knowledge (Core Concepts)

1. Transdisciplinary concepts: (Critical) health literacy, STSE (Science, Technology, Society, Environment) interconnections, One Health approach, socio-scientific research.

2. Specific content concepts: childhood obesity, food pyramid, healthy eating, Mediterranean diet, nutrients, physical activity, social determinants of healthy eating, healthy eating disparities, social inequities.

Skills

1. General skills: Critical thinking, reflective thinking, critical reading, informal and formal reasoning, collaboration and communication within small groups, presentation skills.

2. Specific skills: Critical reading of scientific sources (videos, simulations, scientific models, infographics, informative health texts, academic texts), construction and use of scientific models, argumentation about the social, economic, cultural, and environmental dimensions of socio-scientific

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topics, empirical socioscientific research design, research data collection, conclusions making, presentation of socio-scientific topics, discussion, and reflection about socio-scientific topics.

Attitudes (Affective domain)

1. Attitudes and values: Awareness concerning socioscientific issues related to healthy eating (e.g., obesity) their complexity and multidimensionality, the social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders, taking in consideration economic, social, ethical, political cultural, emotional and other factors

2. Behaviours: Citizenship actions for the limitation of healthy eating disparities, healthy eating behaviour and decision making on controversial socioscientific issues (e.g., childhood obesity), which are defined as open-ended, debatable, complex or ill-structured problems that require the consideration of social, ethical, economic, scientific, and environmental perspectives, considering a variety of perspective shaving an orientation towards socioscientific humanistic values.

<u>Title of the whole module and individual lesson</u>

Title of whole module

Healthy Eating and Obesity: Challenges and Solutions

Titles of individual lessons

- Lesson 1 (40 min): Introduction: Healthy Eating and Obesity
- Lessons 2 & 3 (80 min): Food and organisms: Why do we eat?
- Lesson 4 (40 min): Eating habits, lifestyle, and health
- Lesson 5 (40 min): Investigating causes, health risks and solutions related to childhood obesity
- Lessons 6 & 7 (80 min): Investigating individual and governments' responsibility for reducing childhood obesity
- Lesson 8 (40 min): Designing and presenting a poster on the topic *Healthy Eating and Childhood Obesity: Challenges and Solutions*
- Lesson 9 (40 min): Organizing a forum (students, teachers, parents, social partners of the local community) on the topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions*

<u>Learning goals and objectives per lesson</u>

Lesson 1 (40 min):

1. Awaken interest into the subject

2. Identifying students' preconceptions, alternative ideas (misconceptions) on food and healthy eating. Mapping the preconceptions of the students

3. Discussing why obesity is a socioscientific issue

4. Improving students' epistemological understanding.

Lessons 2 & 3 (80 min):

At the end of lessons 2 & 3 students should be able to…

1. relate one’s own experiences of food with scientific knowledg

2. explain the basic difference between plants and animals in the way they obtain their food

3. identify the organic nutrients essential to human functioning: Carbohydrates, Proteins, Lipids, Vitamins, Nucleic acids

4. provide examples of three types of carbohydrates, and identify the primary functions of carbohydrates in the body

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5. explain the importance of proteins, lipids, vitamins and nucleic acids to human functioning

6. distinguish clearly between organic and inorganing nutrients in food

7. explain the function of inorganic nutrients in human body

8. explain the relationship between food and energy

9. improve critical thinking

10. improve communication and collaboration skills.

Lesson 4 (40 min):

At the end of lesson 4 students should be able to…

1. read and interpret images related to Mediterranean diet of Crete

2. interpret a diagram of food pyramid

3. relate the food pyramid with the Mediterranean diet

4. explain the structure and function of dietary fibres and the relationship between dietary fibres and Mediterranean diet

5. improve critical thinking

6. improve communication and collaboration skills

Lessons 5, 6 & 7 (120 min):

At the end of lessons 5, 6 & 7 students should be able to…

1. improve inquiry-based investigation skills (e.g., planning, searching and evaluating information, analysing, making inferences, synthesising and drawing conclusions, constructing arguments, etc.) in order to answer the primary research questions of a socioscientific issue related to childhood obesity

- ✓ What are the causes, health risks and solutions related to childhood obesity?
- ✓ What are individuals' and governments' responsibility for reducing childhood obesity?

2. develop digital skills (e.g., finding, reviewing, organising, and sharing information effectively, handling data appropriately, using different online resources and tools to study)

3. understand the multiplicity of factors leading to obesity

4. mapping causes, health risks and solutions of childhood obesity

5. design and carry out a prediction model for childhood obesity

6. investigate health risks of being obese

7. investigate economic and societal costs of being obese

8. investigate individual and social responsibilities and solutions to childhood obesity

9. acquire socio-scientific argumentation skills

10. improve communication and collaboration skills

11. acquire the ability to analyse a public health issue and potential solutions from the perspectives of different stakeholders

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12. acquire the ability to identify potential sources of bias that may influence information or the presentation of information about a socioscientific issue related to public health or potential solutions

13. acquire ability to determine how scientific knowledge and processes may contribute to the resolution of a socioscientific issue related to public health and to recognize dimensions of the issue that cannot be addressed by science.

Lesson 8 (40 min):

At the end of lesson 8 students should be able to…

1. design and present a poster with the research questions of this unit, the methodology, the results, and the conclusions of the investigation related to the socioscientific issue: *Healthy Eating and Childhood Obesity: Challenges and Solutions*

2. organise a forum for a discussion (students, teachers, parents, social partners of the local community) on the topic: *Healthy Eating and Obesity: Challenges and Solutions*

3. create a public health brochure promoting healthy eating

4. improve critical thinking skills and communication and collaboration skills

Lesson 9 (40 min):

At the end of lesson 9 students should be able to…

1. holding a forum (students, teachers, parents, social partners of the local community) on the topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions.*

2. inform the public about each of the research questions they have addressed in the previous lessons.

3. distribute public health brochures promoting healthy eating.

3. improve communication and collaboration skills.

4. develop responsible citizenship and critical health literacy.

Summative assessment (Scientific knowledge on food, healthy eating, obesity, and public health. Thinking skills and evidence-based reasoning).

Didactical methods and activities

(Note: For more details, please see the attached teaching and learning activities)

<u>Course of the Lesson 1:</u>

The lesson starts with a multimedia-show related to healthy and unhealthy eating. After the presentation, discussion and reflection can be encouraged with asking: Why is it important to learn about food and healthy eating? How difficult is healthy eating? Are the causes of unhealthy eating only individual or also societal/ political/ cultural?

After short discussion and reflection, the teacher can introduce the socioscientific issue entitled *Healthy Eating and Childhood Obesity: Challenges and Solutions*, as well as the primary research questions related to this topic, and explain that is a societal issue with connections to science. Using the example of the socioscientific issue related to obesity, the teacher can discuss the complexity and multidimensionality of socioscientific issues, the social risks and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders. In addition, it can be discussed that many health issues have dimensions that cannot be addressed by science and can be considered socioscientific issues.

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Course of the Lessons 2 & 3:

1. The lesson starts with a short educational video related to living organisms looking for food.

Then, the teacher starts the lesson asking:

Why do all living organisms necessarily need food?

What is the main difference between plants and animals in the way they obtain their food?

What does food contain?

Students are encouraged to discuss the questions and after short discussion they are asked to start working on Worksheet 1 (Matching activities, Concept mapping activity). For these activities students are provided with a table with information about organic and inorganic nutrients in foods.

Teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students finish activities of worksheet 1, the teacher gives feedback to the plenary of the class (whole class)

2. Next, the teacher uses an educational video related to energy in food (food labels with measurements in kilojoules and calories). The students are asked to read and interpret images related to energy in food and healthy eating.

Next, students are asked to propose possible ways for measuring energy in food: how much energy people get from consuming a food or drink? Students are encouraged to think about the amount of carbohydrate (sugars/starch), protein, fat, and alcohol the food or drink contains, as well as the portion size. After short discussion, the pupils are told to start working on Worksheet 2 (Fill in the blanks worksheet).

Students work in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students finish activities of worksheet 2, the teacher gives feedback to the plenary of the class (whole class)

Course of the Lesson 4:

1. The lesson starts with an educational video related to Mediterranean diet. After the presentation, the students are asked to read a text related to an investigation result about factors that may increase our chances of a longer life. Then, students are asked to discuss with your group why Mediterranean diet is considered as healthy one and answer some related questions. This activity aims at investigating students' alternative ideas about Mediterranean diet, vegan diet and vegetarian diet and promoting conceptual change.

2. Next, teacher shows a 3D model and diagrams of Food pyramid and asks students to interpret the meaning of the model and the diagrams and make association between Food pyramid, Mediterranean diet, and healthy eating.

3. Then, students are asked to apply their knowledge on food pyramid and Mediterranean diet in a new situation working on Worksheet 3 answering open-ended questions.

Students work in group (3-5 students) cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students finish activities of worksheet 3, the teacher gives feedback to the plenary of the class (whole class).

4. At the end of the lesson, teacher informs the students that in the next lesson they will explore the socioscientific issue of childhood obesity and asks them to look for material on the causes and health risks related to childhood obesity.

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Course of the Lessons 5, 6 & 7:

1. The teacher starts the lesson presenting again the SSI *Healthy Eating and Childhood Obesity: Challenges and Solutions* and the primary research questions:

- ✓ What are the causes, health risks and solutions related to childhood obesity?
- ✓ What is individuals' and governments' responsibility for reducing childhood obesity?
- ✓ What are the community's perceptions and knowledge concerning childhood obesity?

2. Then, teacher moderates a discussion on planning, searching and evaluating information, analysing, making inferences, synthesising and drawing conclusions, constructing arguments from evidence in order to answer the research questions of a socioscientific issue.

3. To answer the research questions *What are the causes, health risks and solutions related to childhood obesity?* Students are asked to formulate hypotheses, to collect data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures and videos, tables and diagrams, simulations, and scientific measurements), in order to answer the SSI research questions related to childhood obesity. For this task students are provided with extra appropriate material.

4. Then, students are asked to use Worksheet 4 for organizing and evaluating information, analysing, making inferences, synthesising, and drawing conclusions to answer the research question: What are the causes, health risks and solutions related to childhood obesity?

During this process, teacher consistently encourages students to consider the source and author of the information, the purpose of the publication, potential biases of the author or publisher, evidentiary support for the information, and possible missing information. In addition, teacher draws students' attention to multiplicity of factors leading to obesity, like social, cultural, and political dimensions.

Students work in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions, looking at the students' achievements and, when appropriate, gives permission to go forward to the next task.

5. Then, students are asked to summarize their conclusions on causes, health risks and solutions related to childhood obesity and using the worksheet 4 to construct a childhood obesity concept map.

6. When appropriate, teacher directs discussion towards a prediction model of childhood obesity: What does a prediction model of childhood obesity can inform us? What are predictors of childhood obesity? Could prediction model inform obesity prevention? After this discussion and feedback, students are provided with appropriate model protocol (worksheet 5) to design a prediction model for childhood obesity as homework. Teacher will evaluate the students' models and give feedback in the next lesson.

7. To answer the research question *what is individuals' and governments' responsibility for reducing childhood obesity?* Students are asked to formulate hypotheses, to collect data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures and videos, tables and diagrams, simulations, and scientific measurements), to answer the SSI research questions related to childhood obesity. For this task students are provided with extra material.

8. Then, students are asked to use Worksheet 6 for organizing and evaluating information, analysing, making inferences, synthesising, and drawing conclusions in order to answer the research question: What are individuals' and governments' responsibility for reducing childhood obesity?

During this process, teacher consistently encourages students to consider the source and author of the information, the purpose of the publication, potential biases of the author or publisher, evidentiary support for the information, and possible missing information. In addition, teacher draws students' attention to analyse a public health issue and potential solutions from the perspectives of different stakeholders.

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Students work in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions, looking at the students' achievements and, when appropriate, gives permission to go forward to the next task.

9. Then, students are asked to summarize their conclusions on individuals' and governments' responsibility for reducing childhood obesity and using the worksheet 6.

10. To answer the research question *What are the community's perceptions and knowledge concerning childhood obesity?,* students design a questionnaire to collect data and analyze them to draw conclusions.

11. When appropriate, teacher directs discussion towards design and present a poster with the research questions of this unit, the methodology, the results, and the conclusions of the investigation related to the socioscientific issue related childhood obesity. How do we make a scientific poster in PowerPoint? What should be included in a scientific poster?

After this discussion and feedback, students are provided with appropriate guidance to design a poster as homework. Teacher will evaluate the students' posters and give feedback in the next lesson.

Course of the Lesson 8:

1. The teacher starts the lesson with evaluation and feedback on students' posters related to the socio-scientific issue*: Healthy Eating and Childhood Obesity: Challenges and Solutions.*

Then, each students' group will present its poster to the whole class and respond questions. Each group has 3 min for presentation and 2 min for answering questions.

2. When appropriate, teacher directs discussion towards designing, organizing, and holding a forum (students, teachers, parents) on the topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions.* How do we plan, organize, hold, moderate, and facilitate more effective forums? What is our vision? What do we expect to accomplish at this forum?

After a short discussion, students are asked to prepare the agenda for the forum and a public health brochure promoting healthy eating.

Course of the Lesson 9:

Holding a forum on the topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions.*

Students organize and hold a forum (students, teachers, parents, social partners of the local community) on the topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions.*

Students also distribute a public health brochure promoting healthy eating.

Evaluative tasks

(Note: For more details concerning initial and formative assessment, please see the attached teaching and learning activities. For final assessment, please see the attached educational scenarios impact assessment)

1. Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment)
2. Worksheets evaluation (Formative assessment)
3. Development of a predictive model of childhood obesity
4. Creation and Presentation of a poster on the topic *Healthy Eating and Childhood Obesity: Challenges and Solutions.*
5. Organizing and holding a forum (students, teachers, parents, social partners of the local community) on the topic*: Healthy Eating and Childhood Obesity: Challenges and Solutions.*
6. Create a public health brochure promoting healthy eating.
7. Post-test (Final/ summative assessment)

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Learning objects per lesson

(Note: For more details, please see the attached teaching and learning activities)

Lesson 1:
Supplementary Educational Resources (SERs)
1. Multimedia-show related to healthy and unhealthy eating.
2. Socioscientific topic related to Healthy Eating and Obesity
3. Pictures related to healthy and unhealthy food

Lessons 2 & 3:
Digital Learning Objects (DLOs)
1. Interactive concept map related to the nutrients of food.
2. Interactive match activity related to the function of the different nutrients of food.
3. Interactive fill in the blanks activity related to energy in food.

Supplementary Educational Resources (SERs)
1. Educational video related to living organisms looking for food at. https://youtu.be/2JT02G1GJbI
2. Table with information about organic and inorganic nutrients in foods.
3. Infographic related to energy cycle in plants and animals
4. Educational video related to energy in food at: https://youtu.be/bLKoAsikD-Q
5. Infographic related to food labels with measurements in kilojoules and calories
6. Infographic related to factors influencing daily energy requirements
7. Worksheets.

Lesson 4:
Supplementary Educational Resources (SERs)
1. Educational video related to Benefits of a Mediterranean Diet at: https://youtu.be/jYZ_yf2LBu4
2. 3D Model of Food Pyramid
3. Infographic related to to Food pyramid
4. Infographic related to healthy eating plate
5. Worksheets.

Lessons 5, 6 & 7:
Supplementary Educational Resources (SERs)
1. Infographic related to causes, health risks and solutions concerning childhood obesity
2. Concept map related to causes, health risks and solutions concerning childhood obesity
3. Infographic related to research framework for childhood obesity
4. Model coding sheet in support students to design a prediction model for childhood obesity
5. Worksheets
6. Environment of guided inquiry and critical reading of adapted texts, short videos and infographics concerning individuals’ and governments' responsibility for reducing childhood obesity.
7. Questionnaire for data collection.

Lessons 8:
Supplementary Educational Resources (SERs)
1. Specific information for design and presentation of a poster on the topic Healthy Eating and Childhood Obesity: Challenges and Solutions.
2. Specific information for creation of a public health brochure
3. Specific information for preparation of an agenda for the forum (students, teachers, parents, social partners of the local community) on the topic: *Healthy Eating and Childhood Obesity: Challenges and Solutions.*

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Lesson 9:
Supplementary Educational Resources (SERs)
1. Specific information for holding a forum.

Digital educational resources
Links for pictures, diagrams and text related to healthy and unhealthy eating, food pyramid, Obesity:
https://archeia.moec.gov.cy/sm/40/viologia_b_gymn.pdf
https://www.moh.gov.cy/MOH/moh.nsf/childobesity/childobesity?OpenDocument
http://archeia.moec.gov.cy/sm/745/ChildhoodObesity.pdf
https://www.mednutrition.gr/portal/ygeia/paxysarkia/1244-paidiki-paxysarkia-o-rolos-tis-fysikis-drastiriotitas-stin-prolipsi-kai-antimetopisi-tis-nosou
https://www.reporter.com.cy/local-news/article/784400/sto-27-8-i-pachysarkia-stin-kypro-ti-entopizei-erevna-toy-syndesmoy-diaitologn
http://cydadiet.org/arthra/epidhmiologikh-ereyna-gia-to-pososto-ths-paxysarkias-kai-yperballontos-baroys-sthn-kypro-kai-diapistwsh-twn-diatrofikwn-synh8eiwn-toy-kyprioy-polith/
https://www.betterhealth.vic.gov.au/health/healthyliving/kilojoules-and-calories
https://www.euro.who.int/__data/assets/pdf_file/0004/243292/Cyprus-WHO-Country-Profile.pdf
http://www.glnbi.org/documenti/bc5aad3265ed3185f8b1e7d4e63bd972.pdf
https://academic.oup.com/eurpub/article/20/1/70/609759
https://apps.who.int/iris/bitstream/handle/10665/43943/9789241563703_eng.pdf

School Research Project

Educational Scenario on the topic: Looking after myself and others – Healthy Eating

Topics
- Healthy eating
- Physical activity
- Childhood obesity
- Public health
- Critical health literacy
- Responsible citizenship

Research management, design and administration

Research Questions

- What are the causes, health risks and possible solutions related to childhood obesity?
- What is individuals' and governments' responsibility for reducing childhood obesity?
- What are the community's perceptions and knowledge concerning childhood obesity?

Methodology/Implementation:

Session 1
Students are organized in groups of 3-5 students:
Preparation of a research plan with the components of a research project: theoretical background, objectives, participants, methodology, results and conclusions, approximate timeline, form of actions

Collection of documents and articles for bibliographical analysis.

Evaluation of the documents based on criteria and selection of the relevant valid information.

Each group shortly presents the results of its investigation for valid sources for bibliographical analysis. Teacher and students give feedback for improvement of research plan.

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Session 2
Students are organized in groups of 3-5 students:

Challenge: Drawing a childhood obesity concept map, writing causes, health risks and solutions related to childhood obesity.

An expert will be invited to discuss with the students and answer their questions related to childhood obesity in Cyprus and globally. During the discussion with the expert, students will have the opportunity to ask specific questions, improve their concept maps and write a short report concerning causes, health risks and possible solutions related to childhood obesity.

Students are urged to search information concerning individuals' and governments' responsibility for reducing childhood obesity for the next lesson (homework) and drawing a prediction model for childhood obesity (homework), using a specific Model coding sheet. Teacher will evaluate the students' prediction models and give feedback in the next lesson.

Session 3
Students are organized in groups of 3-5 students:

Challenge: Investigating individuals' and governments' responsibility for reducing childhood obesity.

An expert will be invited to discuss with the students and answer their questions related to individuals' and governments' responsibility for reducing childhood obesity. After the discussion with the expert, students are urged to write a short report concerning individuals' and governments' responsibility for reducing childhood obesity at home (homework).

Challenge: Designing of a questionnaire (social research tool) to investigate the community's perceptions and knowledge concerning childhood obesity.

Teacher explains the fundamental principles of question selection and formulation, when designing a questionnaire. Students decide on the questionnaire form and sections, and they are divided in groups equal in number to the questionnaire sections. Each group is responsible for designing one questionnaire section. Each groupof students shortly presents their questions and design a final questionnaire. Some students get the responsibility to write the questionnaire in an online form, which allows to be more easily delivered to its targets. Students are urged to collect data about the community's perceptions and knowledge concerning childhood obesity. Some students of different groups get the responsibility to analyze the answers of the questionnaire.

Session 4
Students are organized in groups of 3-5 students.

Challenge: Presentation of the results of the questionnaire, trying to identify the community perceptions and knowledge gaps and how to promote conceptual understanding . In the end, build an infographic to summarize the results.

Challenge: Creating a scientific poster in power point, writing Introduction, Methodology, Results, Conclusions and Discussion. Creating a health brochure The poster will be entitled: *Healthy Eating and Childhood Obesity: Challenges and Solutions*. The poster could be printed and be displayed in a prominent place in the school, in local mass media, possibly at some website, and in open schooling event.

Students are provided with appropriate guidance in order to design a poster and health brochure as home work. Teacher will evaluate the students' posters and give feedback in the next lesson.

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Development process:
The project is based on guided research about Healthy Eating and Childhood Obesity The five lessons will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.

Teaching-learning process milestones:
Students will be able to:
1. develop digital skills (e.g., finding, reviewing, organising and sharing information effectively, handling data appropriately, using different online resources and tools to study)
2. understand the multiplicity of factors leading to obesity
3. mapping causes, health risks and solutions of childhood obesity
4. design and carry out a prediction model for childhood obesity
5. investigate health risks of being obese
6. investigate economic and societal costs of being obese
7. investigate individual and social responsibilities and solutions to childhood obesity
8. investigate community's perceptions and knowledge concerning childhood obesity
9. develop responsible citizenship and critical health literacy

Teaching-learning process for school project (summary):

1. Collection of evidence (data, articles, pictures).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Design Concept maps.
4. Design prediction model for childhood obesity
5. Design a questionnaire
6. Create a poster and present this in open schooling event.
7. Create a health prochure and distribute it in open schooling event.

Organization of the open schooling event:
1. Each project output (poster and health prochure) is presented by the students in a community setting.
2. Students will communicate their research project outcomes. Students emphasize that health literacy and health promotion is a responsibility of all, not only of the ministry of health or healthcare providers.
3. Additionaly, students explain the importance of critical health literacy, which mainly consists of the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular the notion of social determinants of health), and the participation in civic collective actions for the promotion of health.

Data Analysis and Reporting
1. Content analysis.
2. Questionnaire results analysis
3. Report writing with most important findings.
4. Development of poster, health prochure and final presentation.

Target Audience for Recommendations
Parents, science teachers, local community – public.
Public Health Authorities and other stakeholders (organisation for family orientation, organisation of nutritionists and health advisers).

<u>Educational Scenario Impact Assessment Questionnaire</u>

Context: Obesity is one of the most serious global public health challenges of the 21st century, affecting every country in the world. In addition, it is not only a chronic disease, but also a major risk factor for

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the world's leading causes of poor health and early death including cardiovascular disease, several common cancers and diabetes.

The main aim of this unit is to raise 8th grade students' awareness of rational nutrition and the health risks of unhealthy eating and not physical activity. Additionally, the unit aims to foster student's understanding about the role of socio-economic, political, and cultural environment in the rising prevalence of childhood obesity worldwide. A socioscientific topic related to childhood obesity provides the scenario for the inquiry-based questions of this unit related to the learning topic Healthy Eating. Additional information on specifications of an educational scenario on the topic of *Looking after myself and others –Healthy Eating.*

The questions that follow provide and assessment for the impact of the given learning scenario on the pre-existing knowledge of the students, the skills that they have acquired throughout the teaching of this topic and the effect of this on their beliefs, attitudes, and behavior.

Knowledge	
1.Understanding the relationship between food and living organisms	Question 1.1 Why do all living organisms necessarily need food? A) To provide energy, to repair of cells, to growth of new cells, to maintain constant internal body temperature. B) To stay alive C) To run and walk. Question 1.2 What is the main difference between plants and animals in the way they obtain their food? A) Plants are autotrophic, while animals are heterotrophic. B) Plants always prepare their own food, while animals do not prepare always their own food C) Plants are heterotrophic, while animals are autotrophic. Question 1.3 What kind of cells use both chloroplasts and mitochondria to make energy from light, air, and water? A) Plant cells. B) Animal cells. C) Plant and Animal Cells. Question 1.4 What is the major source of energy for organisms? A) Sunlight B) Water C) Oxygen.
2. Understanding the structure and function of nutrients in food	Question 2.1 What is the main structural difference between organic and inorganic nutrients? A) Organic nutrients always contain carbon while most inorganic nutrients do not contain carbon. B) Organic nutrients always contain carbon and oxygen while inorganic nutrients contain only carbon. C) Organic nutrients always contain carbon and hydrogen, while inorganic nutrients contain only carbon. Question 2.2 Carbohydrates, proteins, lipids, vitamins and nucleic acids are organic or inorganic nutrients? Carbohydrates, proteins, lipids, vitamins and nuclei acids are organic nutrients. B) Carbohydrates, proteins, lipids and nucleic acids are organic nutrients, while vitamins are inorganic. C) Carbohydrates, proteins and lipids are organic nutrients, while nuclein acids and vitamins are inorganic nutrients. Question 2.3 What is the primary function of carbohydrates in our body? A) To provide body with energy, B) To build and repair cells, C) To play an important role for bones and teeths. Question 2.4 What nutrients are important for the defence of our body? A) Proteins. B) Carbohydrates. C) Vitamins. Question 2.5 What nutrients are important energy-saving substances as well as thermal insulator for animal organisms? A) Lipids. B) Carbohydrates. C) Proteins. Question 2.6 What nutrients are taken up through animal and plant foods and are necessary in small amounts for the functioning of the body? A) Vitamins B) Proteins C) Lipids. Question 2.7 What nutrient makes up 2/3 of the body of most living organisms? A) Water B) Minerals C) Nuclein acids. Question 2.8 What nutrients are very important for bones and teeths? A) Minerals B) Carbohydrates C) Lipids.

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3. Identification of factors influencing daily energy requirements	Question 3.1 Children and adolescents need more energy in comparison to adults.Why? A) They are still growing B) They have increased physical activity B) They work very hard. Question 3.2 Men, generally, have higher energy requirements than women. Why? A) They have greater muscle mass than women. B) They have increased physical activity B) They work very hard. Question 3.3 What happens when we consume too much energy and burn too little? A) Our body stores that excess energy as body fat B) Our body stores that excess energy as body proteins C) Our body stores that excess energy as body carbohydrates.
4. Identification of (a) the most important risk factors for obesity. (b) the main health risks linked to obesity.	Question 4.1 What are the most important risk factors for obesity? A) Eating too much, moving too little, insufficient sleep, genetic reasons. B) Eating large amounts of food. C) Insufficient sleep. Question 4.2 What are the main health risks linked to obesity? A) Heart disease, Stroke, High blood pressure, Diabetes, Cancer. B) Heart disease, Stroke, Anxiety, Happiness. C) Diabetes, Cancer, Anxiety, Happiness. Question 4.3 In last years, researchers looked at factors that may increase our chances of a longer life. Through data collected from men and women who were followed for up to 34 years, researchers examined different low-risk lifestyle factors: healthy diet, regular exercise (at least 30 minutes daily of moderate to vigorous activity), healthy weight, no smoking, and moderate alcohol intake (up to 1 drink daily for women, and up to 2 daily for men). Mediterranean diet is considered as healthy one. Why Mediterranean diet is considered as healthy one. A) The Mediterranean diet emphasizes eating less red meat, sugar and saturated fat and incorporating more fruits and vegetables, nuts and whole grains into your daily diet according food pyramide B) The Mediterranean diet is delicious and easy to follow C) The Mediterranean diet is based on Mediterranean-style cooking..
5. Understanding health socioscientific issues	Question 5.1 What are the characteristics of a controversial health socioscientific issue? A) Different dimensions on the topic, multiple stakeholder groups with conflicting interests, multiple solutions from the perspectives of different stakeholders. B) Different opinions and viewpoints of the topic C) Different scientific data. Question 5.2 What is the additive learning value of using health socioscientific topics to understand scientific issues? A) Better understanding of the nature of scientific knowledge because students discuss issues related to the potentialities, as well as limitations, of the scientific enterprise and its relationship to technology, society and the environment B) Easier to understand scientific concepts C) Easier homework.
SKILLS	
1. Investigating health socioscientific issues	Question 1.1 Which inquiry phases are necessary for investigating health socioscientific issues? A) Generating research questions based on the stated problem, generating hypotheses regarding the stated problem, searching, and evaluating information, analysing, making inferences, synthesising and drawing conclusions. B) Experimentation, results, conclusions. C) Exploration, experimentation, data Interpretation.
2. Constructing and using scientific models	Question 2.1 Scientific models are very important in science because: A) Models help us to visualize a system or phenomenon and specify its structure or behaviour, and they have a representative, interpretive and predictive power. B) Models have a representative and interpretive power C) Models have an interpretive power.

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3. Adopting a healthy lifestyle.	Question 3.1 I will try to adopt a healthy lifestyle (avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months. 1) Definitely true... 5) definitively false. Question 3.2 I am the one who will decide whether to adopt a healthy lifestyle during the next three months. 1) Strongly agree... 5) strongly disagree. Question 3.3 I feel able to resist peer pressure related to unhealthy lifestyle (smoking, drinking, inactivity, diet full of fat).1) Definitely true... 5) definitively false. Question 3.4 I feel capable of identifying the attributes of healthy lifestyles and act based on it. 1) Definitely true... 5) definitively false. Question 3.5 If I wanted, I could adopt a healthy lifestyle during the next three months. 1) Definitely true... 5) definitively false. Question 3.6 For me avoiding smoking, consuming alcohol, inactivity and having a diet full of fat, during the next three months, is: 1) definitely impossible ... 5) definitely possible. Question 3.7 For me adopting a healthy lifestyle during the next three months, would be. 1) Very insignificant... 5) very important. Question 3.8 I will be able to find the necessary strategies and resources for adopting a healthy lifestyle in the next three months 1) probable... 5) improbable.
4. Proposing concrete action towards adopting healthy lifestyles in his/her/others routine.	Question 4.1 I feel able to identify relevant actions for adopting a healthy lifestyle in my routine. 1) Definitively true… 5) definitively false. Question 4.2 I feel able to change my routine to adopt a healthier lifestyle. 1) Definitively true… 5) definitively false.
5. Feels able to influence the adoption of healthy lifestyles by others (e.g., family, peers, friends)	Question 5.1 I feel able to influence the adoption of healthy lifestyles by others (family, friends). 1) Definitely true... 5) definitively false. Question 5.2 I will try to influence the adoption of healthy lifestyles by others (family, friends). 1) Definitely true... 5) definitively false.
6. Selecting appropriate sources to investigate health socioscientific issues (e.g., Childhood obesity).	Question 6.1 I believe that to find scientific information about a health socioscientific issue, I should consult the following sources. A) Scientists, scientific publications, WHO database, EU database. B) Newspapers, google, YouTube. C) Friends, journalists, Facebook.
Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that health is a fundamental component of quality of life.	Question 1.1 Health is a fundamental component of quality of life. 1) Strongly disagree… 5) strongly agree. Question 1.2 Healthy behaviors will promote a better quality of life. 1) Strongly disagree… 5) strongly agree. Question 1.3 I am physically and financially capable of adopting a healthy lifestyle (e.g.: avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) that contribute to the quality of life. 1) Extremely unlikely... 5) Extremely likely. Question 1.4 My family and friends think that I should adopt healthy behaviors that contribute to the quality of life. 1) Extremely unlikely... 5) Extremely likely.

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2. Believes that lifestyles influence the incidence of health risks	Question 2.1 Lifestyles and living environments influence the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. Question 2.2 Alcohol abuse influences the incidence health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. Question 2.3 Diet influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. Question 2.4 Obesity influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, stroke, and diabetes). 1) Strongly disagree… 5) strongly agree. Question 2.5 Inactivity influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, mental disorders, and stroke). 1) Strongly disagree… 5) strongly agree. Question 2.6 Access to fresh products (fish, vegetables, fruits) influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, stroke and mental disorders). 1) Strongly disagree… 5) strongly agree. Question 2.7 Mediterranean diet influences the incidence of health risks (e.g. Heart disease, Stroke, High blood pressure, Diabetes, Cancer). 1) Strongly disagree…. 5) strongly agree.
3. Believes that is important to adopt healthy lifestyles to prevent health threats.	Question 3.1 Youths should adopt healthy lifestyles to prevent health threats and stay healthy in older ages. 1) Strongly disagree… 5) strongly agree. Question 3.2 The adoption of a healthy lifestyle will reduce my risk of health threats and dying prematurely from it. 1) Strongly disagree… 5) strongly agree.
4. Reproves patterns of risky and unhealthy behavior in his/her living environment (e.g., sedentary lifestyle, smoking, drugs consumption).	Question 4.1 The adoption of a healthy lifestyle will ruin my image. 1) Strongly disagree… 5) strongly agree. Question 4.2 For me the adoption of a healthy lifestyle (e.g.: avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months, would be: 1) Bad... 5) Good. Question 4.3 For me to adopt a healthy lifestyle, in the next three months, would be: 1) Useless... 5) useful. Question 4.4 I don't accept patterns of risk and unhealthy behavior in my living environments (e.g., sedentary lifestyle, smoking, drugs consumption). 1) Definitely true... 5) definitively false. Question 4.5 The people in my life whose opinions I value (family, friends) 1) Will use ... 5) will not adopt healthy lifestyles in the next three months.
5. Adopts a healthy lifestyle (e.g., practicing exercise, mediterranean diet, not smoking, going to the supermarket and choosing a basket of healthy products).	Question 5.1 For me following a healthy lifestyle, in the next three months, would be 1) Uncomfortable... 5) Comfortable. Question 5.2 I will make an effort to adopt a healthy lifestyle (avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months. 1) Strongly disagree… 5) strongly agree. Question 5.3 I plan to not smoke in the next three months. 1) Strongly disagree… 5) strongly agree. Question 5.4 I plan to not consume alcohol, drugs and other substance use in the next three months.1) strongly disagree… 5) strongly agree. Question 5.5 I plan to do physical exercise at least 60 minutes every day in the next three months 1) strongly disagree… 5) strongly agree. Question 5.6 I plan to follow low-fat diet or Mediterranean Diet in the next three months. 1) Strongly disagree… 5) strongly agree. Question 5.7 I plan to avoid stress and polluted environments in the next three months. 1) Strongly disagree… 5) strongly agree.

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	Question 5.8 Among the following statements, choose the one that best describes what you currently think. 1) I do not have a healthy lifestyle, and I also have no intention of doing so. 2) I do not have a healthy lifestyle, but I have been thinking about the possibility of starting to do so. 3) I never or rarely have a healthy lifestyle, but soon I will start doing it on a regular basis. 4) I adopt a healthy lifestyle regularly. 5) For more than six months I have always or almost always followed a healthy lifestyle. 6) For several years now, I have adopted a healthy lifestyle, and I will continue to do so.
6. Attitude towards healthy lifestyle	Question 6.1 For me to adopt healthy behaviors is harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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2. Specifications for an educational scenario on the topic "Looking out for my community - Vaccines development and the science that responds to hesitancy"

<u>Main partner responsible</u>
University of Cyprus, Nicosia, Cyprus

Element of the scenario

Subject: Biology

Grade: 9th grade (+/- 14-15 years old students)

Estimated duration: 10 lessons X 40 min

Classroom organization: Students work on groups of 3-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).

PAFSE Topic: This Educational Scenario is an integrated learning unit in Public Health Education related to the topic: *Looking out for my community: Vaccines development and the science that responds to hesitancy*

<u>Overview</u>

The main goal of this unit is to promote students' understanding on the relationships between infectious diseases and microbes, the human defence mechanisms against pathogens, and the impact that infectious diseases had and still have on societies and public health, and how to prevent infections. Another goal of this unit is to promote high-order thinking skills, communication and collaboration skills and critical health literacy.

The unit begins by engaging the students by presenting the impact of infectious diseases from historical and current perspective. It continues with introduction to microbes, the different protective natural barriers that the human body has against microbes, the role of immune system, immunity, and vaccines. At the end of the unit, students will use their new knowledge of infectious diseases, microbes, and vaccines to make an inquiry-based investigation on a socioscientific topic: *Should a low efficacy vaccine be released to the public?*

A socioscientific topic related to microbes and vaccine provides the scenario for the inquiry-based question of this unit related to the learning topic Vaccines development and the science that responds to hesitancy.

Socioscientific topic: Should a low efficacy vaccine be released to the public?

When a person becomes infected with a virus, the immune system responds to attack the virus so the infected person doesn't get too sick. After the virus is eliminated, the person's immune system creates cells that will remember the virus (called memory cells) so that if the person ever gets infected by the same virus again the immune system can respond very quickly, and the person probably won't even notice he/she is infected. Many years ago, scientists developed vaccines, which causes the immune response and the creation of memory cells.

Recently, a new virus has spread around the world, which has caused a lot of businesses to shut down and schools to close to limit the spread. Many pharmaceutical companies try to develop a vaccine that passes rigorous approval tests. One vaccine candidate has passed all of these tests, but it has a low efficacy rate of around 50%, meaning that a person who is vaccinated is only half as likely to get sick from the real virus, compared to a person who is not vaccinated.

The pharmaceutical company argues that the vaccine should be distributed anyway, so that people can be protected, and life can get back to normality. The government people also agree because they want the economy to improve. On the other hand, public health workers are concerned that if a vaccine that has such low efficacy is distributed, people may relax their other preventative behaviours such as

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avoiding large social gatherings or wearing masks. They are, particularly, worried because a lot of people have signalled that they are afraid to get vaccinated at all.

Research questions

- How do vaccines influence the progress of an epidemic and a pandemic?
- Should a low efficacy vaccine be released to the public?
- What are the community's perceptions and knowledge concerning immunity and vaccination?

To answer the research questions of this unit, students are asked to formulate hypotheses, to construct instruments, to collect data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures and videos, tables and diagrams, simulations, and scientific measurements), analyse, make inferences, synthesize and draw conclusions.

Additionally, students organising and holding a public debate (students, teachers, parents, social partners of the local community) on the topic: *Should a low efficacy vaccine be released to the public,* will act as knowledgeable social agents through citizenship education.

Glossary

1. Didactical glossary (or content glossary)

Antibodies: molecules (also called immunoglobulins) produced by a B cell in response to an antigen. An antibody can lead to the indirect destruction of an antigen or the antigen carrier (i.e., bacterium, virus, tutor cell, etc). An antibody will opsonise (label) the antigen, that at the next stage will be destroyed by phagocytes and the complement system

Antigen: a substance or molecule that is recognized by the immune system. The molecule can come from foreign materials such as bacteria or viruses.

B cells: small white blood cells crucial to the immune defences. Also known as B lymphocytes, they come from bone marrow and develop into blood cells called plasma cells, which are the source of antibodies.

Disease: a state in which a function or part of the body is no longer in a healthy condition.

Epidemic: a disease outbreak that affects many people in a region at the same time.

Health: a state of complete physical, social, and mental well-being, and not merely the absence of disease or infirmity

Health behaviour: any activity undertaken by an individual for the purpose of promoting, protecting, maintaining, or regaining health, whether or not such behaviour is objectively effective towards that end.

Health education: any combination of learning experiences designed to help individuals and communities improve their health by increasing knowledge, influencing motivation and improving health literacy.

Health for All: the attainment by all the people of the world of a level of health that will permit them to lead a socially and economically productive life regardless of who they are or where they live.

Health outcomes: a change in the health status of an individual, group or population that is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status.

Health policy: refers to decisions, plans, and actions that are undertaken to achieve specific health care goals within a society.

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Immune response: reaction of the immune system to anything recognised as being foreign to the human body, i.e., microbes

Immune system: a complex network of specialized cells, tissues, and organs, and molecules, that defends the body against protects the human body from infection and disease.

Immunity: a biochemical state of the human body being able to resist a particular infection, through preventing the development and growth of a pathogenic microorganism or by counteracting the effects of its products.

Immunization: vaccination or other process that induces protective immunity against infection or disease caused by microbes and/or viruses.

Infection: a state in which disease-causing microbes and particles (viruses) have invaded or multiplied in body tissues.

Infectious diseases: diseases caused by microbes that can be passed to or among humans by several methods of transmission.

Microorganisms: microscopic organisms, including bacteria, viruses, protozoa, algae, and fungi. Although viruses are not considered living organisms, they are sometimes wrongly classified as microorganisms.

Pandemics: diseases that affect many people in different regions around the world.

Pathogens: disease-causing organisms. Pathogens (Pathogenic microorganisms) are viruses, harmful bacteria, fungi, protozoa.

Vaccination: Inoculation with a vaccine to protect against a particular infection**.**

Vaccines: A weakened (attenuated) or killed microbe, such as a bacterium or virus, or a portion of the microbe's structure that when incorporated into the human body (via subcutaneous/skin injection or orally) leads to the production of specialised pathogen-specific cells and molecules that can effectively act against the specific microbe. By stimulating the generation of specific immune memory cells (most times not leading to disease), they protect the human body against subsequent infection. Vaccines constructed from parts of a pathogen cannot cause infection, however, attenuated vaccines have been reported to result to infection following possible activation of the microbe component following administration in some subjects.

2.Pedagogical glossary

a. Brainstorming

Brainstorming is an instructional technique with several variations that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

b. Collaborative learning

Collaborative learning is a pedagogical method, using group (3-5 students) teaching -learning activities (except those activities which require an individual reflection on one's own learning or those that require whole-class discussions).

The role of the teacher is to guide students, stating explicitly the aims of each task or reformulating and adapting new key questions to help them to find their own learning path. This teacher's role as a facilitator is necessary to promote a gradual development of students' learning autonomy when questioning, thinking, planning, reflecting, interacting, discussing, and gradually developing conceptual frameworks through the active participation in tasks.

c. Argumentation-Based Science Teaching Approach

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Argumentation-based science teaching stresses the evidence-based justification of knowledge claims, and it underpins reasoning across STEM domains. It helps students use cognitive/metacognitive strategies and processes, develops their collaboration and communication skills, supports their critical thinking skills, promotes scientific literacy, and makes it easier for them to understand scientific culture and practice.
For Argumentation-based science teaching approach the focus is on how the teachers:

(a) structured the task (b) used group discussions, (c) questioned for evidence and justifications, (c) modelled argument, (d) used presentations and peer review, (e) established the norms of argumentation, and (f) provided feedback during group discussions.

d. Socio-scientific Inquiry-Based Teaching and Learning Approach

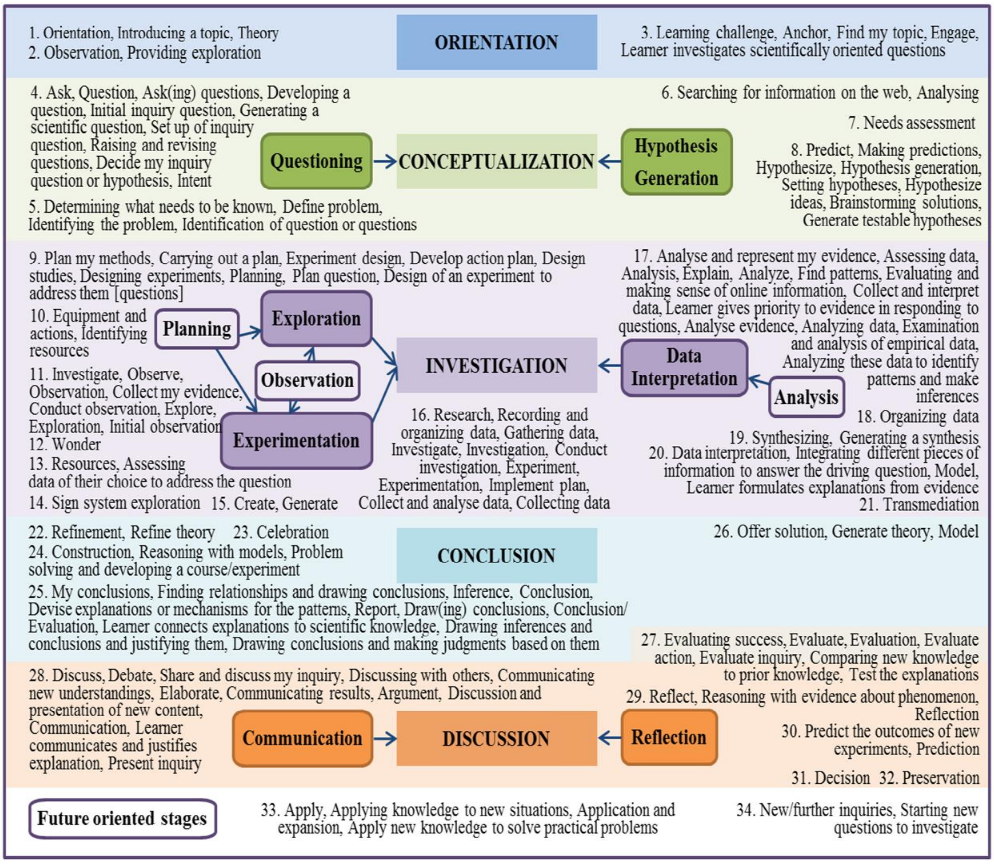
Socio-scientific inquiry-based teaching and learning approach is a pedagogical approach which connects science and society in the classroom through the use of socio-scientific issues. Socio-scientific issues (SSIs) are complex and contentious societal issues with substantive connections to science ideas and principles.
Socio-scientific inquiry-based teaching and learning approach has three main stages:

i. Use of SSI for raising inquiry-based authentic questions.

ii. For exploring these questions, social and scientific inquiry is used (e.g. planning, searching and evaluating information - using a variety of evidence sources, such as research, expert knowledge, practice experience and data to capture the complexity of a problem, analysing, negotiating the social and scientific dimensions of the SSI, making inferences, synthesising and drawing conclusions, constructing arguments, etc.).

iii. Students are stimulated to form opinions and formulate solutions related to the SSI - questions.

The main inquiry phases sub-phases are described below (Pedaste et al., 2015).



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e. Learning Science by Using Models

Modelling-based Learning approach is an approach for teaching and learning in science whereby learning takes place via student construction and/or use of models as representations of physical phenomena that include representations of physical objects and their characteristics, physical entities and physical processes involved in the physical phenomena. This leads to an externalized representation of the underlying mechanism of a physical phenomenon and helps students build an understanding of that mechanism.

Particularly, models help us to visualize a system and specify its structure or behaviour. Moreover, the modelling process usually simplifies a phenomenon thereby revealing its more fundamental concepts and downgrading any secondary information that is not directly relevant to those aspects of the system that are of interest for investigation purposes. Models have a representative, interpretive and predictive power.

f. Learning Science by Constructing Concept maps

Concept maps are a kind of graphic organizers similar to mind maps. They include concepts in frames interconnected with arrows. A verb is written above each arrow which determines the kind of the semantic connection, in a way that the two interconnected concepts and the arrow (mainly verb) form a semantically independent sentence. In addition, concept maps are a direct method of looking at the organization and structure of an individual's knowledge within a particular domain and at the fluency and efficiency with which the knowledge can be used

g. Learning Science by Using Infographic

An infographic (information graphic) is a kind of multimodal representation of facts and information. It usually forms a broad graphic composition combining short texts, numerical data, graphs, diagrams, sketches, colors, and shapes. The aim of the infographic is to present a big load of information on a topic in a visual way, making it comprehensible immediately.

h. Open Schooling

Open Schooling is an educational perspective in which schools become open to society by bidirectionally collaborating with different institutions with the aim to:

iv. Improve community well-being by raising awareness and co-creating solutions to both personal and socially relevant problems that have a direct impact at a local level.

v. Enrich the curricula and pedagogical repertoire of schools, by sharing different views and expertise from both educational and non-educational agents and institutions with the aim to promote students' meaningful learning and competence development.

vi. Give epistemic authority to all agents from within and outside the school, specifically to the students and their families, by engaging them in sustained inquiry, knowledge creation, creative action, and dissemination on issues of relevance to the local community and beyond.

To do so, projects and initiatives on Open Schooling take advantage of the knowledge, practices, visions, attitudes, resources, and values of all involved agents, empowering them to collectively transform society from a reflective and critical standpoint that focuses on sustainability, equity, social justice, and inclusion.

Open Schooling emerges as a new term first in the report Science Education for Responsible Citizenship and in EU's Work Programme 2016-2017 and continues to be a priority in the Work Programme 2018-2020. However, despite the term not being explicitly there, we can identify the Open Schooling idea already in the Work Programme 2014-2015.

The EU WPs from 2016 to 2020 followed up on the report Science Education for Responsible Citizenship to explicitly promote the concept of Open Schooling in their strategy of Science with and

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for Society, which revolves around the concept of Responsible Research and Innovation (RRI) and its pillar on Science Education.

i. Critical Health Literacy

Critical health literacy is an important dimension of health literacy beyond fundamental literacy and comprehension skills in health contexts. It includes quite useful notions and skills for a health literate citizen in modern society. Critical health literacy mainly consists of the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular the notion of social determinants of health), and the participation in civic collective actions for the promotion of health.

j. Constructing an Assessment Rubric

Assessment rubric is a strictly organised assessment system with certain assessment criteria, which is used for the precise quantitative assessment of several features of an answer, arguments, debate, a project etc., according to certain criteria and grading scales.

k. One Health Approach

The One Health approach is a transdisciplinary approach that considers human health under a broad context highlighting the direct interconnections with animal health and the environment. Zoonoses, vector-transmitted diseases and antibiotic-resistant bacteria strains are common issues of the One Health approach.

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STEM Content

1. Fundamental concepts of biological sciences (e.g. Microbes, infectious diseases, non- infectious diseases, communicable diseases, non-communicable diseases, natural barriers against microorganisms, immune system, immunity, of antigens, antibodies, vaccines, vaccination).
2. Promotion of the interconnection among science, technology, society, and environment (STSE).
3. Promotion of critical STEM literacy, critical health literacy and critical scientific literacy aspects in STEM instruction with a view to promote active citizenship.
4. Highlight of the role of science for the establishment of public health.
5. Conduction of authentic socio-scientific research by students.
6. Promoting argumentation skills
7. Construction, use and nature of scientific models.
8. Promoting understanding of nature of science and epistemological beliefs.
9. Illustration of the convergence between science and technology at the development of different types of vaccines (biomedical technology).

General Learning Objectives

Knowledge (Core Concepts)

1. Transdisciplinary concepts: Critical health literacy, STSE (Science, Technology, Society, Environment) interconnections, One Health approach, socio-scientific research.

2. Specific content concepts: Microbes, infectious diseases, non- infectious diseases, communicable diseases, non-communicable diseases, natural barriers against microorganisms, immune system, immunity, antigens, antibodies, vaccines, vaccination.

Skills

1. General skills: Critical thinking, reflective thinking, critical reading, formal and informal reasoning, decision making, collaboration and communication within small groups, presentation skills.

2. Specific skills: Critical reading of scientific sources (videos, simulations, scientific models, infographics, informative health texts, academic texts), construction and use scientific models, argumentation about the social and environmental dimensions of socio-scientific topics, empirical socio-scientific research design, research data collection, conclusions making, presentation of socio-scientific topics, discussion and reflection about socio-scientific topics.

Attitudes (Affective domain)

1. Attitudes and values: Awareness concerning socioscientific issues related to vaccines development and vaccination, their complexity and multidimensionality, the social risks and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders, taking in consideration economic, social, ethical, political cultural, emotional and others factors

2. Behaviours: Citizenship actions for the limitation of health disparities, and decision making on controversial socioscientific issues (e.g vaccines development and vaccinations, which are defined as open-ended, debatable, non-complex or ill-structured problems that require the consideration of social, ethical, economic, scientific, and ecological perspectives, considering a variety of perspectives and having an orientation towards socio-scientific humanistic values.

Title of whole module and titles of individual lessons

Title of whole module

Discovering the World of Microbes...and Vaccines

Titles of individual lessons

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- Lesson 1 (40 min): Introduction: Infectious diseases, Microbes (microorganisms) and Vaccines
- Lessons 2 & 3 (80 min): Categories, Structure and Functions of Microorganisms
- Lessons 4 & 5 (80 min): Defence against Microbes and the role of Vaccines
- Lessons 6 & 7 (80 min): Investigating the socioscientific issue on the topic: *Vaccines development and the science that responds to hesitancy.*
- *Lessons 8 & 9 (80 min): Organising a public debate on the topic: Vaccines development and the science that responds to hesitancy*
- Lesson 10 (40 min): Conducting a public debate (students, teachers, parents, social partners of the local community) on the topic: *Vaccines development and the science that responds to hesitancy*

Learning goals and objectives

Lesson 1 (40 min):

1. Awaken interest into the subject

2. Identifying students' preconceptions, alternative ideas (misconceptions) on Infectious diseases, Microbes and Vaccines. Mapping the preconceptions of the students.

3. Introducing and discussing a socioscientific issue: *Should a low efficacy vaccine be released to the public?*

4. Improving students' epistemological understanding.

Lessons 2 & 3 (80 min):

At the end of lessons 2 & 3 students should be able to…

1. relate one's own experiences of infectious diseases and microbes with scientific knowledge.

2. explain what a disease is.

3. identify infectious diseases

4. explain the difference between infectious diseases and non- infectious diseases

5. explain the difference between communicable diseases and non-communicable diseases?

6. explain what makes a disease infectious

7. explain what microbes are

8. identify the categories, structure and functions of microorganisms

9. explore life cycles of microorganisms and identify similarities and differences between the various categories of microorganisms

10. improve critical thinking.

11. improve communication and collaboration skills.

Lessons 4 & 5 (80 min):

At the end of lessons 4 & 5 students should be able to…

1. read and interpret images related to human body's defence mechanisms against microorganisms that can cause infection (pathogens).

2. differentiate between contamination, infection, and disease

3. identify the human defence mechanisms against pathogens

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4. identify the natural barriers against microorganisms (skin, mucous membranes, tears, earwax, mucus, and stomach acid. Also, the normal flow of urine washes out microorganisms that enter the urinary tract)

5. explain how the natural barriers defend the body against microorganisms that can cause infection (human body's first line of defence against infection)

6. define immune system and immunity

7. explain how immune system using white blood cells and antibodies can identify and eliminate organisms that get through the body's natural barriers (human body's second line of defence against infection and human body's third line of defence against infection).

8. explain the role of antigens in immunity

9. explain the role of antibodies in immunity

10. explain the role of vaccines in immunity

11. improve critical thinking.

12. improve communication and collaboration skills

Lessons 6 & 7 (80 min)

At the end of lessons 6 & 7 students should be able to…

1. improve inquiry-based investigation skills (e.g. planning, searching and evaluating information, analysing, making inferences, synthesising and drawing conclusions, constructing arguments, etc.) to answer the research questions:

- How do vaccines influence the progress of an epidemic and a pandemic?
- Should a low efficacy vaccine be released to the public?
- What are the community's perceptions and knowledge concerning immunity and vaccination?

2. develop digital skills (e.g., finding, reviewing, organising and sharing information effectively, handling data appropriately, using different online resources and tools to study)

3. explain what vaccines are and why they are an important part of public health

4. explain how vaccines work against pathogens

5. explain the difference between vaccination and immunization

6. identify the most important vaccines in human history

7. understand the multiplicity of factors leading to vaccine challenges

8. develop the ability to construct different types of arguments, counterarguments and rebuttals in order to make a decision on the socio-scientific question: *Should a low efficacy vaccine be released to the public?*

9. investigate how vaccines influence the progress of an epidemic and a pandemic, as well as the community's perceptions and knowledge concerning immunity and vaccination.

10. develop the ability to construct an assessment rubric for arguments, counterarguments and rebuttals evaluation.

11. improve communication and collaboration skills

12. acquire the ability to analyse a public health issue and potential solutions from the perspectives of different stakeholders

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13. acquire the ability to identify potential sources of bias that may influence information or the presentation of information about a socioscientific issue related to public health or potential solutions

14. acquire the ability to determine how scientific knowledge and processes may contribute to the resolution of a socioscientific issue related to public health and to recognize dimensions of the issue that cannot be addressed by science

15. acquire the ability to recognize the possibilities and limitations of science

Lessons 8 & 9 (80 min):

At the end of lessons 8 and 9 students should be able to…

1. present arguments, counter arguments, and rebuttals on the topic: *Should a low efficacy vaccine be released to the public?*

2. evaluate the validity and reliability of the arguments/ counterarguments/ rebuttals

3. organise a public debate (students, teachers, parents, social partners of the local community) on the topic: *Should a low efficacy vaccine be released to the public?*

4. improve communication and collaboration skills.

5. investigate the community's perceptions and knowledge concerning immunity and vaccination.

Lesson 10 (40 min):

At the end of lesson 10 students should be able to…

1. conduct a public debate (students, teachers, parents, social partners of the local community) on the topic: *Vaccines development and the science that responds to hesitancy*

2. present the results of their investigation of the research questions:

- ✓ *How do vaccines influence the progress of an epidemic and a pandemic?*
- ✓ *What are the community's perceptions and knowledge concerning immunity and vaccination?*

3. improve communication skills

4. develop responsible citizenship

Summative assessment: Scientific knowledge (categories, structure and function of microorganisms, contamination, infection, disease, natural barriers against microorganisms, immune system, immunity, white blood cells antigens, antibodies, Vaccines), thinking skills and evidence-based reasoning.

Didactical methods and activities

<u>Course of the Lesson 1:</u>

The lesson starts with a short video related to the Spanish flu 1918. After the presentation, discussion and reflection can be encouraged with asking: What others infectious diseases do you know? What is a pandemic? What is the impact of infectious disease on society? How do infectious diseases affect the world? What is the role of microbes? How can people prevent microbes?

After short discussion and reflection, the teacher can introduce the socioscientific issue entitled *Should a low efficacy vaccine be released to the public?* and explain that is a societal issue with connections to science. Using the example of the socioscientific issue related to vaccines, the teacher can discuss the complexity and multidimensionality of socioscientific issues, the social risks and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders. In addition, it can be discussed that many health issues can be considered socioscientific issues because are open-ended, ill-structured problems and subject to multiple perspectives and solutions.

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Course of the Lessons 2 & 3:

1. The lesson starts with a multimedia-show related to different infectious diseases caused by viruses, by bacteria, by fungi and by protozoa.

Then, the teacher starts the lesson asking:

What is a disease?

Can you give examples of infectious diseases that you experience?

What is the difference between infectious diseases and non- infectious diseases?

What is the difference between communicable diseases and non-communicable diseases? Examples.

Presentation of a video related to pathogens spread.

Then, students are encouraged to discuss the questions and after short discussion the students are asked to start working on **Worksheet 1** (Matching activity related to infectious diseases and microbes). For this activity students are provided with a table with information about infectious diseases caused by viruses, by bacteria, by fungi and by protozoa. Students work first individually and then in group (3-5 students) cooperatively and teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students complete activities of worksheet 1, the teacher gives feedback to the plenary of the class.

2. Next, the teacher uses an educational video related to the categories, size, structure and functions of microorganisms. The students are asked to read and interpret images related to the size, structure and functions of viruses, bacteria, fungi and protozoa, and construct criteria for microorganisms' taxonomy using **Worksheet 2**. Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When students complete activities of worksheet 2, the teacher gives feedback to the plenary of the class.

3. When appropriate, teacher directs discussion towards microorganisms' life cycles After short discussion about the key stages of life for all organisms (birth, growth, reproduction, and death) students are asked to read and interpret images related to microorganism's life cycles and identify similarities and differences between the various categories of microorganisms using **Worksheet 3** (Fill in the blanks worksheet).

Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students complete activities of worksheet 3, the teacher gives feedback to the plenary of the class.

Course of the Lessons 4 & 5

1. The lesson starts with a play card activity related to various pathogens, the places that pathogens can enter the human body and how the body protects itself from infectious diseases. The aim of this activity is that students gain a basic understanding of how each defence works.

After short discussion, teacher presents a video (https://youtu.be/aq-F4rNuj3Y?) related to Human Defence Systems against Pathogens. After the presentation, the students are asked to work on **Worksheet 4** to identify and name the places that pathogens can enter the body and explain how the body tries to prevent this (human body's first line of defence against infection). In addition, when appropriate, they are asked to complete the matching activity of Worksheet 4 related to contamination, infection, and disease.

Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students complete activities of worksheet 4, the teacher gives feedback to the plenary of the class.

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2. When appropriate, the students are asked to attend a short video related to the immunity system and a multimedia-show "human body's second line of defence against infection" and then read, interpret and pairing images related to non-specific cellular and molecular responses of the immune system with appropriate text using **Worksheet 5.**

Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback.

3. When appropriate, the students are asked to attend multimedia-show "human body's third line of defence against infection" and then read, interpret and pairing images related to the specific immune response with appropriate text using **Worksheet 6**. In addition, when appropriate, they are asked to complete the matching activity of worksheet 6 related to antigens, antibodies, vaccines, and immunity.

Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students complete activities of worksheet 6 the teacher gives feedback to the plenary of the class.

At the end of the lesson, teacher informs students that in the next lesson they will explore the socioscientific issue related to vaccines and asks them to look for material on history of vaccines, the role of vaccines in infectious diseases and in the prevention of communicable diseases.

Course of the Lessons 6 & 7

1. The teacher starts the lesson presenting again the SSI topic and the driving question of this unit: *Should a low efficacy vaccine be released to the public?*

2. Then, teacher moderates a discussion on planning, searching and evaluating information about vaccines, analysing, making inferences, synthesising and drawing conclusions, constructing arguments from evidence in order to manage the research questions of a socioscientific topic: *Vaccines development and the science that responds to hesitancy*

3. To manage the question, *should a low efficacy vaccine be released to the public?* Students are asked to formulate hypotheses, to collect data from a variety of inquiry-based sources (e.g. such as texts, articles, pictures and videos, tables and diagrams, simulations and scientific measurements). For this task students are provided with extra appropriate material.

4. Then, students are asked to use **Worksheet 7** for organizing and evaluating information, analysing, making inferences, synthesising and drawing conclusions in order to make decision on the driving question: *Should a low efficacy vaccine be released to the public?*

During this process, teacher consistently encourages students to consider the source and author of the information, the purpose of the publication, potential biases of the author or publisher, evidentiary support for the information, and possible missing information. In addition, teacher draws students' attention to multiplicity of factors leading to use or not use of vaccines, like medical, ethical, social, economic, and political.

Students work in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions, looking at the students' achievements and, when appropriate, gives permission to go forward to the next task.

5. When appropriate, teacher directs discussion towards a construction of arguments, counter-arguments and rebuttals in order to make a decision on the socio-scientific question: *Should a low efficacy vaccine be released to the public?*

6. Students are asked to construct criteria and create a template that can be used for arguments 'evaluation and improving arguments/ counter-arguments/ rebuttals **(Worksheet 8).** The criteria and the arguments will be presented and evaluated in the next lesson.

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Course of the Lessons 8 & 9

1. The teacher starts the lesson with evaluation and feedback on students' arguments/ counterarguments/ rebuttals related to the socio-scientific topic: Should a low efficacy vaccine be released to the public? Then, students improve their arguments.

2. To answer the research questions: How do vaccines influence the progress of an epidemic and a pandemic? and What are the community's perceptions and knowledge concerning immunity and vaccination? Students are asked to formulate hypotheses, to construct instruments, to collect data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures and videos, tables and diagrams, simulations, and scientific measurements), analyse, make inferences, synthesize and draw conclusions.

3. When appropriate, teacher directs discussion towards organizing and conducting a public debate on the topic: *Health and Vaccines: Should a low efficacy vaccine be released to the public?* How do we plan, organize, and conduct a public debate? Students and teacher will discuss on the following for the debate preparation:

- ✓ Develop the resolution to be debated.
- ✓ Organize the teams.
- ✓ Establish the rules of the debate, including timelines.
- ✓ Research the topic and prepare logical arguments.
- ✓ Gather supporting evidence and examples for position taken.
- ✓ Anticipate counter arguments and prepare rebuttals.
- ✓ Team members plan order and content of speaking in debate.
- ✓ Prepare room for debate.
- ✓ Establish expectations, if any, for assessment of debate.

Then, students and teacher will discuss on conducting debate and express opinions and suggestions:

For example, the debate opens with the affirmative team (the team that supports the resolution) presenting their arguments, followed by a member of the opposing team. This pattern is repeated for the second speaker in each team. Finally, each team gets an opportunity for rebutting the arguments of the opponent. Speakers should speak slowly and clearly. The judges and members of the audience should be taking notes as the debate proceeds.

Then, students and teacher will discuss on post-debate discussion and assessment and express opinions and suggestions:

When the formal debate is finished, allow time for debriefing and discussion. Members of the audience should be given an opportunity to ask questions and to contribute their own thoughts and opinions on the arguments presented. Members of the debate teams may also wish to reflect on their performance and seek feedback from the audience, including the teacher.

Assessment could be conducted by the teacher, the judging team, or the entire class, using a specific rubric.

At the end of a lesson, teacher and students agree for the preparation of a public debate (students, teachers, parents, social partners of the local community) on the topic: *Health and Vaccines*: *Should a low efficacy vaccine be released to the public?*

Course of the Lesson 10

Conducting a public debate on the topic: *Health and Vaccines: Should a low efficacy vaccine be released to the public?*

Evaluative tasks

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(Note: For more details concerning initial and formative assessment, please see the attached teaching and learning activities. For final assessment, please see educational scenarios impact assessment)

1. Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment)

2. Worksheets evaluation (Formative assessment)

3. Post-test (Final/ summative assessment)

4. Conducting a public debate on the topic: *Health and Vaccines: Should a low efficacy vaccine be released to the public?*

5. Presentation for the research questions on the topic: *Vaccines development and the science that responds to hesitancy*

Assessment could be conducted by the teacher, the judging team, or the entire class, using a specific assessment rubric.

Learning objects as per lesson

Lesson 1

Supplementary Educational Resources (SERs)

1. Educational short video related to the Spanish flu 1918: *The Spanish flu: the biggest pandemic in modern history* at: https://youtu.be/4H2S97URb_w
2. Socioscientific topic related to vaccines development and the science that responds to hesitancy.
3. Reflection questions related to Microorganisms, Pathogens, Infection: Infectious diseases, Diseases, Epidemics, Pandemics, Antigen, Immune system, Immune response and Vaccines for identification and mapping of students' preconceptions.

Lessons 2& 3

Digital Learning Objects (DLOs)
1. Interactive true or false activity related to general characteristics of pathogens.
2. Interactiv match activity concerning the relation between microbes and diseases.
3. Interactive match activity related to microbes and their way of transmission and infectious diseases
4. Interactive fill in the blanks activity related to microbes size (bacteria, monocellular fungi, protozoa, viruses size).
5. Interactive concept map related to useful and harmful microbes

Supplementary Educational Resources (SERs)
1. Educational video related to viruses, by bacteria, by fungi and by protozoa at: https://youtu.be/wUm71FPuVCQ
2. Infographic related to 4 groups of microbes: viruses, bacteria, fungi and protozoa.
3. Educational video related to spread of pathogens at: https://youtu.be/wUm71FPuVCQ
4. Educational video related to Microbes size at https://youtu.be/h0xTKxbIElU
5. Scientific texts "WHAT DOES SCIENCE TELL US?" concerning microbes and ways to prevent infections
6. Worksheets (see the attached relevant teaching and learning activities).

Lesson 4 & 5

Digital Learning Objects (DLOs)
1. Interactive mini game play card activity related to various pathogens, the places that pathogens can enter the human body and how the body protects itself from infectious diseases. (Mechanisms concerning how each barrier is specialised to fight microbes).

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2. Interactive fill in the blanks-activity related to innate and acquired/ adaptive immunity.
3. Interactive match activity related to antigens, antibodies, vaccines, and immunity.
4. Interactive match activity related to vaccines and vaccination

Supplementary Educational Resources (SERs)

1. Short educational video related to Human Defence Systems against Pathogens at: **https://youtu.be/aq-F4rNuj3Y**
2. Educational video related to the human immune system at: **https://youtu.be/HSrrPdJDqxM**
3. Multimedia-show "Human body's second line of defence against infection"
4. Multimedia-show "Human body's third line of defence against infection"
5. Infographics related to first, second and third line of defence.
6. Educational video related to the history of vaccines at: **https://youtu.be/WZ7g1nGjGbQ**
7. Educational video related to vaccination at: **https://youtu.be/uPeZBhJYlnU**
8. Infographics related to herd and not herd immunity
9. Worksheets (see the attached relevant teaching and learning activities)

Lessons 6 & 7

Supplementary Educational Resources (SERs)

1. Infographics related to vaccines and vaccination
2. Worksheets (see the attached relevant teaching and learning activities)
3. Table for organizing and conducting a public debate on a socio-scientific topic

Lessons 8& 9

Supplementary Educational Resources (SERs)

1. Assessment Rubrics for arguments evaluation and argumentation
2. Specific information for creation of a public health brochure related to vaccination
3. Specific information for preparation of an agenda for the forum (students, teachers, parents, social partners of the local community) on a socioscientific topic.
4. Worksheets (see the attached relevant teaching and learning activities).
5. Questionnaire.

Lesson 10

Supplementary Educational Resources (SERs)

1. Specific information for holding a public debate

Digital educational resources

Pictures and text related to microbes and human body's defence mechanisms against pathogens.
https://archeia.moec.gov.cy/sm/41/viologia_c_gymn.pdf
www.e-bug.eu
https://youtu.be/WZ7g1nGjGbQ
https://youtu.be/-muIoWofsCE
https://youtu.be/WOvvyqJ-vwo
https://youtu.be/wUm71FPuVCQ
https://youtu.be/wUm71FPuVCQ
https://youtu.be/h0xTKxbIElU
https://youtu.be/aq-F4rNuj3Y
https://youtu.be/HSrrPdJDqxM
https://youtu.be/WZ7g1nGjGbQ
https://youtu.be/uPeZBhJYlnU

School Research Project

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Educational_Scenario on the topic: Looking out for my community - Vaccines development and the science that responds to hesitancy

Topics
- Infectious diseases
- Epidemic
_ Pandemic
- Immunity
- Vaccines
- Vaccination
- Nature of science
- Public health
- Critical health literacy
- Responsible citizenship

Research management, design and administration

Research Questions

- How do vaccines influence the progress of an epidemic and a pandemic?
- Should a low efficacy vaccine be released to the public?
- What are the community's perceptions and knowledge concerning immunity and vaccination?

Methodology/Implementation:

Session 1
Students are organized in groups of 3-5 students:
Preparation of a research plan with the components of a research project: theoretical background, objectives, participants, methodology, results and conclusions, approximate timeline, form of actions

Collection of documents and articles for bibliographical analysis.

Evaluation of the documents based on criteria and selection of the relevant valid information.
Each group shortly presents the results of its investigation for valid sources for bibliographical analysis.
Teacher and students give feedback for improvement of research plan.

Session 2
Students are organized in groups of 3-5 students:
Challenge: Investigating how vaccines influence the progress of an epidemic and a pandemic
An expert will be invited to discuss with the students and answer their questions related to vaccines and vaccinations in Cyprus and globally. During the discussion with the expert, students will have the opportunity to ask specific questions, and write a short report concerning the vaccines' influence on the progress of an epidemic and a pandemic, as well as how science responds to hesitancy (nature of science).
Students are urged to formulate hypotheses concerning the question: *Should a low efficacy vaccine be released to the public*? (Homework) Teacher will evaluate the students' hypotheses and give feedback in the next lesson.

Session 3
Students are organized in groups of 3-5 students:
Challenge: Argumentation and decision making concerning the socio-scientific dilemma: *Should a low efficacy vaccine be released to the public?*
Students discuss in their group towards a construction of arguments, counter-arguments and rebuttals in order to make a decision on the socio-scientific question: *Should a low efficacy vaccine be released*

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to the public? Students are asked to Support their claims, using as many as possible justifications supported by evidences, and construct different types of arguments according to your opinion (e.g., scientific, social, ethical, economic, etc.). The groups discuss their arguments in the classroom. Teacher and students give feedback for the improvement of arguments.
Challenge: Creating a template that can be used for arguments' evaluation and improving arguments, counter-arguments and rebuttals
Students work in their groups constructing criteria and creating a template that can be used for arguments' evaluation and improving arguments/ counter-arguments/ counter-counterarguments.

<u>Session 4</u>
Students are organized in groups of 3-5 students.
Challenge: Creating a rubric for evaluation of public debate
Students are provided with appropriate guidance in order to design a rubic for evaluation of public debate. They are urged to take in consideration their participation in group discussion, cooperation, quality of arguments' construction and argumentation skills. The groups discuss their criteria for evaluation of public debate in the classroom. Teacher and students give feedback for the improvement of criteria.
Challenge: Designing a questionnaire (social research tool) to investigate the community's perceptions and knowledge concerning immunity and vaccination.
Teacher explains the fundamental principles of question selection and formulation, when designing a questionnaire. Students decide on the questionnaire form and sections, and they are divided in groups equal in number to the questionnaire sections. Each group is responsible for designing one questionnaire section. Each groupof students shortly presents their questions and design a final questionnaire. Some students get the responsibility to write the questionnaire in an online form, which allows to be more easily delivered to its targets. Students are urged to collect data about the community's perceptions and knowledge concerning vaccination. Some students of different groups get the responsibility to analyze the answers of the questionnaire.

<u>Session 5</u>
Students are organized in groups of 3-5 students.
Challenge: Presentation of the results of the questionnaire, trying to identify the community perceptions and knowledge gaps concerning immunity and vaccinations and how to promote conceptual understanding and nature of science. In the end, build an infographic to summarize the results.

Challenge: Creating an informative flyer (brochure) explaining the role of vaccinations for public health.
Students are provided with appropriate guidance in order to design an informative flyer (brochure) explaining the role of vaccinations for public health. (home work). Teacher will evaluate the students' brochure and give feedback in the next lesson.

<u>Session 6</u>
Challenge: Preparing a public debate and the post-debate discussion for open schooling event.
A fruitful discussion takes place among students and teacher, discussing all the steps of the open schooling event. Some students get the responsibility to organize a public debate for open schooling event.
Challenge: Preparing an agenda for the open schooling event on the topic *Vaccines development and the science that responds to hesitancy*

Development process:
The project is based on guided research about *Vaccines development and the science that responds to hesitancy*. The six (6) lessons will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.

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Teaching-learning process milestones:

Students will be able to:
1. develop digital skills (e.g., finding, reviewing, organizing and sharing information effectively, handling data appropriately, using different online resources and tools to study)
2. explain how vaccines work against pathogens
3. understand the multiplicity of factors leading to vaccine challenges
4. develop the ability to construct different types of arguments, counterarguments and rebuttals in order to make a decision on the socio-scientific question: *Should a low efficacy vaccine be released to the public?*
5 develop the ability to construct an assessment criterion for arguments, counterarguments and rebuttals evaluation.
6. develop the ability to create a rubric for evaluation of public debate
7. investigate community's perceptions and knowledge concerning vaccination
8. develop responsible citizenship and critical health literacy

Teaching-learning process for school project (summary):

1. Collection of evidence (data, articles, pictures).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Design criteria for arguments evaluation
4. Design rubric for evaluation of public debate
5. Design a questionnaire
6. Design an agenda for open schooling event.
7. Create a brochure related to vaccination and distribute it in open schooling event.

Organization of the open schooling event:
1. Each project output (public debate, a post-debate discussion, results of investigation, brochure, etc.) is presented by the students in a community setting.
2. Students hold a public debate entitled "*Should a low efficacy vaccine be released to the public?"* Students communicate their research outcomes related to community's perceptions and knowledge concerning vaccination.
3. . Students emphasize that health literacy and health promotion is a responsibility of all, not only of the ministry of health or healthcare providers.
4. Additionally, students explain the importance of critical health literacy, which mainly consists of understanding the nature of science, the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular the notion of social determinants of health), and the participation in civic collective actions for the promotion of public health.

Data Analysis and Reporting
1. Content analysis.
2. Questionnaire results analysis
3. Report writing with most important findings.
4. Organize a public debate,
5. Create a health prochure and final presentation.

Target Audience for Recommendations
Parents, science teachers, local community – public.
Public Health Authorities and other stakeholders (organisation for family orientation, organisation of doctors and health advisers).

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Educational Scenario Impact Assessment Questionnaire

Context: The main goal of this module is to promote students' understanding on the relationship between infectious diseases and microbes, the human defense mechanisms against pathogens, and the impact that infectious diseases had and still have on societies and public health and how to prevent infections using vaccines. Another goal of this unit is to promote high order thinking skills and communication and collaboration skills.

The unit begins by engaging the students by presenting the impact of infectious diseases from historical and current perspective. It continues with introduction to microbes, the different protective natural barriers that the human body has against microbes, the role of immune system, immunity and vaccines. At the end of the unit, students will use their new knowledge of infectious diseases, microbes and vaccines to make an inquiry-based investigation on a socioscientific topic: *Should a low efficacy vaccine be released to the public?*

Additional information on specifications of an educational scenario on the topic of *Looking out for my community* - *Vaccines development and the science that responds to hesitancy*

The questions that follow provide and assessment for the impact of the given learning scenario on the pre-existing knowledge of the students, the skills that they have acquired throughout the teaching of this topic and the effect of this on their beliefs, attitudes, and behavior.

Knowledge	
1.Understanding the nature of microbes	**Question 1.1** What are microbes (microorganisms)? A) Microbes are living organisms that are so small that they can only be seen through a microscope. B) Microbes are very harmful living organisms C) Microbes are not living organisms. **Question 1.2** what are the main categories of microbes? A) Bacteria, viruses, fungi, protozoa and some algae. B) Bacteria and viruses C) Fungi and viruses **Question 1.3** What are viruses? A) Viruses are non-living organisms, requiring the use of the host cell to replicate and create new infectious virus particles. B) Viruses are living organisms requiring the use of the host cell to replicate and create new virus particles. C) Viruses are non-living organisms that do not use host cell to replicate and create new infectious virus particles. **Question 1.4** Where are microbes found?? A) Microbes are everywhere B) Microbes are only in the food we eat C) Microbes are only in water. **Question 1.5** Are microbes always harmful? A) No. Microbes can be useful, harmful or both. B) Yes. Microbes are always harmful. C) No. Microbes are always useful. **Question 1.6** Many microbes are useful because: A) They can help us make food such as bread, yoghurt, cheese and butter, as well as medicines. Yet, some microbes break down dead animals and plant material to make compost; and some microbes help us digest foods B) They are used to turn milk into yoghurt, cheese and butter. C) They cannot make us ill. **Question 1.7** Microbes are microscopic**.** Which is the smallest? A) Virus B) Bacteria C) Fungi.
2. Understanding the structures and functions of microbes	**Question 2.1** What is the main difference between bacteria and viruses? A). Bacteria are single celled organisms that, under the right conditions, can multiply exponentially, on average once every 20 minutes, while viruses cannot survive by themselves, and they require a 'host' cell in which to live and reproduce. B) Viruses are single celled organisms that, under the right conditions, can multiply exponentially, on average once every 20 minutes, while bacteria cannot survive by themselves, and they require a 'host' cell in which to live and reproduce C) Bacteria and viruses are single celled organisms that, under the right conditions, can multiply exponentially, on average once every 20 minutes.

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	Question 2.2 In general, bacteria can be classified according to different basic shapes. What are the main types of shapes we usually find bacteria? A) Coccus, Bacillus, and Spiral). Coccus and Bacillus. C) Bacillus, and Spiral. **Question 2.3** Why is it important to know the shape of a bacteria? A) Scientists can use these shapes to help identify the microbes and tell which infection a patient has. B) Scientists can understand whether they are harmful or not. C) Scientists can understand whether they are prokaryotes or eukaryotes. **Question 2.4** When did bacteria first begin to exist on Earth? A) 4 billion years ago B) 2 billion years ago C) 1 billion years ago. **Question 2.5** Which microbes are prokaryotes? A) Bacteria B) Fungi C) Viruses. **Question 2.6** Which microbes are eukaryotes? A) Fungi, Protozoa B) Bacteria, Protozoa C) Protozoa, Viruses. **Question 2.7** Which microbes obtain their food by either decomposing dead organic matter or by living as parasites on a host? A) Fungi B) Bacteria C) Viruses.
3. Understanding the relationship between pathogens and infectious diseases	**Question 3.1** What are microbes that cause diseases in all humans called? A) Pathogens B) Bacteria C) Bacteria and Viruses. **Question 3.2 What** are infectious diseases**?** A) Diseases caused by pathogens **and can be spread to other people** B) Diseases caused only by bacteria C) Diseases caused only by viruses. **Question 3.3** What is the difference between pandemics and epidemics A) In both an occurrence of transmissions is noted but, in an epidemic the number of cases increases, whereas in a pandemic the number of cases increases and spreading occurs worldwide. B) In both an occurrence of transmissions is noted but, in an epidemic the number of cases remains constant, whereas in a pandemic the number of cases increases but remain local. C) In both an occurrence of transmissions is noted but, in a pandemic the number of cases increases, whereas in an epidemic the number of cases increases and spreading occurs worldwide. **Question 3.4** As public health officials they must decide how they can stop the spread of the infection. What questions would they ask that could help them stop the spread of the sickness? A) How many people are sick? How is the infectious agent spreading? Who needs to know about this? B) What is the origin of the disease? C) What are the symptoms of the infectious disease? **Question 3.5** What are the main mode(s) of transmission for pathogenic microbes: By air including droplet transmission, Direct contact, By consumption - eating raw, undercooked, or contaminated food, or drinking water containing sewage, Vector – some diseases e.g. malaria, are vector-borne, this means that some living organism can transmit infectious pathogens between humans, or from animals to humans. B) Lifestyle C) Animals and food.
4 Identification the human defense mechanisms against pathogens and ways of prevention	**Question 4.1**. What are the defense mechanisms of the body against pathogens? A) physical and chemical barriers, non-specific innate responses, and specific adaptive responses) Physical and chemical barriers, non-specific innate responses C) Non-specific innate responses, and specific adaptive responses **Question 4.2** The immune system protects our body from outside invaders What are these invaders? A) Bacteria, viruses, fungi, and toxins. B) Bacteria, and viruses C) Viruses. **Question 4.3** What does a first line of defense consist of? A) Skin, mucous membranes, tears, earwax, mucus, and stomach acid. B) Skin, tears, mucus. C) Skin, tears. **Question 4.4** Which blood cells are involved in our body's second and third line of defense? A) white blood cells (leukocytes). B) Red blood cells (erythrocytes) C) platelets. **Question 4.5** What type of white blood cells are involved in our body's second line of defense? A) Phagocytic cells B) B *lymphocytes* (B cells) C) T *lymphocytes* (T cells) **Question 4.6** What type of white blood cells are involved in our body's third line of defense? A) B *lymphocytes* (B cells), T *lymphocytes* (T cells) B) Phagocytic cells, B *lymphocytes* (B cells), T *lymphocytes* (T cells) C) Phagocytic cells ,

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	Question 4.7 How we can prevent infections? A) Good hygiene, good food safety techniques, animal-control, vaccinations, B) Good hygiene, good food safety techniques, C) Wash hands well. **Question 4.8** What are the ingredients in a vaccine? A) Cells which are similar to, but not exact copies of, the microbe cells that make us ill B) Antibodies C) White blood cells. **Question 4.9** How do mRNA vaccines work? A) Vaccines that teach our cells how to make a protein, or piece of protein, to trigger an immune response inside our bodies. B) Vaccines that do not trigger in our bodies the production of antibodies. C) Vaccines that teach our cells to produce macrophage cells.
5. Understanding health socioscientific issues	**Question 5.1.** What are the characteristics of a controversial health socioscientific issue? A) Different dimensions on the topic, multiple stakeholder groups with conflicting interests, multiple solutions from the perspectives of different stakeholders. B) Different opinions and viewpoints of the topic C) Different scientific data. **Question 5.2.** What is the additive learning value of using health socioscientific topics to understand scientific issues? A) Better understanding of the nature of scientific knowledge because students discuss issues related to the potentialities, as well as limitations, of the scientific enterprise and its relationship to technology, society and the environment. B) Easier to understand scientific concepts. C) Easier homework**.**
SKILLS	
1. Investigating health socioscientific issues	**Question 1.1** Which inquiry phases are necessary for investigating health socioscientific issues? A) Generating research questions based on the stated problem, generating hypotheses about the stated problem, searching and evaluating information, analyzing, making inferences, synthesizing and drawing conclusions. B) Experimentation, results, conclusions. C) Exploration, experimentation, data Interpretation.
2. Constructing and using scientific models	**Question 2.1** Scientific models are very important in science because: A) Models help us to visualize a system or phenomenon and specify its structure or behaviour, and they have a representative, interpretive and predictive power. B) Models have a representative and interpretive power C) Models have an interpretive power.
3. Adopting a healthy lifestyle and ways to prevent infections	**Question 3.1** I will try to follow good personal hygiene habits (e.g., Wash my hands well, cover a cough). 1) Strongly agree... 5) strongly disagree. **Question 3.2** I will try to receive the recommended childhood vaccinations) definitely true... 5) definitively false. **Question 3.3** I will make sure my pet's vaccinations are up to date 1) definitely true... 5) definitively false. **Question 3.4.** When I travel abroad, I check with my health care provider about additional immunizations. 1) Definitely true... 5) definitively false. **Question 3.5** I will try to adopt a healthy lifestyle (avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months. 1) Definitely true... 5) definitively false. **Question 3.6** I will be able to find the necessary strategies and resources for adopting a healthy lifestyle in the next three months 1) Probable... 5) improbable.
4. Proposing concrete action towards adopting healthy lifestyles in his/her/others routine and ways to prevent infections.	**Question 4.1** I feel able to identify relevant actions for adopting a healthy lifestyle in my routine and prevent infections. 1) Definitively true… 5) definitively false. **Question 4.2** I feel able to change my routine in order to adopt a healthier lifestyle and prevent infections. 1) Definitively true… 5) definitively false.

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5. Feels able to influence the prevention of infections by others (e.g., family, peers, friends).	**Question 5.1** I feel able to influence the prevention of infections by others (family, friends). 1) Definitely true... 5) definitively false. **Question 5.2** I will try to influence the prevention of infections by others (family, friends). 1) Definitely true... 5) definitively false.
6. Propose plausible actions towards promoting protection from possible viral infections in his/her lifestyle.	**Question 6.1** Which individual actions can be taken to help containment of a spreading virus within your school community? A) Notify your school community of your unwellness and take a leave to stay home until you recover, while arranging to participate in lessons online. B) No need to notify your school community and go to school as normal. C) Notify your school community and go to school and try and keep a mask on at most times. **Question 6.2** Which individual actions can be taken to help containment of a spreading virus in the vast community? A) Seek the advice of your personal doctor and contain yourself until you are free of all symptoms, and you are no longer infectious to others. B) If feeling that your symptoms are milt, continue to interact within your community. C) Continue to interact within your community, ensuring that you follow precautions such as the use of a face mask.
7. Selecting appropriate sources to investigate health socioscientific issues (e.g., Vaccination).	**Question 7.1** I believe that to find scientific information about a health socioscientific issue, I should consult the following sources. A) Scientists, scientific publications, WHO database, EU database B) Newspapers, google, YouTube. C) Friends, journalists, Facebook. **Question 7.2** To find scientific information about the historical course of vaccines I should consult the following sources. A) researchers, scientific publications, CDC database B) newspapers, google, YouTube, C) friends, journalists, Facebook **Question 7.3** I feel able to identify scientific sources to describe the historical course of viral pandemics. 1) Strongly disagree… 5) strongly agree.
Beliefs, attitudes and behavior	**Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.**
1. Believes that health is a fundamental component of quality of life.	**Question 1.1** Health is a fundamental component of quality of life. 1) Strongly disagree… 5) strongly agree. **Question 1.2** Healthy behaviors will promote a better quality of life. 1) Strongly disagree… 5) strongly agree. **Question 1.3** I am physically and financially capable of adopting a healthy lifestyle (e.g.: avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) that contribute to the quality of life. 1) Extremely unlikely... 5) Extremely likely. **Question 1.4** My family and friends think that I should adopt healthy behaviors that contribute to the quality of life. 1) Extremely unlikely... 5) Extremely likely.
2. Believes that vaccinations influence the incidence of health risks	**Question 2.1** Vaccinations influence the incidence of Infectious diseases (e.g., 1) Strongly disagree… 5) strongly agree. **Question 2.2** Pets' vaccinations influence the incidence of infectious diseases.1) Strongly disagree… 5) strongly agree. **Question 2.3.** Vaccinations have been one of the most effective methods to prevent disease and have helped to lower mortality associated with infectious diseases worldwide. 1) Strongly disagree… 5) strongly agree. **Question 2.4.** If enough of a population is vaccinated, unvaccinated individuals are less likely to come into contact with the disease due to its decreased prevalence. 1) Strongly disagree… 5) strongly agree.

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3. Believes that is important to prevent infectious diseases than treat diseases once you have caught.	**Question 3.1** Prevent infectious diseases than treat diseases once you have caught will reduce my risk of health threats and dying prematurely from it. 1) Strongly disagree… 5) strongly agree.
4. Believes that learning about the history of vaccines and about how vaccines work associated with the spread of infectious diseases can lead to positive outcomes at the community level.	**Question 4.1** To learn about the history of vaccines and the how vaccines work that lead to the spread of disease will lead to positive outcomes at my community. 1) Strongly disagree… 5) strongly agree. **Question 4.2** My community thinks that learning more about vaccination will bring positive outcomes 1) Extremely unlikely... 5) Extremely likely.
5. Attitude towards healthy lifestyle	**Question 5.1** For me to adopt healthy behaviors is harmful: _____: _____: _____: _____: _____: beneficial pleasant: _____: _____: _____: _____: _____: unpleasant good: _____: _____: _____: _____: _____: bad worthless: _____: _____: _____: _____: _____: valuable enjoyable: _____: _____: _____: _____: _____: unenjoyable

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3. Specifications for an educational scenario on the topic "Looking after myself and others - Substance Tobacco"

Main partner responsible
University of Cyprus, Nicosia, Cyprus

Element of the scenario

Subject: Biology

Grade: 9th grade (+/- 14-15 years old students)

Estimated duration: 10 lessons X 40 min

Classroom organization: Students work on groups of 3-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).

PAFSE Topic: This Educational Scenario is an integrated learning unit in Public Health Education related to the topic: *Looking after myself and others. Substance: Tobacco*

Overview

Currently tobacco products are estimated to be responsible for 3 million deaths annually worldwide, or about 6% of all deaths. But by the early 2030s, it is expected to cause 10.9% of all deaths in developing countries and 17.7% of those in developed countries, more than any single disease. The statistics of tobacco-related mortality worldwide are devastating. Tobacco is a known or probable cause of about 25 diseases; hence its impact on global disease is tremendous, if not yet fully appreciated (WHO, 2016).

The main goal of this unit is to promote students' understanding on the structure and function of the human respiratory system, the health effects of tobacco smoking, the biological, social, cultural and economic dimensions of smoking, as well as challenges of stopping smoking. Understanding human respiratory system's function is critical to keeping human body healthy and responsive to situations and medical problems that could be encountered. Another goal of this unit is to promote students' epistemological understanding, high-order thinking skills and communication and collaboration skills.

A socioscientific topic related to biological, social, cultural, and economic dimensions of tobacco smoking provides the scenario for the inquiry-based primary questions of this unit related to the learning topic: *Looking after myself and others: Tobacco*.

Socioscientific topic: Biological, social cultural and economic dimensions of tobacco smoking

According to different researchers, tobacco smoking has been implicated as the cause of cancer of the lung, oral cavity, larynx, oesophagus, bladder, kidney, and pancreas. The risk of developing cancer is greater for people who smoke more and who start smoking at a younger age. Yet, exposure to passive tobacco smoke is very likely a significant cause of cancer in non-smokers. It has been estimated that thousands of people die each year due to exposure to passive tobacco smoke.

Additionally, nicotine in tobacco has been identified as very addicting, and nicotine addiction is the fundamental reason that individuals persist in using tobacco products. Many people begin smoking as teenagers, and once started, have a very difficult time quitting. In addition to this, documents have come to light that indicate that some tobacco companies have used a variety of methods to increase the amount and potency of nicotine in cigarette tobacco.

Unfortunately, young people do not give up smoking even when knowing the biological hazards.

Primary research questions

- ✓ *What are the biological, social, cultural and economic dimensions of tobacco smoking?*
- ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

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To answer the primary research questions of this unit, students are asked to formulate hypotheses, to collect data from a variety of inquiry-based sources (e.g. such as texts, articles, pictures and videos, tables and diagrams, simulations and scientific measurements), analyse, make inferences, synthesize and draw conclusions.

Additionally, students organising and holding a forum for a discussion about the biological, social, cultural and economic dimensions of smoking, as well as challenges of non-smoking, and distributing public health brochures promoting non-smoking, will act as knowledgeable social agents through citizenship education.

Glossary: didactical glossary (or content glossary) and pedagogical glossary

1. Didactical glossary (or content glossary)

Aerobic respiration: It is a process of cellular respiration which takes place in the presence of oxygen.

Anaerobic respiration: It is a process of cellular respiration which takes place in the absence of oxygen.

Alveoli: Very small air sacs that are the final place air goes when breathed in. Blood passes through capillaries that are embedded in the alveoli walls, taking up oxygen from the air and giving off carbon dioxide.

Bronchial tube: When the windpipe (trachea) reaches the lungs it splits into two main tubes, one to each lung. The tubes divide again into each lobe of the lung, and then continue to divide even further.

Bronchiole: The smallest subdivision in the bronchial tubes. At the end of the bronchioles are air sacs, called alveoli.

Cilia: Very small hairs that line the bronchial tubes. Their wave-like motion carries mucus up and out into the throat. The mucus catches and holds much of the dust, germs and other unwanted particulate materials that find their way into the lungs and releases them from the body by coughing and sneezing.

Diaphragm: A strong wall of muscle that, when moved downward, creates suction in the chest that draws in air and expands the lungs. The diaphragm separates the chest cavity from the abdominal cavity. It contracts and flattens when someone inhales. This creates a vacuum effect that pulls air into the lungs. When someone exhales, the diaphragm relaxes, and the air is pushed out of lungs.

Epiglottis: A tissue flap at the entrance to the windpipe (trachea) that closes during swallowing, preventing food or drink (destined for the oesophagus and stomach) from entering the lower respiratory tract.

Oesophagus: The vessel that leads from the mouth and throat to the stomach.

Health is a state of complete physical, social, and mental well-being, and not merely the absence of disease or infirmity

Health behaviour is any activity undertaken by an individual for the purpose of promoting, protecting, maintaining or regaining health, whether or not such behaviour is objectively effective towards that end.

Health education is any combination of learning experiences designed to help individuals and communities improve their health by increasing knowledge, influencing motivation, and improving health literacy.

Health for All is the attainment by all the people of the world of a level of health that will permit them to lead a socially and economically productive life regardless of who they are or where they live.

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Health outcomes is a change in the health status of an individual, group or population that is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status.

Health policy refers to decisions, plans, and actions that are undertaken to achieve specific health care goals within a society.

Health promoting schools can be characterised as a school constantly strengthening its capacity as a healthy setting for living, learning, and working.

Healthy life expectancy is a population-based measure of the proportion of expected life span estimated to be healthful and fulfilling, or free of illness, disease, and disability according to social norms and perceptions and professional standards.

Health status is the state of health of a person or population assessed with reference to morbidity, impairments, anthropological measurements, mortality, and indicators of functional status and quality of life.

Larynx: Part of human respiratory system. It's a hollow tube that lets air pass from pharynx to trachea on the way to lungs. It also contains vocal cords and is essential to human speech, so it's often called the voice box.

Mouth: The secondary entrance of air into the respiratory system**.**

Nose: The primary and preferred entrance of outside air into the respiratory system. The walls of the nasal cavity are covered with hair, or cilia. The cilia trap dust and harmful particles to purify the inhaled air. Nose hair moisturizes and warms the air to the approximate temperature and moisture within the lungs.

Pharynx: The passage that collects outside air from the nose and mouth and moves it down toward the windpipe (trachea).

Rib: A bone that both supports and protects the chest cavity and lungs.

Trachea: A long tube that connects larynx to bronchi. Bronchi send air to lungs. Trachea is a key part of respiratory system. The trachea is made of rings of cartilage. It is lined with cells that produce mucus.

2. Pedagogical glossary

a. Brainstorming

Brainstorming is an instructional technique with several variations that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

b. Socio-scientific Inquiry-Based Teaching and Learning Approach

Socio-scientific inquiry-based teaching and learning approach is a pedagogical approach which connects science and society in the classroom through the use of socio-scientific issues. Socio-scientific issues (SSIs) are complex and contentious societal issues with substantive connections to science ideas and principles.

Socio-scientific inquiry-based teaching and learning approach has three main stages:

i. Use of SSI for raising inquiry-based authentic questions.
ii. For exploring these questions, social and scientific inquiry is used (e.g., planning, searching and evaluating information - using a variety of evidence sources, such as research, expert knowledge, practice experience and data to capture the complexity of a problem-, analysing,

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negotiating the social and scientific dimensions of the SSI, making inferences, synthesising and drawing conclusions).

iii. Students are stimulated to draw conclusions, make decisions, construct arguments, and formulate solutions related to the SSI - questions.

The main inquiry phases and sub-phases are described below (Pedaste et al., 2015)

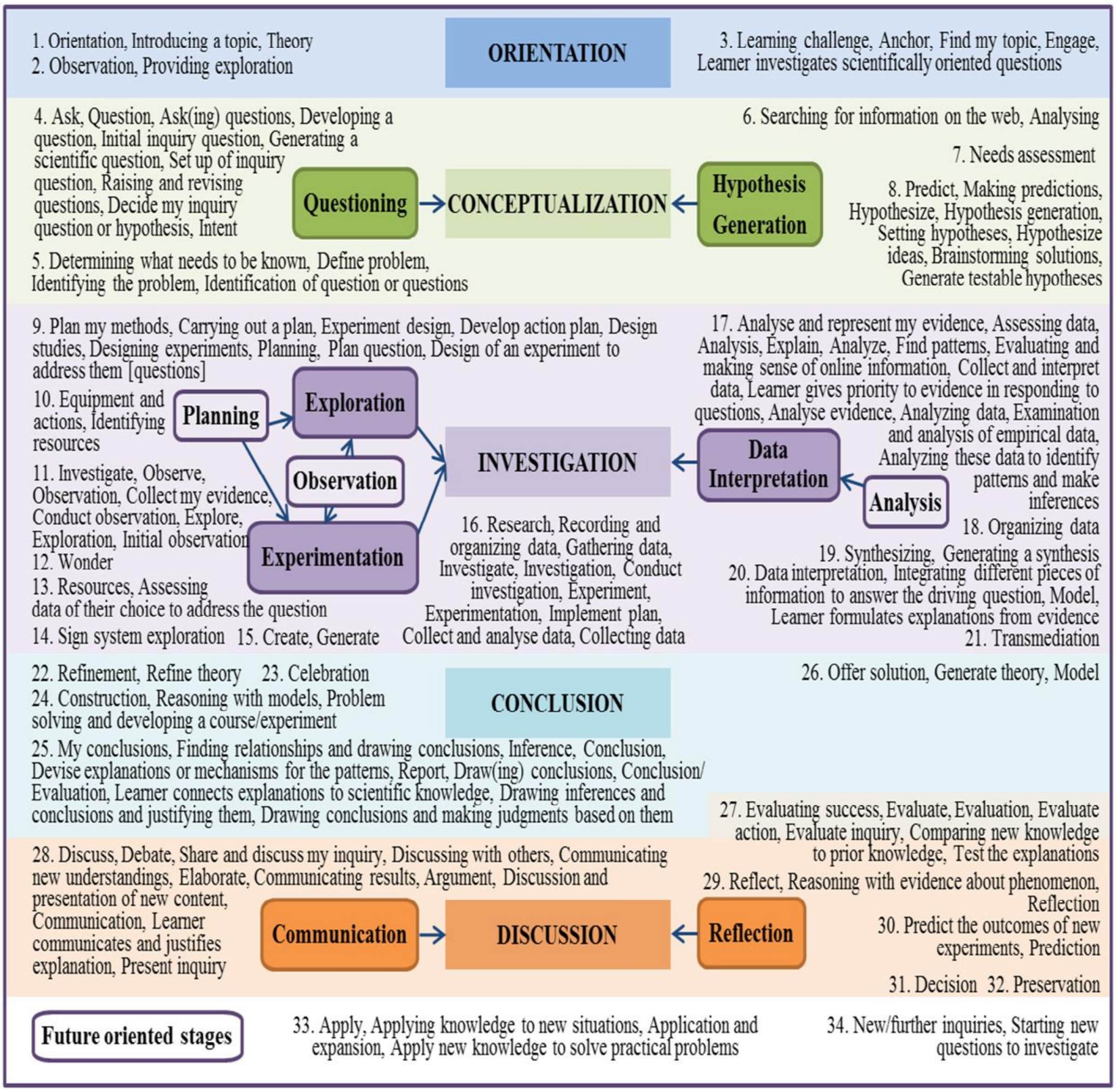

Fig. 1. The main inquiry phases sub-phases are described below (Pedaste et al., 2015).

c. Collaborative learning

Collaborative learning is a pedagogical method, using group (3-5 students) teaching -learning activities (except those activities which require an individual reflection on one's own learning or those that require whole-class discussions).

The role of the teacher is to guide students, stating explicitly the aims of each task or reformulating and adapting new key questions to help them to find their own learning path. This teacher's role as a facilitator is necessary to promote a gradual development of students learning autonomy when questioning, thinking, planning, reflecting, interacting, discussing, and gradually developing conceptual frameworks through the active participation in tasks.

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d. Modelling-based Learning approach

Modelling-based Learning approach is an approach for teaching and learning in science whereby learning takes place via student construction of models as representations of physical phenomena that include representations of physical objects and their characteristics, physical entities and physical processes involved in the physical phenomena. This leads to an externalized representation of the underlying mechanism of a physical phenomenon and helps students build an understanding of that mechanism.

Particularly, models help us to visualize a system and specify its structure or behaviour. Moreover, the modelling process usually simplifies a phenomenon thereby revealing its more fundamental concepts and downgrading any secondary information that is not directly relevant to those aspects of the system that are of interest for investigation purposes. Models have a representative, interpretive and predictive power.

e. Learning Science by Using Infographic

An infographic (information graphic) is a kind of multimodal representation of facts and information. It usually forms a broad graphic composition combining short texts, numerical data, graphs, diagrams, sketches, colors, and shapes. The aim of the infographic is to present a big load of information on a topic in a visual way, making it comprehensible immediately.

f. Open Schooling

Open Schooling is an educational perspective in which schools become open to society by bidirectional collaborating with different institutions with the aim to:

vii. Improve community well-being by raising awareness and co-creating solutions to both personal and socially relevant problems that have a direct impact at a local level.
viii. Enrich the curricula and pedagogical repertoire of schools, by sharing different views and expertise from both educational and non-educational agents and institutions with the aim to promote students' meaningful learning and competence development.
ix. Give epistemic authority to all agents from within and outside the school, specifically to the students and their families, by engaging them in sustained inquiry, knowledge creation, creative action, and dissemination on issues of relevance to the local community and beyond.

To do so, projects and initiatives on Open Schooling take advantage of the knowledge, practices, visions, attitudes, resources, and values of all involved agents, empowering them to collectively transform society from a reflective and critical standpoint that focuses on sustainability, equity, social justice, and inclusion.

Open Schooling emerges as a new term first in the report Science Education for Responsible Citizenship and in EU's Work Programme 2016-2017 and continues to be a priority in the Work Programme 2018-2020. However, despite the term not being explicitly there, we can identify the Open Schooling idea already in the Work Programme 2014-2015.

The EU WPs from 2016 to 2020 followed up on the report Science Education for Responsible Citizenship to explicitly promote the concept of Open Schooling in their strategy of science with and for Society, which revolves around the concept of Responsible Research and Innovation (RRI) and its pillar on Science Education.

g. Critical Health Literacy

Critical health literacy is an important dimension of health literacy beyond fundamental literacy and comprehension skills in health contexts. It includes quite useful notions and skills for a health literate citizen in modern society. Critical health literacy mainly consists of the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular the

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notion of social determinants of health), and the participation in civic collective actions for the promotion of health.

h. One Health Approach

The One Health approach is a transdisciplinary approach that considers human health under a broad context highlighting the direct interconnections with animal health and the environment. Zoonosis, vector-transmitted diseases, and antibiotic-resistant bacteria strains are common issues of the One Health approach.

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STEM Content

1. Fundamental concepts of biological sciences (e.g. human respiratory system, aerobic respiration and anaerobic respiration, cellular respiration, etc.).

2. Promotion of the interconnection among science, technology, society and environment (STSE).

3. Promotion of critical STEM literacy, critical health literacy and critical scientific literacy aspects in STEM instruction with a view to promoting active citizenship.

4. Highlight of the role of science for the establishment of public health.

5. Conduction of authentic socio-scientific research by students.

6. Research data collection, analyse, make inferences, synthesize and draw conclusions.
and appropriate research project presentation by students.
7. Construction, use and nature of scientific models.

8. Promoting understanding of nature of science and epistemological beliefs.

General Learning Objectives

Knowledge (Core Concepts)

1. Transdisciplinary concepts: (Critical) health literacy, STSE (Science, Technology, Society, Environment) interconnections, One Health approach, socio-scientific research.

2. Specific content concepts: human respiratory system, aerobic respiration and anaerobic respiration, cellular respiration, gas exchange process in lungs, lung diseases, cigarettes' chemicals, biological, social, cultural and economic dimensions of tobacco smoking, etc.

Skills

1. General skills: Critical thinking, reflective thinking, critical reading, informal and formal reasoning, collaboration and communication within small groups, presentation skills.

2. Specific skills: Critical reading of scientific sources (videos, simulations, scientific models, infographics, informative health texts, academic texts), construction and use of scientific models, argumentation about the social, economic, cultural and environmental dimensions of socio-scientific topics, empirical socioscientific research design, research data collection, conclusions making, presentation of socio-scientific topics, discussion and reflection about socio-scientific topics.

Attitudes (Affective domain)

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1. Attitudes and values: Awareness concerning socioscientific issues related to public health (Looking after myself and others, e.g. tobacco use), their complexity and multidimensionality, the social risks and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders, taking in consideration economic, social, ethical, political cultural, emotional and others factors

2. Behaviours: Citizenship actions for the limitation of tobacco smoking, healthy personal and social behaviour and decision making on controversial socioscientific issues (e.g. tabacco use), which are defined as open-ended, debatable, complex or ill-structured problems that require the consideration of social, ethical, economic, scientific, and environmental perspectives, considering a variety of perspectives having an orientation towards socioscientific humanistic values.

Title of whole module and titles of individual lessons

Title of whole module: Human respiratory system and tobacco use

Titles of individual lessons

> Lesson 1 (40 min): Introduction: A social and cultural history of tobacco use and public health
> Lesson 2 (40 min): Structure and Function of the Human Respiratory System
> Lessons 3 & 4 (80 min): Creating a Model: “How do lungs work?”
> Lesson 5 (40 min): Gas exchange and cellular respiration
  > Lessons 6 & 7 (80 min): Investigating the research questions on the topic: Looking after myself and others - Substance Tobacco.

  ✓ *What are the biological, social, cultural and economic dimensions of tobacco smoking?*
  ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

  > Lessons 8 & 9 (80 min): Design and present a poster on the topic *Biological, social, cultural and economic dimensions of tobacco smoking,* as well as a presentation concerning *the main reasons 9th grade students in our school give for tobacco smoking*
  > Lesson 10 (40 min): Conducting a public forum (students, teachers, parents, social partners of the local community) on the topic: *Looking after myself and others - Substance Tobacco*

<u>Learning goals and objectives per lesson</u>

Lesson 1 (40 min)

1. Awaken interest into the subject

2. Identifying students' preconceptions, alternative ideas (misconceptions) on biological, social, cultural and economic impact of tobacco smoking. Mapping the preconceptions of students

3. Introducing and discussing a socioscientific issue: Biological, *social, cultural, and economic dimensions of tobacco smoking*

4. Improving students' epistemological understanding.

Lesson 2 (40 min)

At the end of lesson 2 students should be able to…

1. explain what is breathing.

2. explain how we breathe.

3. identify the human body’s parts involved in breathing

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4. complete a diagram of the parts of the human respiratory system

5. improve critical thinking

6. improve communication and collaboration skills

Lessons 3 & 4 (80 min):

At the end of lessons 3 & 4 students should be able to…

1. create a Model: "How do lungs work?"

2. evaluate the representative, interpretive and predictive power of a model of the lungs

3. understand how the lungs and diaphragm work, how air pollution affects lungs and respiratory functions, and some widespread respiratory problems

4. explain the gas exchange process that occurs in the lungs

5. improve critical thinking

6. improve communication and collaboration skills

Lesson 5 (40 min)

At the end of lesson 5 students should be able to…

1. explain what respiration is

2. explain the difference between breathing and respiration

3. explain the difference between aerobic respiration and anaerobic respiration

4. explain the mechanism of breathing

5. explain the mechanism of cellular respiration

6. improve critical thinking

7. improve communication and collaboration skills

Lessons 6 & 7 (80 min)

At the end of lessons 6 & 7 students should be able to…

1. improve inquiry-based investigation skills (e.g. planning, searching and evaluating information, analysing, making inferences, synthesising and drawing conclusions, constructing arguments, etc.) in order to answer the research questions of a socioscientific topic: *Biological, social, cultural and economic dimensions of tobacco tobacco smoking:*

- ✓ *What are the biological, social, cultural, and economic dimensions of tobacco smoking?*
- ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

2. develop digital skills (e.g., finding, reviewing, organising, and sharing information effectively, handling data appropriately, using different online resources and tools to study)

3. investigate chemicals in tobacco that can be harmful to human health

4. investigate health risks of tobacco use

5. read and interpret images related to common diseases of the human respiratory system

6. explain the effects of tobacco smoking on the respiratory system

7. understand the multiplicity of factors leading to tobacco smoking

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8. investigate individual and social responsibilities for tobacco smoking

9. investigate reasons 9th grade students give for tobacco smoking

10. improve critical thinking and communication and collaboration skills

11. acquire the ability to analyse a public health issue and potential solutions from the perspectives of different stakeholders

12. acquire the ability to identify potential sources of bias that may influence information or the presentation of information about a socioscientific issue related to public health or potential solutions

13. acquire the ability to determine how scientific knowledge and processes may contribute to the resolution of a socioscientific issue related to public health and to recognize dimensions of the issue that cannot be addressed by science

14. acquire the ability to recognize the possibilities and limitations of science

Lessons 8 & 9 (80 min)

At the end of lessons 8 and 9 students should be able to…

1. design and present a poster with the research questions of this unit, the methodology, the results and the conclusions of the investigation related to the socioscientific issue: *Biological, social, cultural and economic dimensions of tobacco smoking*

   - ✓ *What are the biological, social, cultural, and economic dimensions of tobacco smoking?*
   - ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

2. organise a forum (students, teachers, parents, social partners of the local community) on the topic: *Biological, social, cultural, and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products*.

3. create a public health brochure promoting non-smoking

4. improve communication and collaboration skills.

Lesson 10 (40 min)

At the end of lesson 10 students should be able to…

1. holding a forum (students, teachers, parents, social partners of the local community) on the topic: *Biological, social, cultural, and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products*.

2. inform the public about each of the research questions they have addressed in the previous lessons and answer questions:

- ✓ *What are the biological, social, cultural and economic dimensions of tobacco smoking?*
- ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

3. distribute public health brochures promoting non-smoking

4. improve communication skills.

5. develop responsible citizenship and critical health literacy.

6. promote citizenship education.

Summative assessment (Scientific knowledge on respiratory system. Thinking skills and evidence-based reasoning).

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Didactical methods and activities

(Note: For more details, please see the attached teaching and learning activities)

Course of the Lesson 1:

The lesson starts with a multimedia-show related to the history of tobacco use. After the presentation, discussion can be encouraged with asking: e.g. what is the history of tobacco smoking? Who started smoking tobacco? How does culture affect smoking? Why was tobacco smoking so popular in the past? What can tobacco smoking cause? What are health and social impact of tobacco smoking?

After short discussion, the teacher can introduce the socioscientific issue entitled *Biological, social, cultural, and economic dimensions of tobacco smoking*, and explain that is a societal issue with connections to science. Using the example of the socioscientific issue related to tobacco, the teacher can discuss the complexity and multidimensionality of socioscientific issues, the social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders. In addition, it can be discussed that many health issues can be considered socioscientific issues because are open-ended, ill-structured problems and subject to multiple perspectives and solutions.

Course of the Lesson 2

1. The lesson starts with a video related to human respiratory system anatomy. Then, the teacher asks students: e.g., what is breathing? Why breathing is essential for life? Then students are asked to complete a labelled diagram related to human respiratory system anatomy, and, with the help of the labelled diagram, explain the structure and function of human respiratory system, using **Worksheet 1** (Matching activity).

Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students finish activities of worksheet 1, the teacher gives feedback to the plenary of the class (whole class)

Course of the Lessons 3& 4

1. The lesson starts with a presentation of some models for teaching and learning biological structures and phenomena. After short discussion related to models' nature and the importance of modelling for learning biology, the teacher explains that students will construct a simple model of the human lungs and use this model to identify the structure and function of the lungs and make predictions.

Then, the teacher presents a video concerning how lungs work and asks students to place their hands on both sides of their rib cage. After taking several deep breaths, he asks them to describe what they felt as they breathed in and out. (They should feel their rib cage move up and expand while they breathe in, and move down and return to its original size when they breathe out) Then, the teacher asks: Can you explain what the lungs look like? How big are the lungs? Where are the lungs located? When you took several deep breaths the lungs got larger and then smaller, can you explain why? Teacher does not correct students' responses at this point in the lesson - after students manipulate the model and class discussion follows, he/she will have an opportunity for this discussion and conceptual change.

After this discussion, students are provided with appropriate model protocol **(worksheet 2)** in order to construct a model "How do lungs work?" The teacher displays a diagram/model of the lungs and provides each working group with appropriate materials. Each group will construct its own model.

Then students are asked *How does the extra "mucus" caused by some respiratory diseases affect how much air can be inhaled? How might dirty air affect your breathing?*

How can you evaluate the predictive power of your model?

After discussion, students are asked to explore the effect this extra mucus has on the lungs, adding one spoonful of water to the balloons inside the bottle and observe what happens. Yet, students are asked to explore the effect of dirty air, putting some sand in the airway of their model Then, students are asked

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to use Worksheet 3 to write their observations and answer the questions: *How does the extra "mucus" caused by some respiratory diseases affect how much air can be inhaled? How might dirty air affect your breathing?*

Students work in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When all students complete activities of worksheet 2, the teacher gives feedback to the plenary of the classroom. Students reflect on what they have learnt and achieved during that teaching period.

At the end of the lesson, teacher informs students that in the next lesson they will explore the socioscientific issue related to tobacco smoking and asks them to look for material on the history of tobacco use, and the effects of tobacco smoking on the respiratory system.

Course of the Lesson 5

The teacher presents a short video related to breathing and respiration and asks: e.g., what is respiration? Why is respiration essential for life? How do breathing and respiration differ? What is cellular respiration? What is the role of mitochondria in cellular respiration? Do all living organisms use oxygen to release energy?

Students are encouraged to discuss the questions and after short discussion the students are asked to start working on **Worksheet 3** (Activities related to breathing and respiration, cellular respiration, energy release, mitochondria, aerobic and anaerobic respiration). Then, students are asked to observe some pictures related to lungs diseases and identify lung diseases caused by smoking. In addition, students are asked to observe microscopic observations of three different samples of three patients and explain what structures of the lungs are affected by smoking. Finally, are asked the following question: Knowing the different chemicals in cigarettes can you predict five (5) health risks of tobacco smoking?

Students work first individually and then in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students complete activities of worksheet 3, the teacher gives feedback to the plenary of the class.

Course of the Lessons 6 & 7

1. The teacher starts the lesson presenting again the SSI topic and the primary research questions of this unit:

Biological, social, cultural and economic dimensions of tobacco smoking

- ✓ *What are the biological, social, cultural and economic dimensions of tobacco smoking?*
- ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

2. Then, teacher moderates a discussion on planning, searching and evaluating information about tobacco smoking, analysing, making inferences, synthesising and drawing conclusions, constructing arguments from evidence in order to answer the primary research questions of a socioscientific topic:

- ✓ *What are the biological, social, cultural and economic dimensions of tobacco smoking?*
- ✓ *What are the main reasons 9th grade students in our school give for tobacco smoking?*

3. To answer the first primary research question *What are the biological, social, cultural and economic dimensions of tobacco smoking?* students are asked to formulate hypotheses, to collect data from a variety of inquiry-based sources (e.g. such as texts, articles, pictures and videos, tables and diagrams, simulations and scientific measurements). For this task students are provided with extra appropriate material.

Then, students are asked to use **Worksheet 4** for organizing and evaluating information, analysing, making inferences, synthesising, and drawing conclusions in order to answer the research question *What are the biological, social, cultural and economic dimensions of tobacco smoking?*

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During this process, teacher consistently encourages students to consider the source and author of the information, the purpose of the publication, potential biases of the author or publisher, evidentiary support for the information, and possible missing information. In addition, teacher draws students' attention to multiplicity of factors leading to use or not use of tobacco smoking, like medical, ethical, social, economic and political.

Students work in group cooperatively and the teacher moves around the classroom asking reflective and supportive questions, looking at the students' achievements and, when appropriate, gives permission to go forward to the next task.

4. When appropriate, teacher directs discussion towards the second research question of the socio-scientific topic of this unit: *What are the main reasons 9th grade students in our school give for tobacco smoking?* Then, after discussion for data collection for this research question, students are asked to create a questionnaire on Google Forms. They discuss how to create a survey using Google Forms and how to collect and analyse the data.

After this discussion and feedback, students are provided with appropriate guidance in order to create a questionnaire using Google Forms and collect data as homework. Additionally, students are provided with appropriate guidance in order to design a poster as homework. The title of the poster: *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products*.

Teacher will evaluate the students' posters and give feedback in the next lesson.

<u>Course of the Lessons 8 & 9</u>

1. The teacher starts the lesson with evaluation and feedback on students' posters entitled: *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products*.

Research questions:

- ✓ What are the biological, social, cultural and economic dimensions of tobacco smoking?
- ✓ What are the main reasons 9th grade students in our school give for tobacco smoking?

Then, each students' group will present its poster to the plenary and respond questions. Each group has 3 min for presentation and 2 min for answering questions.

2. When appropriate, teacher directs discussion towards designing, organizing and holding a forum (students, teachers, parents): *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products*.

Teacher and students discuss: *How do we plan, organize, hold, moderate and facilitate more effective forums? How do we create public health brochure promoting non-smoking? What is our vision? What do we expect to accomplish at this forum?*

After a short discussion, students are asked to...

- ✓ Prepare the agenda for the forum (students, teachers, parents, social partners of the local community) on the topic: *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products.*
- ✓ Create a public health brochure promoting non-smoking

<u>Course of the Lesson 10</u>

Holding a forum (students, teachers, parents, social partners of the local community) on the topic: *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products.*

Students distribute public health brochures promoting non-smoking

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Evaluative tasks

(Note: For more details concerning initial and formative assessment, please see the attached teaching and learning activities. For final assessment, please see educational scenarios impact assessment)

1. Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment)

2. Worksheets evaluation (Formative assessment)

3. Construction of a model: "*How do lungs work?*"

4. Creation and Presentation of a poster on the topic *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products.*

5. Creation of public health brochures promoting non-smoking

6. Holding a forum on the topic: *Biological, social, cultural and economic dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products.*

7. Post-test (Final/ summative assessment)

Learning objects per lesson

(Note: For more details, please see the attached teaching and learning activities)

Lesson 1

Supplementary Educational Resources (SERs)
1. Multimedia-show related to the history of the tobacco use
2. Text related to the history of tobacco use
3. Worksheet

Lesson 2

Digital Learning Objects (DLOs)
1. Interactive labelled diagram related to human respiratory system anatomy
2. Interactive table related to the percentages of gases in inhaled and exhaled air.
3. Interactive matching activity related to the structure and function of the human respiratory system.

Supplementary Educational Resources (SERs)
1. Short educational video related to human respiratory system anatomy
https://youtu.be/cL0mP3IfmHE
2. Images explaining how the nose warms and humidifies the air that is breathed in.
3. Images explaining the role of epiglottis in breathing and swallowing
4. Labelled diagram related to the structure of trachea
5. Labelled diagram related to the structure of lungs
6. Worksheet

Lessons 3 & 4

Digital Learning Objects (DLOs)
1. Interactive table related to differences between Inhalation and Exhalation
2. Interactive matching activity related to the parts of model entitled "How do lungs work? "and the parts of human respiratory system

Supplementary Educational Resources (SERs)
1. Short educational video: How do lungs work?
https://youtu.be/8NUxvJS-_0k

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2. Presentation of 3D Model entitled "How do lungs work?"
3. Pictures related to Breathing (Inspiration and Expiration)
4. Worksheets

Lesson 5

Supplementary Educational Resources (SERs)
1. Short educational video related to Breathing and Respiration
https://youtu.be/r-l0O8K1BFQ
2. Images related to gas exchange
3. Images related to lung diseases
4. Images related to Bronchial Mucosa of a smokers
5. Short educational video related to Aerobic and Anaerobic Respiration
https://youtu.be/WsqP1O7388g
6. Worksheet

Lessons 6 & 7

Supplementary Educational Resources (SERs)
1. Educational video: The effects of tobacco smoking on the human respiratory system.
https://youtu.be/XYLi9zCghd8
2. Text with statements related to the biological, social, cultural and economic dimensions of tobacco smoking
3. Text with information focusing on World Health Organization (WHO) and Eurostat reports on smoking.
4. Information related to qualities & some characteristics of a good questionnaire
5. Information to create Questionnaire using Google Forms
6. Worksheets

Lessons 8 & 9

Supplementary Educational Resources (SERs)
1. Information for creation of scientific poster
2. Information for creation of a public health brochure
3. Worksheet
4. Questionnaire.

Lesson 10
1. Specific information for creation of agenda for a forum
2. Specific information for holding a forum.

Digital educational resources

Links for pictures and text related to human respiratory system and tobacco smoking:
https://archeia.moec.gov.cy/sm/41/viologia_c_gymn.pdf
https://www.cancercouncil.com.au/news/a-brief-history-of-smoking/
https://www.cancer.org/cancer/cancer-causes/tobacco-and-cancer/carcinogens-found-in-tobacco-products.html
https://www.naac.org.cy/el/stoixeia-kapnisma
https://www.moh.gov.cy/moh/mphs/phs.nsf/All/76DEA99CE21DB4CAC2258211003E8D82?OpenDocument
https://www.anticancersociety.org.cy/el/page/non-smokers-league
https://youtu.be/H6DrSG_KQjo
https://youtu.be/cL0mP3IfmHE

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https://youtu.be/8NUxvJS-_0k
https://youtu.be/r-l0O8K1BFQ
https://youtu.be/WsqP1O7388g
https://youtu.be/XYLi9zCghd8

School Research Project

Educational Scenario on the topic: Looking after myself and others - Substance Tobacco"

Topics
- Human respiratory system
- Aerobic respiration and anaerobic respiration, cellular respiration
- Gas exchange process in lungs,
- Lung diseases,
- Cigarettes' chemicals
- Tobacco use and health risks
- Public health
- Critical health literacy
- Responsible citizenship

Research management, design and administration

Research Questions

- What are the biological, social, cultural and economic dimensions of tobacco smoking?
- What are the main reasons 9th grade students in our school give for tobacco smoking?

Methodology/Implementation:

Session 1
Students are organized in groups of 3-5 students:
Preparation of a research plan with the components of a research project: theoretical background, objectives, participants, methodology, results and conclusions, approximate timeline, form of actions
Collection of documents and articles for bibliographical analysis.
Evaluation of the documents based on criteria and selection of the relevant valid information.
Each group shortly presents the results of its investigation for valid sources for bibliographical analysis.
Teacher and students give feedback for improvement of research plan.

Session 2
Students are organized in groups of 3-5 students:
Challenge: Investigating biological, social, cultural and economic dimensions of tobacco smoking
An expert will be invited to discuss with the students and answer their questions related to tobacco smoking in Cyprus and globally. During the discussion with the expert, students will have the opportunity to ask specific questions. Then, students are urged to search information and write a short report concerning biological, social, cultural and economic dimensions of tobacco smoking.
Teacher will evaluate the students' report and give feedback in the next lesson.

Session 3
Students are organized in groups of 3-5 students:
Challenge: Investigating the main reasons 9th grade students in our school give for tobacco smoking.
Designing of a questionnaire (social research tool) to investigate the above research question.

Teacher explains the fundamental principles of question selection and formulation, when designing a questionnaire. Students decide on the questionnaire form and sections, and they are divided in groups equal in number to the questionnaire sections. Each group is responsible for designing one

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questionnaire section. Each groupof students shortly presents their questions and design a final questionnaire. Some students get the responsibility to write the questionnaire in an online form, which allows to be more easily delivered to its targets. Students are urged to collect data about the community's perceptions and knowledge concerning tobacco smoking. Some students of different groups get the responsibility to analyze the answers of the questionnaire.

Session 4

Students are organized in groups of 3-5 students.
Challenge: Presentation of the results of the questionnaire, trying to identify the the main reasons 9th grade students in their school give for tobacco smoking. In the end, build an infographic to summarize the results.
Challenge: Creating a scientific poster in power point, writing Introduction, Methodology, Results, Conclusions and Discussion. Creating a health brochure related to tobacco smoking. The poster will be entitled *Tobacco smoking, and suggestions for tackling the use of tobacco products*. The poster could be printed and be displayed in a prominent place in the school, in local mass media, possibly at some website, and in open schooling event.
Students are provided with appropriate guidance in order to design a poster and health brochure promoting non-smoking as home work. Teacher will evaluate the students' posters and brochure and give feedback in the next lesson.

Development process:

The project is based on guided research about *Tobacco smoking, and suggestions for tackling the use of tobacco products* The four (4) lessons will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.

Teaching-learning process milestones:

Students will be able to:

1. develop digital skills (e.g., finding, reviewing, organising and sharing information effectively, handling data appropriately, using different online resources and tools to study)
2. investigate chemicals in tobacco that can be harmful to human health
3. investigate health risks of tobacco use
4. read and interpret images related to common diseases of the human respiratory system
5. explain the effects of tobacco smoking on the respiratory system
6. understand the multiplicity of factors leading to tobacco smoking
7. investigate individual and social responsibilities for tobacco smoking
8. investigate reasons 9th grade students give for tobacco smoking
9. develop responsible citizenship and critical health literacy
10. acquire the ability to analyse a public health issue and potential solutions from the perspectives of different stakeholders
11. acquire the ability to identify potential sources of bias that may influence information or the presentation of information about a socioscientific issue related to public health or potential solutions
12. acquire the ability to determine how scientific knowledge and processes may contribute to the resolution of a socioscientific issue related to public health and to recognize dimensions of the issue that cannot be addressed by science

Teaching-learning process for school project (summary):

1. Collection of evidence (data, articles, pictures).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Write a scientific report concering the results of a research question.
4. Design a questionnaire
5. Create a poster and present this in open schooling event.

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6. Create a health prochure and distribute it in open schooling event.

Organization of the open schooling event:

2. Each project output (poster and health prochure) is presented by the students in a community setting.
3. Students will communicate their research project outcomes. Students emphasize that health literacy and health promotion is a responsibility of all, not only of the ministry of health or healthcare providers.
4. Additionaly, students explain the importance of critical health literacy, which mainly consists of the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular the notion of social determinants of health), and the importance to recognize the possibilities and limitations of science.

Data Analysis and Reporting

1. Content analysis.
2. Questionnaire results analysis
3. Report writing with most important findings.
4. Development of poster, health prochure and final presentation.

Target Audience for Recommendations

Parents, science teachers, local community – public.

Public Health Authorities and other stakeholders (organisation for family orientation, organisation of doctors and health advisers).

Educational Scenario Impact Assessment

Context: Currently tobacco products are estimated to be responsible for 3 million deaths annually worldwide, or about 6% of all deaths. But by the early 2030s, it is expected to cause 10.9% of all deaths in developing countries and 17.7% of those in developed countries, more than any single disease. The statistics of tobacco-related mortality worldwide are devastating. Tobacco is a known or probable cause of about 25 diseases; hence its impact on global disease is tremendous, if not yet fully appreciated (WHO, 2016).

The main goal of this unit is to promote students' understanding on the structure and function of the human respiratory system, the health effects of tobacco smoking, the biological, social, cultural and economic dimensions of smoking, as well as challenges of stopping smoking. Understanding human respiratory system's function is critical to keeping human body healthy and responsive to situations and medical problems that could be encountered. Another goal of this unit is to promote students' epistemological understanding, high-order thinking skills and communication and collaboration skills.

A socioscientific topic related to biological, social, cultural and economic dimensions of tobacco smoking provides the scenario for the inquiry-based questions of this unit related to the learning topic: Looking after myself and others -Tobacco.

Additional information on specifications of an educational scenario on the topic of *Looking after myself and others –Tobacco*

The questions that follow provide and assessment for the impact of the given learning scenario on the pre-existing knowledge of the students, the skills that they have acquired throughout the teaching of this topic and the effect of this on their beliefs, attitudes, and behaviour.

Knowledge	
1. Understanding structure and function of the human respiratory system.	**Question 1.1** What is the pathway air follows as it passes through your nose to bronchus? A) Pharynx → Larynx → Trachea → Bronchus → Bronchioles → Alveoli.

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	B) Nose → Larynx → Pharynx → Trachea → Bronchus → Bronchioles → Alveoli. C) Nose → Larynx → Pharynx → Trachea → Bronchioles → Bronchus → Alveoli. **Question 1.2** Which is the composition of inhaled air ?A) 78% nitrogen, 21% oxygen, 0.04% carbon dioxide, 0.97% water vapour and other gases , . B) 78% nitrogen, 0.04% oxygen, 21% carbon dioxide, 0.97% water vapour and other gases C) 78% nitrogen, 19% oxygen, 0.04% carbon dioxide, 0.97% water vapour and other gases. **Question 1.3** Which part of a respiratory system is a hollow tube that lets air pass from pharynx to trachea on the way to lungs? A) Larynx B) Bronchioles C) Larynx and Bronchioles. **Question 1.4** What is the name of a tissue flap at the entrance to the windpipe (trachea) that closes during swallowing, preventing food or drink (destined for the esophagus and stomach) from entering the lower respiratory tract? A). Epiglottis. B) Alveolus. C) Epiglottis and alveolus. **Question 1.5** What is the role of diaphragm during Inhalation? A) The diaphragm contracts and flattens and the chest cavity enlarges. B) The diaphragm relaxes and returns to its domelike shape, and air is forced out of the lungs C) The diaphragm contracts and relaxes.
2. Creating a Model: "How do lungs work?"	**Question 2.1** How could you represent the lungs in a model in order to explain how lungs work? Please identify the appropriate material. A) 2 Water balloons B) 2 Plastic water bottle. C) 2 Plastic tubes. **Question 2.2** How would you represent a diaphragm in your model? A) Plastic film B). 1 Water balloon. C) 1 Plastic water bottle. **Question 2.3** Which question would you investigate in order to evaluate the predictive power of a model concerning lungs function? A) How does the size of your lungs affect breathing? B) How would you represent a chest cavity in a model concerning lungs? C) What is inhalation?
3. Understanding gas exchange and cellular respiration.	**Question 3.1** How the lungs are adapted for gas exchange? A) Large surface area because of many alveoli, thin walls of alveoli, Moist walls of alveoli, alveoli are surrounded by a dense capillary network. B) Large surface area, short diffusion distance, C) moist surfaces, capillary network. **Question 3.2** What are the reactants and the end products of cellular respiration? A) Glucose and oxygen are the reactants, and the end products are carbon dioxide and water with the liberation of energy in form of ATP. B) Light energy, carbon dioxide and water are the reactants, and the end products are glucose and oxygen C) Glucose and oxygen are the reactants and the end products are carbon dioxide and water with the liberation of energy in form of light.
4. Identification of (a) the most important health risk factors of tobacco smoking. (b) factors influencing smoking levels among high smoking prevalence groups	**Question 4.1** What are the five important health risk factors of tobacco smoking? A) Lung cancer, heart disease, bronchial asthma, emphysema, and chronic bronchitis. B) Cholera, diphtheria, dysentery, pneumonia, tuberculosis. C) Cholera, diphtheria, lung cancer, heart disease, bronchial asthma. **Question 4.2** What are the factors that increase the risk factors of a person choosing to smoke? A) Parental and peer example, anxiety and depression, stress, nicotine exposure during childhood. B) Unhealthy diet, inactivity, stress, genetics, poverty. C) Genetics, family history of disease, unaffordable prices, access to healthcare.

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5. Understanding health socioscientific issues	**Question 5.1** What are the characteristics of a controversial socioscientific issue? A) Different dimensions on the topic, multiple stakeholder groups with conflicting interests, multiple solutions from the perspectives of different stakeholders. B) Different opinions and viewpoints of the topic C) Different scientific data. **Question 5.2** What is the additive learning value of using socioscientific topics to understand scientific issues? A) Better understanding of the nature of scientific knowledge because students discuss issues related to the potentialities, as well as limitations, of the scientific enterprise and its relationship to technology, society, and the environment. B) Easier to understand scientific concepts. C) Easier homework**.**
SKILLS	
1. Investigating health socioscientific issues	**Question 1.1** Which inquiry phases are necessary for investigating health socioscientific issues? A) Generating research questions based on the stated problem, generating hypotheses regarding the stated problem, searching and evaluating information, analyzing, making inferences, synthesizing and drawing conclusions. B) Experimentation, results, conclusions. C) Exploration, experimentation, data Interpretation.
2. Anticipating the consequences of unhealthy lifestyles and risky behavior.	**Question 2.1** Urbanization, pollution, smoking, alcohol consumption and unhealthy diet and inactivity are risk factors for ischemic heart disease. Considering that factors that elevate disease risk accumulate gradually over the life course, anticipate the most important consequences for the future of having these conditions in your lifestyle. A) Abdominal fat, overweight, obesity, hypertension. B) Anxiety, happiness, overweight, obesity. C) Insulin resistance, weight loss, pain.
3. Adopting a healthy lifestyle.	**Question 3.1** I will try to adopt a healthy lifestyle (avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months. 1) Definitely true... 5) definitively false. **Question 3.2** I am the one who will decide whether to adopt a healthy lifestyle during the next three months. 1) Strongly agree... 5) strongly disagree. **Question 3.3** I feel able to resist peer pressure related to unhealthy lifestyle (smoking, drinking, inactivity, diet full of fat).1) definitely true... 5) definitively false. **Question 3.4** I feel capable of identifying the attributes of healthy lifestyles and act based on it. 1) Definitely true... 5) definitively false. **Question 3.5** If I wanted, I could adopt a healthy lifestyle during the next three months. 1) Definitely true... 5) definitively false. **Question 3.6** For me avoiding smoking, consuming alcohol, inactivity and having a diet full of fat, during the next three months, is: 1) definitely impossible ... 5) definitely possible. **Question 3.7** For me adopting a healthy lifestyle during the next three months, would be. 1) Very insignificant... 5) very important. **Question 3.8** I will be able to find the necessary strategies and resources for adopting a healthy lifestyle in the next three months 1) Probable... 5) improbable.
4. Proposing concrete action towards adopting healthy lifestyles in his/her/others routine.	**Question 4.1** I feel able to identify relevant actions for adopting a healthy lifestyle in my routine. 1) Definitively true… 5) definitively false. **Question 4.2** I feel able to change my routine in order to adopt a healthier lifestyle.
5. Feels able to influence the adoption of healthy lifestyles by others (e.g., family, peers, friends)	**Question 5.1** I feel able to influence the adoption of healthy lifestyles by others (family, friends). 1) Definitely true... 5) definitively false. **Question 5.2** I will try to influence the adoption of healthy lifestyles by others (family, friends). 1) Definitely true... 5) definitively false.

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6. Selecting appropriate sources to investigate health socioscientific issues (e.g., Tobacco smoking).	**Question 6.1** I believe that to find scientific information about a health socioscientific issue, I should consult the following sources. A) Scientists, scientific publications, WHO database, EU database. B) Newspapers, google, YouTube. C) Friends, journalists, Facebook.
Beliefs, attitudes and behavior	**Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.**
1. Believes that health is a fundamental component of quality of life.	**Question 1.1** Health is a fundamental component of quality of life. 1) Strongly disagree… 5) strongly agree. **Question 1.2** Healthy behaviors will promote a better quality of life. 1) Strongly disagree… 5) strongly agree. **Question 1.3** I am physically and financially capable of adopting a healthy lifestyle (e.g.: avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) that contribute to the quality of life. 1) Extremely unlikely... 5) extremely likely. **Question 1.4** My family and friends think that I should adopt healthy behaviors that contribute to the quality of life. 1) Extremely unlikely... 5) extremely likely.
2. Believes that lifestyles influence the incidence of health risks	**Question 2.1** Lifestyles and living environments influence the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. **Question 2.2** Alcohol abuse influences the incidence health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. **Question 2.3** Diet influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. **Question 2.4** Smoking influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. **Question 2.5** Inactivity influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. **Question 2.6** Access to fresh products (fish, vegetables, fruits) influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree. **Question 2.7** Pollution influences the incidence of health risks (e.g.: cancer, cardiovascular diseases, and mental disorders). 1) Strongly disagree… 5) strongly agree.
3. Believes that is important to adopt healthy lifestyles to prevent health threats.	**Question 3.1** Youths should adopt healthy lifestyles to prevent health threats and stay healthy in older ages. 1) Strongly disagree… 5) strongly agree. **Question 3.2** The adoption of a healthy lifestyle will reduce my risk of health threats and dying prematurely from it. 1) Strongly disagree… 5) strongly agree.
4. Reproves patterns of risky and unhealthy behavior in his/her living environment (e.g., sedentary lifestyle, smoking, drugs consumption).	**Question 4.1** The adoption of a healthy lifestyle will ruin my image. 1) Strongly disagree… 5) strongly agree. **Question 4.2** For me the adoption of a healthy lifestyle (e.g.: avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months, would be: 1) Bad... 5) Good. **Question 4.3** For me to adopt a healthy lifestyle, in the next three months, would be: 1) useless... 5) useful. **Question 4.4** I don't accept patterns of risk and unhealthy behavior in my living environments (e.g., sedentary lifestyle, smoking, drugs consumption). 1) Definitely true... 5) definitively false. **Question 4.5** The people in my life whose opinions I value (family, friends) 1) will use ... 5) will not adopt healthy lifestyles in the next three months.

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5. Adopts a healthy lifestyle (e.g., practicing exercise, not smoking, going to the supermarket, and choosing a basket of healthy products).	**Question 5.1** For me following a healthy lifestyle, in the next three months, would be 1) Uncomfortable... 5) Comfortable. **Question 5.2** I will make an effort to adopt a healthy lifestyle (avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months. 1) Strongly disagree… 5) strongly agree. **Question 5.3** I plan to not smoke in the next three months. 1) Strongly disagree… 5) strongly agree. **Question 5.4** I plan to not consume alcohol, drugs and other substance use in the next three months.1) strongly disagree… 5) strongly agree. **Question 5.5** I plan to do physical exercise at least 60 minutes every day in the next three months 1) strongly disagree… 5) strongly agree. **Question 5.6** I plan to follow low-fat diet or Mediterranean Diet in the next three months. 1) Strongly disagree… 5) strongly agree. **Question 5.7** I plan to avoid stress and polluted environments in the next three months. 1) Strongly disagree… 5) strongly agree. **Question 5.8** Among the following statements, choose the one that best describes what you currently think. 1) I do not have a healthy lifestyle, and I also have no intention of doing so. 2) I do not have a healthy lifestyle, but I have been thinking about the possibility of starting to do so. 3) I never or rarely have a healthy lifestyle, but soon I will start doing it on a regular basis. 4) I adopt a healthy lifestyle regularly. 5) For more than six months I have always or almost always followed a healthy lifestyle. 6) For several years now, I have adopted a healthy lifestyle, and I will continue to do so.
6. Attitude towards healthy lifestyle	**Question 6.1** For me to adopt healthy behaviors is harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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4. Specifications for an educational scenario on the topic "History of pandemics: what do we know about powerful viruses and their impact?"

Introduction to the module

This topic will investigate the historical virus-related pandemics, shedding light on the existing knowledge that we have on powerful viruses, and their impact on the aspect of health, society, economy, and governance. Students of the age range 12 – 15 years old (preferably students of 15-years old) will be given the opportunity to expand their knowledge by learning about different classes of virus pathogens, in terms of their size, morphology, ways of invading the human immune system and causing disease, and how these may develop into new variants to re-emerge years after and cause reoccurrence of disease. They will also be presented with a timeline of historically documented pandemics, all related to virus causative agents.
Using differentiated instruction to teach immunological concepts related to infection and disease, to a diverse group of learners, of various ages, provides a comprehensive learning module designed to expose high school students to immunological concepts related to infectious agents that can cause spreading of disease leading to epidemics and possible pandemics, by using active hands-on and minds-on teaching strategies. This module includes:

- Activity 1: a student created collaborative poster
- Activity 2: an Immune-response Action Model
- Activity 3: a simulation of virus antigenic drifting/shifting to clearly demonstrate and assess acquired knowledge on how a future pandemic may arise.
- Activity 4: School Research Project for Educational Scenario: discussion and proposal of possible strategies for dealing with future pandemics, at local community, national and international level, that is presented to the local school community, as well as the wider educational community, promoting open schooling.

Expected student prior knowledge

Students should have a basic Cell Biology knowledge of the characteristics and the Variety of living organisms, including:

- ✓ knowledge and ability to describe the common features shown by eukaryotic organisms (i.e., animals, fungi and protoctists, and prokaryotic organisms such as bacteria),
- ✓ an understanding of the term pathogen and know that pathogens may include fungi, bacteria, protoctists or viruses,
- ✓ an understanding that viruses are not living organisms, but very small particles (smaller than bacteria) that have a parasitic nature since these can multiply only inside the living cells that they infect (including cells of animal, plant, and bacterial origin),
- ✓ knowledge of structures and functions in living organisms, including levels of cell organisation, cell structure, biological molecules (including amino-acids, proteins, enzymes, DNA, RNA),
- ✓ an understanding of the different ways of transport of substances in and out of living cells, with emphasis on receptor-mediated active transport.

Expected outcomes

Learns will have the opportunity to refresh their prior knowledge, but mainly will acquire new knowledge about:

- ✓ the meaning of the term epidemic and pandemic and the difference between the two,
- ✓ the past pandemics of the current and previous centuries,
- ✓ the present and newly emerging viral pathogens,
- ✓ classifying viral pathogens in terms of their size and morphology,
- ✓ understanding how such pathogens emerged in the first place,
- ✓ the different ways that viruses use to evade human defence mechanisms and cause disease,

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- ✓ how existing viruses may develop into new variants to re-emerge years after and cause recurrent epidemics and sometimes pandemics,
- ✓ different remediation approaches that are used or can be used to mitigate the occurrence of future virus-related pandemics.

Learners will also acquire the use of transferable skills such as critical thinking, problem solving, analysis, reasoning, interpretation, adaptive learning, creativity, continuous learning, self-direction, responsibility, perseverance, self- regulation (metacognition, forethought, and reflection), integrity, self- monitoring, self- evaluation, self- reinforcement, and apply all these to their everyday life within their community.

Relation to other topics

This module could complement the teaching of the existing curriculum of general biology of the immune system, and the activities proposed within this learning module are designed to give students opportunities to explore, learn, and peer teach concepts related to more specialized functions of the immune system against invading virus pathogens. The specific assignments are geared toward a general biology course, but the strategies are applicable for higher-level biology classes (A-level, undergraduate students) if the content is scaled up. The order in which these activities should be applied follows a scaffolding approach where students uncover new knowledge at each level and then use it to bridge their understandings to new learning.

Pedagogical methods utilised in the teaching of this module

The goal of this module is to help students build on prior learning and develop further skills and attitudes. Meanwhile, this also expands the current knowledge of the educators, enabling them to present this module in a way that is relevant to the students' needs.

A range of different pedagogical methods are implemented through all the different activities catering for a broad range of different learners. To begin with, the current learning module is based on the pedagogical approach of inquiry-based learning, where students are encouraged to ask questions and complete research while learning various concepts of basic virology and immunology. In this way, individual learners acquire the skills necessary to develop their own ideas, as well as question themselves and group members in a constructive way.

In the initial **poster preparation activity**, students are asked to collaborate with their peers and conduct their own research on the given topic to produce a poster or a power point presentation, on what is known about past centuries virus-related pandemics. During this first activity, student will have to apply and develop their own critical thinking, learning, and writing skills through peer-to-peer interaction and interpersonal engagement.

In the second activity, students are asked to create an **Immune-response Action Model** (IRAM). This activity allows students to actively participate in inquiry-based learning where they work on a simple materials model that simulates the dynamic biological process of immune response mechanisms following virus evasion. This method of learning increases student accountability for their own learning and allows multiple opportunities for the educator to check for understanding. Additionally, the modelling of the immune response against an incoming virus will help students take an abstract concept and make it tangible and more concrete.

The third activity proposed involves problem-based learning, during which students will be asked to simulate virus antigenic drifting and shifting, by simple creative classroom methods (Marintcheva B., 2016), and via and discuss the consequence of this ability of a virus pathogen to re-emerge and cause continuity of disease. The activity is a continuation of the IEAM; students acquire knowledge by devising a solution to a real-world problem. As they do, they acquire knowledge, as well as communication and collaboration skills.

The final activity comes to conclude on the sequence of all previous activities and promotes the application of open schooling, where the educator asks from students to proposed and discuss possible strategies for dealing with future virus pandemics. In this way, the educator wraps up the delivery of

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this module with problem-based learning, where students acquire knowledge by devising a solution to a real-world current problem and as they do so, they acquire knowledge, as well as essential communication and collaboration skills. During this final activity, the students will be requested to demonstrate their individual understanding by preparing their own essay work, presenting their own and acquired knowledge regarding the specific topic taught. The combined work of the students will be presented in the form of an article, where the thoughts and conclusions of the students will be featured and discussed further by their educator. This article shall be made available within the school community (published in school's newsletter) as well as the wider educational community (published in the local educational news website, paideia-news.com) and therefore promoting open schooling.

Background science

Brief review on the history of virus-related pandemics

Along the centuries, novel strains of viruses have been the causative agents of global pandemics (Figure 1, Table 1). Examples such as influenza have resulted in pandemics which increase illness, loss of lives, causing economic, social, and political disruption in affected countries. Figure 1 provides an outline of the most notable pandemics recorded throughout the history of humankind and associated with various types of parasitic pathogens. Those being virus-associated have been indicated in red.

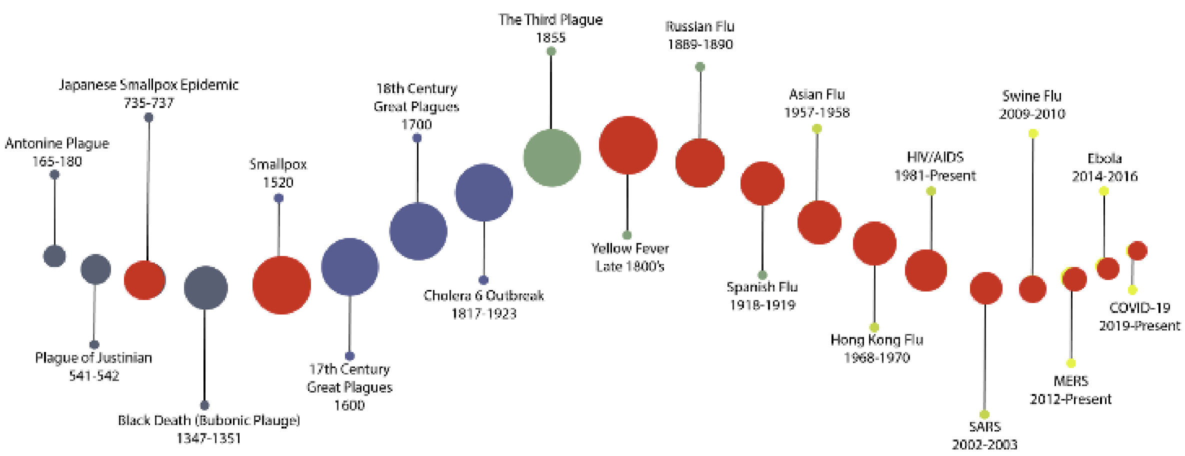

Figure 1: A schematic view of historical pandemics
Indicated in red are pandemics caused by viral pathogens including, smallpox, yellow fever, influenza, human immunodeficiency virus-1, severe acute respiratory syndrome Corona Virus-1 (SARS-CoV-1), Middle East respiratory syndrome virus, Ebola, severe acute respiratory syndrome Corona Virus-2 (SARS-CoV-2), respectively. (A modification of the image produced by Gabrielle Rodriguez, taken from https://trinitonian.com/2020/09/10/a-history-of-sports-and-diseases).

Spanish flu that had originated in Kansas (US) in 1918, also known as the "Great Influenza epidemic" was caused by the avian (bird-related) influenza A-virus, H1N1. The virus had spread rapidly around the globe in four successive infection waves, infecting around 500 million people, and resulting in a highest of 100 million deaths. Similarly, in 1957, the Asian flu was the result of another strain of the influenza A-virus, subtype H2N2, which originated in Guizhou province in the southwest region of China and resulted in an estimated one to four million deaths worldwide. N3H2, a variant arising from influenza H2N2 during the Asian flu pandemic, was the causative agent of the Hong Kong flu pandemic in 1968, which resulted in the deaths of almost four million people, globally. Apparently, N3H2 was a variant of H2N2 that had emerged following an antigenic shift that occurred in the virus during its transmission, a genetic alteration that resulted in a dramatic change in the structure of its protein antigens and its degree of virulence. Interestingly, the swine flu pandemic in 2009 was the outcome of a virus that appeared to be a new strain of H1N1 that had resulted from a previous triple re-assortment

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of bird, swine, and human flu viruses which further combined with a Eurasian pig flu virus, to give rise to a variant that resulted to an estimated total of 284,000 deaths globally.

It seems that zoonotic transmission of pathogens from animals to humans has always acted as a pivotal mechanism by which emerging infections have afflicted humans throughout history. Pandemics of the past have various characteristics in terms of morbidity (suffering from disease) and mortality (death resulting by disease). The recent pandemic caused by a novel corona virus, severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), in 2019, was first identified during an outbreak in the Chinese city of Wuhan, and was very similar to Spanish, Hong Kong, and Asian as well as swine influenza pandemics in terms of spreading globally through person-to-person transmission. Humans have witnessed another two such deadly pandemics so far in the twenty-first century which have been associated with corona viruses and include SARS-Cov-1 and the Middle East respiratory syndrome (MERS), both being of zoonotic origin. It is therefore evident that since the time of the human hunter-gatherer, human populations have been suffering for millions of years from infectious diseases similar or identical to diseases of other wild primate populations, some of which could have emerged only within the past 11,000 years, following the rise of agriculture (Wolfe et al., 2007). The increasing interactions between humans and animals have facilitated the transmission of zoonotic pathogens, and the expanded cities, extended trade territories, increased travels as well as effects on ecosystems due to increased human population raised the emergence and spread of infectious diseases leading to higher risks for outbreaks, epidemics, and pandemics. Interestingly, some scientists point out that major infectious diseases seem to have arisen overwhelmingly in the past in Europe, the Mediterranean, and some in the Middle East (Old World), often from diseases of Old-World domestic animals (Wolfe et al., 2007).

Table 1: History of pandemics linked to viral infection (Modified from, Piret J. and Boivin G., 2021)

Occurring period	Disease	Causative agent (virus)
1520	Smallpox	Variola major
1889 – 1893	Russian flu	Influenza A –H3N8
1918 – 1919	Spanish flu	Influenza A – H1N1
1957 – 1959	Asian flu	Influenza A – H2N2
1968 – 1970	Hong Kong flu	Influenza A – H3N2
1981 – on going	AIDS	Human Immune-deficiency virus (HIV)
2002 – 2003	Severe acute respiratory syndrome (SARS)	SARS-CoV-1
2009 –2010	Swine flu	Influenza A –H1N1
2013 – 2015	Ebola virus disease	Ebola virus
2014 – 2016	Chikungunya	Chikungunya virus
2015 – ongoing	Middle East respiratory syndrome (MERS)	MERS-CoV
2019 – ongoing	COVID-19	SARS-CoV-2

In their review, Wolfe et al., (2007) defined the five stages in the transformation of an animal pathogen into a specialized pathogen, able to infect humans (Figure 2). Stage 1 represents microbes that are present in animals but that have not been detected in humans under natural conditions. Stage 2 represents animal pathogens that, under natural conditions, have been transmitted directly from animals to humans via primary infection, but no secondary human-to-human infection has been reported. Such an example is rabies, caused by Rabies lyssavirus, member of the group of rhabdoviruses. Stage 3 represents pathogens that can undergo only a few cycles of secondary transmission between humans, so that occasional human outbreaks triggered by a primary infection soon die out. An example of such pathogens includes the Ebola virus. Stage 4 can be subdivided into three subsequent parts, including (a) disease that exists in animals, and that has a natural (sylvatic) cycle of infecting humans by primary transmission from the animal host (an example is yellow fever, caused by a Flavivirus), but (b) also

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undergoes long sequences of secondary human-to-humans transmission without the involvement of animal hosts (an example includes dengue fever, caused by Dengue fever virus, a Flavivirus), that in time (c) the greatest spread observed is between humans (example being Influenza A). Finally, stage 5 includes pathogens that are exclusive to humans, such as measles, mumps, rubella, smallpox and syphilis that most likely became confined to humans either as an ancestral pathogen already present in the common ancestor of chimpanzees and humans and co-speciated long ago, when the chimpanzee and human lineages diverged around five million years ago; or could have risen from an animal pathogen that have colonized humans more recently and evolved into a specialized human pathogen.
Most virus pathogens don't seem to make it to stage 5, and this can be explained in terms of the following:

a) increasing phylogenetic distance (using DNA sequences, protein amino acid sequences, and/or morphology) between the existing host and new host,
b) *variability* among pathogens as some viruses can infect a wide range of hosts, while others can only infect a narrow range, and this variation is related to a pathogen's characteristics, such as its ability to generate genetic variability, or to overcome host molecular barriers of potential new hosts (such as humoral and cellular defences or lack of cell membrane receptors essential for the entry of the pathogen into host cells),
c) high abundance and frequent encounters between the existing hosts with humans in dwellings (i.e., rodents being a source of zoonoses transmission to humans),
d) differences between human and animal behaviour affecting transmission (for example, animals often bite humans, but humans rarely bite other humans),
e) need of the pathogen to evolve adaptations to the new human host and possibly also to a new vector,
f) obstacles to a pathogen's spread between human tissues (i.e., bovine spongiform encephalopathy is restricted to the central nervous system and lymphoid tissue),
g) Presence of barriers between Stages 3 and 4 (i.e., Ebola virus) include those related to human population size and to transmission efficiency between humans.

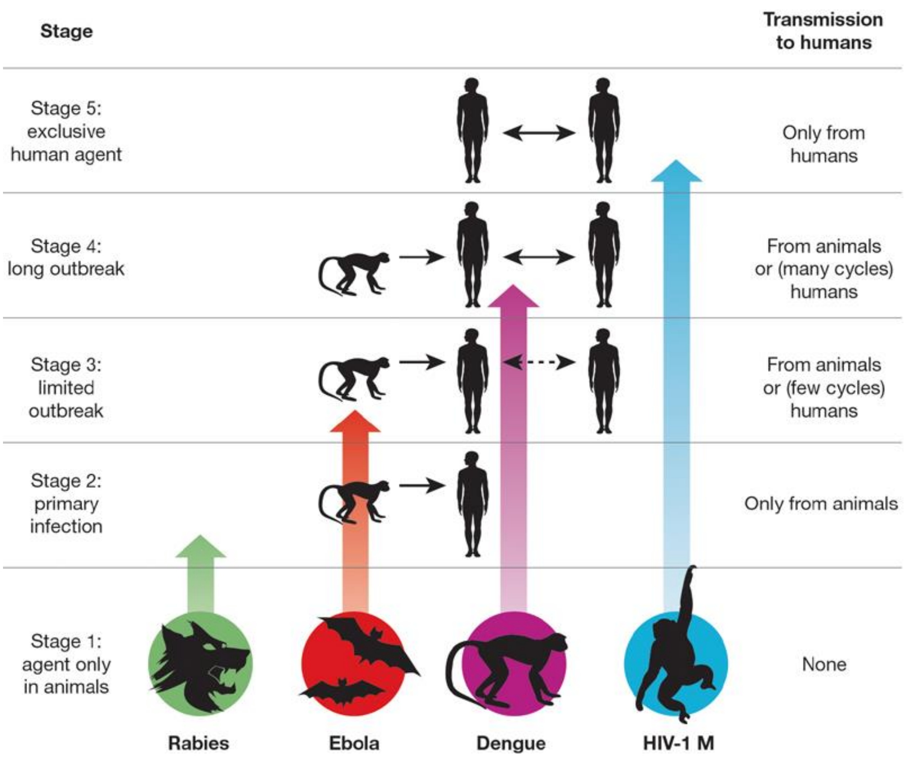

Figure 2: Pathogens of animals evolve to cause diseases confined to humans (Figure taken from Wolfe N. D., Panosian Dunavan C., Diamond J. 2007)

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The emergence of novel pathogenic viruses is now made possible by modern developments exposing more human and/or making human-to-human transmission more efficient than before. Such developments include blood transfusion allowing transmission of hepatitis C, the commercial bush-meat trade allowing animal-to-human secondary infection by retroviruses, industrial food production allowing for the secondary infection with bovine spongiform encephalitis (BSE), international travel allowing human-to-human transmission of influenza and coronavirus strains, intravenous drug use allowing human-to-human transmission of human immunodeficiency virus (HIV), vaccine production using viral vectors such as simian virus-40 (SV40), and susceptible pools of elderly, antibiotic-treated, and immunosuppressed patients.

What are viruses?

A virus is characterized as an obligate intracellular parasite, requiring the use of the host cell's biochemical machinery to replicate and sustain its numbers by creating new infectious virus particles, known as **virions.** Viruses are extremely diverse in terms of their structure and genetic complexity, some having RNA genomes, encoding for only a few genes, whereas others have DNA genomes, encoding for up to 200 genes. Regardless of their diversity, viruses share several common characteristics, such as:

- **their small size** – the smallest virus being just 20 nm in diameter and belonging to the family of "pico-rna-virus", which is a large group of the smallest known animal/human viruses. The prefix "pico" refers to its small size and "rna" refers to its core of ribonucleic acid (RNA). The family of picornaviruses includes enteroviruses, which attack the intestinal tract and often invade the central nervous system, rhinoviruses, which infect the nasal epithelium, and the virus agent of foot-and-mouth disease. Amongst the enteroviruses are polioviruses, echoviruses, and Coxsackie viruses. Echoviruses cause fever with rash and meningitis, whereas Coxsackie viruses cause sore throat or fever with chest or abdominal pains. Looking at larger viruses, influenza, and the human immunodeficiency virus (HIV), these have a more typical size of about 100nm in diameter, compared to the 10–30μm diameter of an average human cell. This is a 100 to 1000 times smaller than the size of cells that they infect (Figure 3).
- **their intracellular parasitic nature** – they enter the host cell via receptor-mediated attachment. Within the host intracellular environment, the virus disassembles and deposits its genetic material that encodes the instructions for the proteins that will spontaneously assemble into the new virions, into the cell nucleus. It will use the cell's energy and machinery to create and assemble new virions piece by piece, completely from scratch that will be then released from the initially infected cell into the extracellular environment to infect adjacent cells.
- **their genetic material being either of deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) nature** – some viruses have **genomes** that can be composed of DNA *or* RNA, but not both, this being either double-stranded (ds) or single stranded (ss). The size of viral genome can vary greatly, with a typical size falling in the range of 7000–20,000 base pairs (bp). Smaller-sized virions naturally can hold less nucleic acid than larger virions, but large viruses do not necessarily have large genomes.

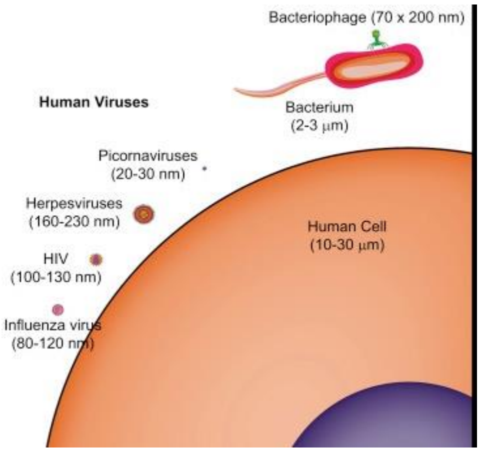

Figure 3: Comparing the size of a virus to its host cell.

Human viruses can vary in size but are generally in the range of 20–200 nm in diameter, in comparison to bacteria that are generally 2–3 μm in length, and average human cells, having a diameter of 10–30 μm. (Figure taken from Louten J., 2016).

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Architecture of viruses

The structure of a typical virus consists of a capsid which is essentially a protective protein coat. The term is derived from Latin term "capsa", meaning box. Usually, the capsid is composed of one or more different types of proteins that are repeated to create the entire capsid structure. This continuous repetitive pattern of proteins to create the entire capsid, results from the fact that most viruses have very small genomes with only a few genes encoding for capsid proteins. These capsid proteins can self-assemble into the capsid structure without requiring additional information. This was first reported in 1955, by Fraenkel-Conrat and Robley Williams, who witnessed the *in-vitro*, automatic and spontaneous reassembly of RNA genome and protein subunits of tobacco mosaic virus, to generate infectious virions. The repeating protein pattern forms a strong, but slightly flexible capsid that is physically very difficult to break open and sufficiently protects the nucleic acid that is packed inside it. Both the virus nucleic acid and capsid compose the nucleocapsid (Figure 4).

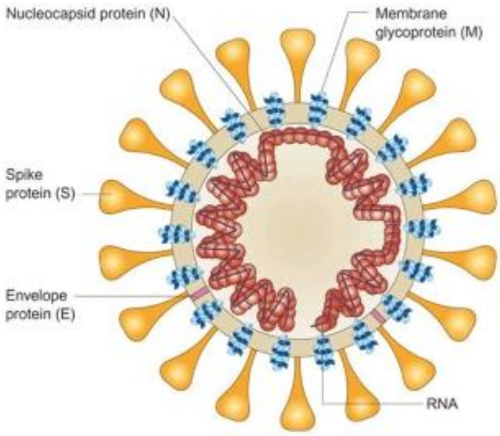

Figure 4: Structure of SARS-CoV-2 virus

Viral capsid proteins protect the fragile genome, composed of nucleic acid, from the harsh environment. In the case of SARS-CoV-2, the capsid and nucleic acid are embedded together to form the nucleocapsid.. (Figure taken from https://www.lubio.ch/).

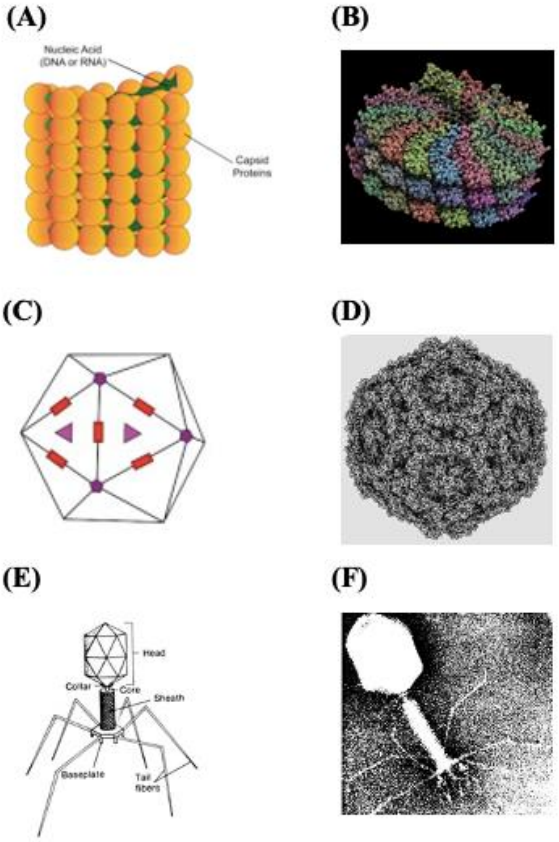

Figure 5: Variability in the structure of the capsid in different viruses.

(A) Viral capsid proteins wind around the nucleic acid, forming a helical nucleocapsid. (B) Helical structure of tobacco mosaic virus. (C) Icosahedron faces (fuchsia triangles), edges (red rectangles), and vertices (violet pentagons) are indicated on the white icosahedron. (D) llustration of human hepatitis B virus, as viewed on the twofold axis of rotation (Louten J., 2016). (E) Model of bacteriophage T4, (F) Electron Micrograph of bacteriophage-T4 (Todar K., www.textbookofbacteriology.net).

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The shape of the capsid varies between different viruses. This can be a simple helical shape as seen in the tobacco mosaic virus (Figure 5A/B) or an icosahedral form (Figure 5C/D), as seen in most viruses, to even more complex structures of some isolated examples of viruses such as the bacteriophage-T4 (Figure 5E/F). The capsid provides protection for the viral genome against the environment and functions in receptor recognition, targeting the virus to a susceptible host and cell type. Some viruses have an additional phospholipid-envelope, derived from the infected host's cell membrane, surrounding the protein capsid. Inserted into the phospholipid-envelope there are usually viral encoded proteins know as spike projections, these being typically glycoproteins usually involved in receptor recognition and viral tropism (Figure 4). A classic example is the neuraminidase and haemagglutinin glycoproteins expressed on the surface of the influenza-A virus. Other, more recent examples include the S (spike), E (envelope) and M (membrane) proteins creating the viral envelope of ARS-CoV-2 virions (Figure 4). The spike protein is responsible for allowing the virus to attach to and fuse with the membrane of a host cell, with the S1 subunit catalysing the attachment, and the S2 subunit allowing fusion with the cell membrane of the target cell.

Classification of viruses

Classification of viruses allows scientists to study the origin of viruses and how they have evolved over time, reporting contrast between viruses, but also revealing newly discovered viruses by allowing comparison to similar, current viruses. There are currently over 2800 different viral species with very different properties that are classified using the Baltimore classification system that categorizes viruses based on the type of nucleic acid genome (RNA or DNA) and replication strategy of the virus. According to the Baltimore classification system, there are seven classification types, referring to single-stranded RNA viruses that possess a positive RNA-strand (+) or a negative RNA-strand (−). A **positive** RNA-strand can be immediately translated into protein (for example, messenger RNA in cells, mRNA), whereas a **negative RNA-strand** cannot be translatable into proteins, as it first needs to be transcribed into a positive RNA-strand. Some viruses possess accessory components such as the enzyme reverse transcriptase, allowing the performance of **reverse transcription**, converting their RNA template into DNA, before inserting this into the host cell's genome.

In summary, the seven classes of viruses include, dsDNA viruses, ssDNA viruses, dsRNA viruses, positive-sense ssRNA viruses, negative-sense ssRNA viruses, RNA viruses that reverse transcribe, DNA viruses that reverse transcribe.

Viruses and host co-evolution

There is a constant competition between a host and a virus pathogen, with the later applying evolutionary pressures to their host, also influencing themselves in return. As an example, the high level of compatibility identified between the phylogenetic trees of mammalian herpes-viruses and their hosts, indicates co-evolution over many millions of years. Similarly, retroviruses have been shown to influence host evolution in more direct ways, through the integration of retroviral pro-viruses into the host's germ-line DNA, leading to permanent residence of the virus genome within the host genome, providing a survival benefit to the host, in situations where such integrated defective pro-viruses may interfere with non-defective, invading viruses.

Base substitution mutations are also a major mechanism of virus evolution, as well as recombination and re-assortment of virus and host genes, which can give rapid rise to viruses with novel properties, just like in the case of influenza viruses, where antigenic shift resulting from re-assortment can give rise to pandemic strains. Evolution of a virus can also occur within an individual host during infection, where potentiators, such as the virus escaping the host's immune response and the use of antiviral drugs, may have important implications for the control of viral diseases of humans (Stern et al., 2016).

Mode of infection

A typical virus infection involves the initial attachment of the virion to the cell membrane of its target. This is mediated by specific receptor intermolecular binding by both the pathogen and its target. This specificity identifies the tropism of a virus for a particular host.

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For example, the HIV enters cells by means of a complex of two non-covalently associated viral glycoproteins, gp120 and gp41 (Figure 6A). These form trimers within the viral envelope. The gp120 subunits of trimeric gp120/gp41 complexes bind with high affinity to the cell-surface molecule CD4, which is expressed on CD4 T-cells, and to a lesser extent on subsets of dendritic cells, macrophages, and monocytes. Before fusion and entry of the virus, gp120 must also bind a co-receptor on the host cell, this being the chemokine receptors CCR5 and CXCR4. While CCR5 is predominantly expressed on subsets of effector memory CD4 T-cells, dendritic cells, and macrophages, CXCR4 is expressed primarily by naive and central memory CD4 T-cells.

Similarly, the virus SARS-CoV-2 infects mainly lymphatic epithelial cells and type II pneumocytes with the initiation of human body's innate response by producing interferons (IFNs), which in turn, activate the expression of the angiotensin-converting enzyme-2 (ACE-2) that acts as receptor for virus attachment to host cells. Interaction between the virus Spike-protein (S) and ACE-2 leads to its cleavage by host proteases into two subunits, a receptor-binding fragment (S1) and a fusion fragment (S2), during biogenesis or virus assembly. The single-stranded RNA in the viral genome is translated by host machinery to produce viral polypeptides, which result in the formation of a replication transcription complex (RTC, see step 5 of Figure 6B), which continuously replicates and produces a series of sub-genomic messenger RNAs that encode the accessory and structural proteins. The viral genomic RNA and proteins are assembled to form the virus particles in the Endoplasmic Reticulum and Golgi Intermediate Compartments (ERGIC). The vesicle-containing virus then fuses with plasma membrane of the host, releasing the viral particles out of the cell (Figure 6B), to infect neighbouring cells and tissues. The details of this process depend on the virus and the metabolic state of the host cell, i.e., picornaviruses require around eight hours producing new virions, whereas the human Cytomegalovirus (hCMV) requires 48 hours.

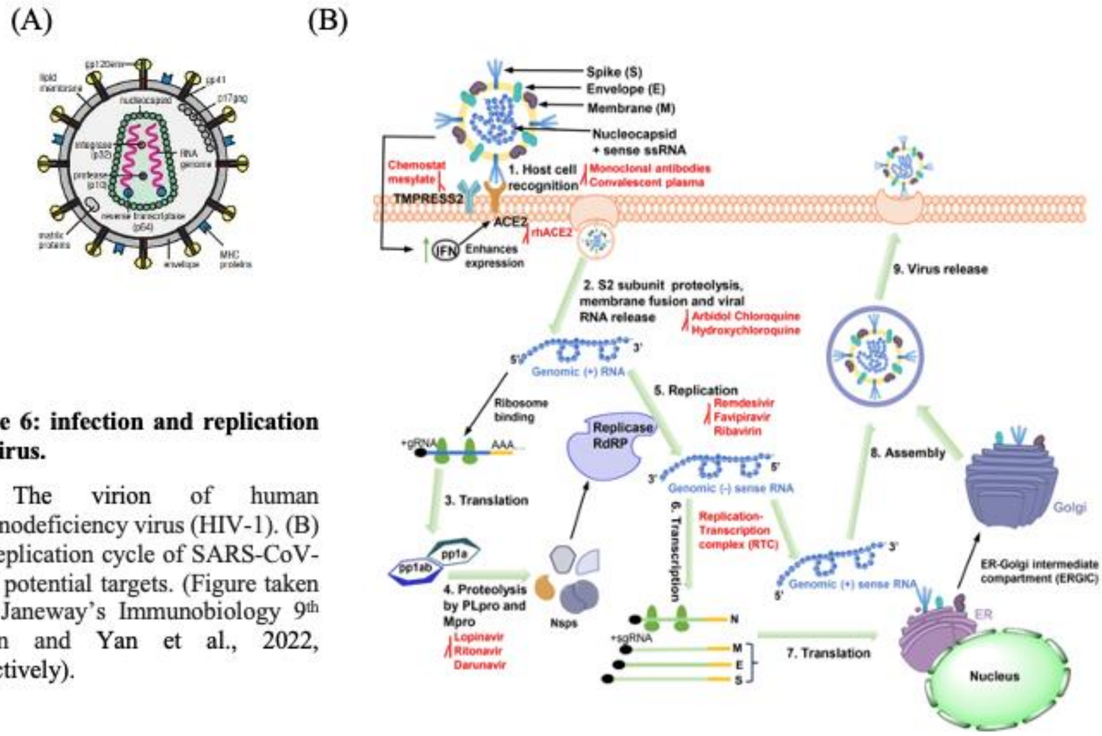

Figure 6: infection and replication of a virus.

(A) The virion of human immunodeficiency virus (HIV-1). (B) The replication cycle of SARS-CoV-2 and potential targets. (Figure taken from Janeway's Immunobiology 9th edition and Yan et al., 2022, respectively).

It should be noted that viruses are extremely divert in their ability to infect and cause disease in a host. Entry usually occurs from mucosal epithelial surfaces, and then into the bloodstream. Replication takes part within epithelial host cells, producing vast numbers of virions released into interstitial tissues and bloodstream, spreading infection, and causing viraemia. Recovery from infection can involve the elimination of the virus by the host's immune system. However, some viruses persist within the host's tissues in a non-infectious (latent) form following acute infection recovery and can be reactivated under

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low immune surveillance to produce new infectious virions. Such an example is the human herpes virus. Other viruses, such as the human hepatitis B virus, can persist in infectious form within the host, despite of the presence of active immunity.

An overview of the human immune defence mechanisms against invading viruses

The defence against incoming viral pathogens involves a four-level barrier (Figure 7). This includes the anatomical barriers of the skin, oral mucosa, respiratory epithelium, and the intestine, with the complementary action of a chemical barrier composed of a group of antimicrobial proteins, and the cellular barriers of the innate and specialized adaptive immunity. Anatomic and chemical barriers are the initial defence against infection. The skin and mucosal surfaces introduce an avoidance strategy that prevents the exposure of internal tissues to microbes. Additional resistance mechanisms that further strengthen host defences involve mucosal surfaces and a variety of antimicrobial proteins that they produce and act as natural antibiotics to prevent microbes from entering the body (complement system).

Once the anatomical barrier is breached, early non-specific, innate immune defence becomes active. The innate immune response includes the first line of the cellular barrier defence involving the action of phagocytic cells, including macrophages, dendritic cells, neutrophils, Natural killer (NK) cells and their molecular secretions. Macrophages, dendritic cells, and neutrophils, can all act as phagocytes able to internalize external agents, degrade and/or process and present to specialized cells of the adaptive immune system, T and B lymphocytes, which constitutes a specialized cellular barrier.

The innate immune response involves the early phase of a viral infection and is often a race between the host's defence systems and the virus (Figure 8, innate immune system). As soon as the integrity of the anatomical barrier is breached, the cellular barrier becomes activated, regulating phagocytosis and secretion of chemical components that can inhibit viral replication, but also eliminate virally infected cells.

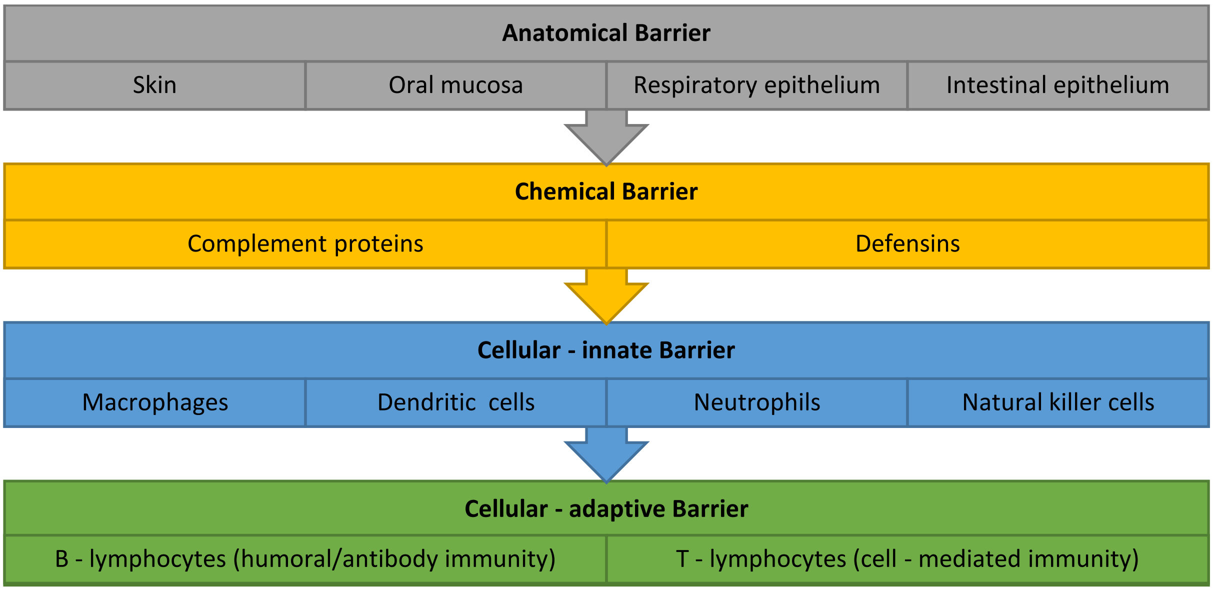

Figure 7: The four-level barrier of defence against incoming pathogens.

The secretion of interleukin-8 (IL-8) by phagocytic cells (macrophages, neutrophils) and epithelial cells during inflammation plays a key role in the enhanced recruitment of neutrophils and other immune cells to the site of infection. Additionally, virus infected cells can and will also secrete interferon (IFN), another important chemical component, as part of activating antiviral mechanisms in neighbouring cells, enabling them to resist viral infection, as well as promote macrophage activation, enhance antigen presentation, orchestrate activation of the innate immune system, coordinate lymphocyte–endothelium

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interaction, regulate T-helper-1/T-helper-2 balance, and control cellular proliferation and apoptosis of senescent/infected cells (Tau et al., 1999).

Interferon-alpha (IFN-α) and Interferon-beta (IFN-β) are produced by cells in response to infection with virus and both contribute to the direct inhibition of viral replication by the activation of antiviral mechanisms in neighbouring cells, enabling them to resist infection, by blocking the translation of the virus genome into viral protein, and the activation of a specific endonuclease that degrades viral RNA. In addition, Interferon-gamma (IFN-γ) enhances the efficiency of the adaptive immune system by up-regulating the viral – antigen presentation and activating macrophages and Natural killer cells.

Activated Natural killer (NK) cells are cytotoxic lymphocytes that can directly lyse cells that become infected with a virus or any other intracellular pathogen, and act as essential components of the immune response mediating protective immunity. Their cytolytic/cytotoxic function can be initiated through a variety of processes, including degranulation (the release of enzymes, such as perforins that will cause pore formation in cell membranes of target cells) and death receptor ligation, and is critical for the clearance of diseased and dysfunctional cells. Additionally, NK cells can produce a variety of inflammatory cytokines in response to activation receptor stimulation as well as inflammatory cytokine-induced activation signalling (Abel A. M., et al., 2018), promoting thus the action of adaptive immune responses.

The adaptive immune response involves the activation of pathogen-specific defence mechanisms against incoming pathogens (Figure 8, B and T lymphocyte responses). This specialized cellular barrier includes both T and B lymphocyte associated responses, which are regarded as the “special forces” of the immune system. In athymic “nude” mice (absence of a functional thymus gland that is the organ specializing in T lymphocyte maturation), infection with virus can be lethal, since these animals lack mature T lymphocytes and are thus susceptible to viral attacks. Spreading of lesions and eventual infestation of the central nervous system resulting in death was the result when such animals were infected with herpes simplex virus (HSV). Transfer of mature HSV-specific T lymphocytes, early on in their infection with HSV, ensured the survival of these animals (Kapoor A. K. et al., 1982). Since those studies, it is now clear that T lymphocytes play an important key role in the protection against virus attacks. In fact, $CD4^+$ T lymphocytes mediate viral immunity in many ways. These cells are responsible for the activation of $CD8^+$ cytotoxic T lymphocytes, which are the principal surveillance system operating against viruses in a highly efficient and selective manner, focusing on and destroying virally infected cells. In a similar way, $CD4^+$ T lymphocytes also have cytotoxic activity, specifically targeting and eliminating infected antigen presenting cells (macrophages, dendritic, epithelial cells). $CD4^+$ T lymphocytes are also responsible for the recruitment of macrophages at the site of virus exposure. Additionally, T lymphocytes will also mediate most antibody responses, since these are thymus-depended meaning that B lymphocytes require an interaction with specialized $CD4^+$ T lymphocytes for their immunoglobulin class switching and maturation into antibody producing plasma cells.

Anti-viral antibodies are the result of humoral immunity brought about by B lymphocytes. Such antibodies provide a major barrier to virus spread between cells and surrounding tissues, restricting access of the virus within cells (neutralization), identifying viral antigens on infected cells through a process known as opsonisation, promoting cell destruction via the action of the complement proteins, and resulting in the massive clustering and coagulation of virus particles together ensuring their elimination. Immunoglobulin-A (Ig-A) is the major form of antibody observed at mucosal surfaces, whether these are part of the respiratory or the intestinal system, and a major molecular component of the immunological barrier to incoming pathogens. Ig-G is found in the bloodstream and is important in restricting virus spread throughout the body. Antibodies may be generated against any part of a viral protein, however, only those directed against viral glycoproteins of the envelope structure of the virus or towards those expressed on the cell membrane of infected cells are of importance in controlling the infection.

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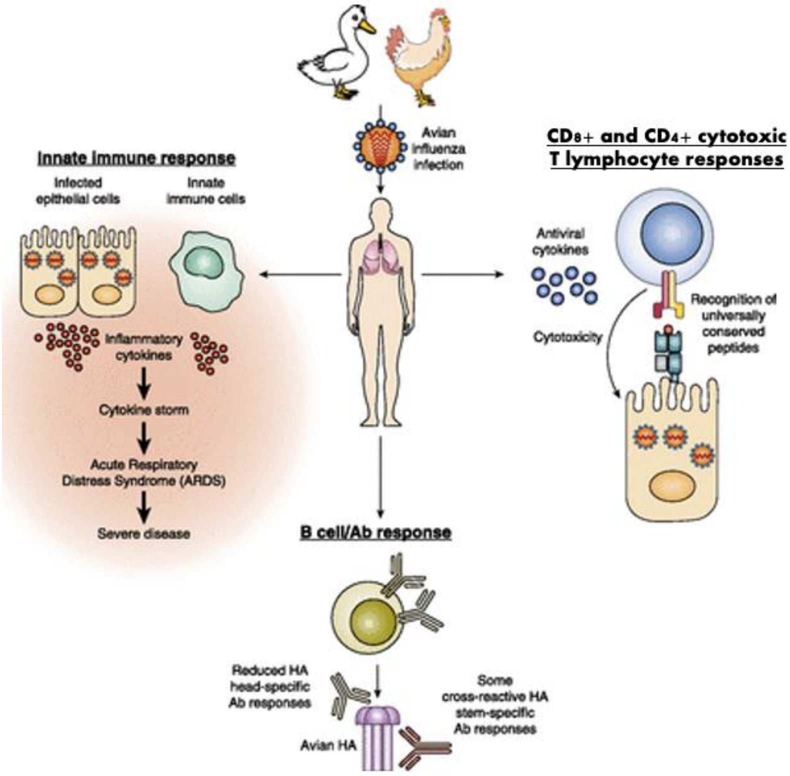

Figure 8: The immune response to avian influenza virus infection.

Infection with novel avian influenza viruses triggers innate and adaptive immune responses. The humoral response (antibodies) results in the production of antibodies. Cytotoxic $CD8^+$ T lymphocytes that recognize conserved peptides can kill virus-infected cells and also produce antiviral cytokines, promoting viral clearance and recovery. (Figure taken from Koutsakos et al., 2019).

Strategies of viruses for evading immune defences

Viruses have evolved various strategies for evading the immune system and escaping recognition by antibodies, the most effective one being antigenic variation. This involves the mutation of specific regions of key proteins that are the usual targets of antibodies. Antigenic variation is a common strategy used by a broad range of viral pathogens to avoid host immune responses. However, the rate of genomic mutation and the diversity of antigenic variants vary markedly among different viral species, as viral antigenicity is tightly linked with the capacity of a virus to be bound by specific antibodies, especially neutralizing antibodies. Such antigenic variation is seen with HIV and influenza viruses (Figure 9) and antibody mediated immunity lasts until a new virus variant emerges.

Some viruses such as the HSV can make glycoproteins that result in binding a different site of antibodies, alternative to the usual antigen-binding site, thus escaping immune recognition, but also interfering with immune complimentary activation and elimination of infected cells. Other viruses, such as Epstein-Barr virus (EBV), will produce short stretches of RNA that compete with the action of the host's protein kinase of blocking viral protein translation. This is the virus's own defence mechanism against the action of IFN-α and IFN-β. There are also viruses, such as the cytomegalovirus (CMV) that encode for proteins that inhibit the transport of specific antigen presenting molecules to the cell surface of virally infected cells and prevent the expression and presentation of viral antigens to $CD8^+$ cytotoxic T lymphocytes. Part of the numerous mechanisms developed by viruses to evade immune responses, includes the ability to encode for proteins that target the function of the host's cytokines and immune signals triggered by cytokines (Alcami A., 2016). An example of such a virus is EBV that has been shown to encode for protein that mimic the molecular structure of host's specific cytokines.

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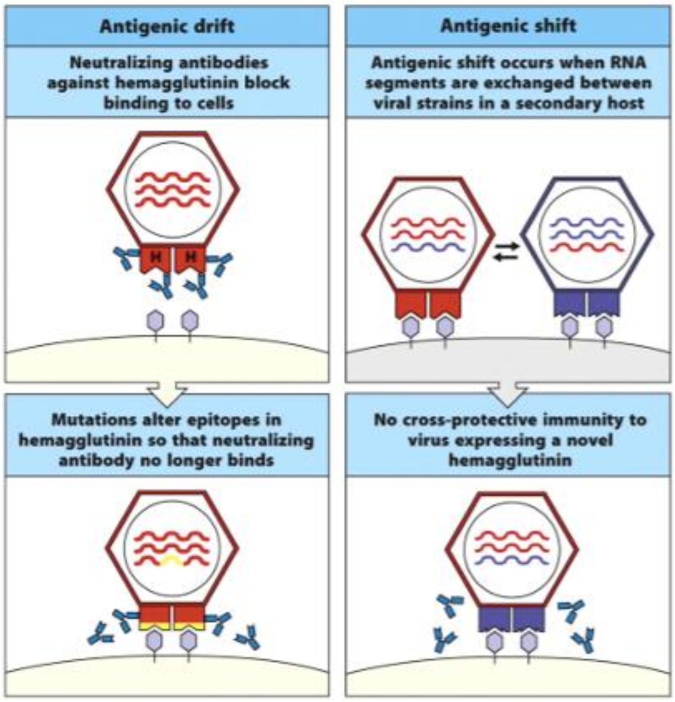

Figure 9: Antigenic drift and shift occurring in viruses, providing the engine for genetic diversity.

Antigenic drift can results in the virus changing its surface antigens slightly, whereas antigenic shift results in radical changes that result in the generation of novel strains.
(Figure taken from Janeway's Immunobiology, 9th Edition)

Defining the term pandemic

Let us begin with a question, "what is a pandemic?" Some would casually, say that a pandemic is defined as a disease outbreak that spreads across countries or entire continents, or even globally, and it affects more people and results in more deaths than an epidemic. Back in the early 19th century, the terms epidemic and pandemic were considered synonyms, which lead into an increasing abandonment of the term. Since the 1889 and 1918 influenza pandemics, as a result of globalization, change of lifestyles, social and economic improvement, the meaning of the word pandemic has been clarified and made widely understood, but it soon drifted into looseness and vagueness as it began to be used popularly to signify large-scale occurrences of other infections (not related to influenza) and to chronic and lifestyle-associated diseases (such as cancer incidences); it thus returned to its previous vague status, describing almost anything that increased and appeared to spread within or among groups of people, such as obesity, cardiovascular disease, traffic accidents, factory closings, even fear.

In their review, David M. Morens, Gregory K. Folkers, and Anthony S. Fauci (2009), refer to a vast number of scientific, modern definitions of the tem pandemic that include "extensively epidemic", "epidemic that has spread over a very wide area and usually affecting a large proportion of the population", and "distributed or occurring widely throughout a region, country, continent or globally", among others. All these definitions convey the initial idea that a pandemic is a very large epidemic, however, such definitions remain vague. Even though there seems to be little disagreement that a pandemic is a large epidemic, the question remains on whether pandemics must be also new, explosive, and/or severe, must they be infectious, what if they rapidly spread globally without causing high attack rates? All such questions need to be taken into consideration when coming to identify potential pandemics. Figure 10 provides an easy way, allowing the distinguishing between the terms endemic, epidemic and pandemic, that one could use to explain and clarify the difference between each term, ensuring the correct understanding and use of each term.

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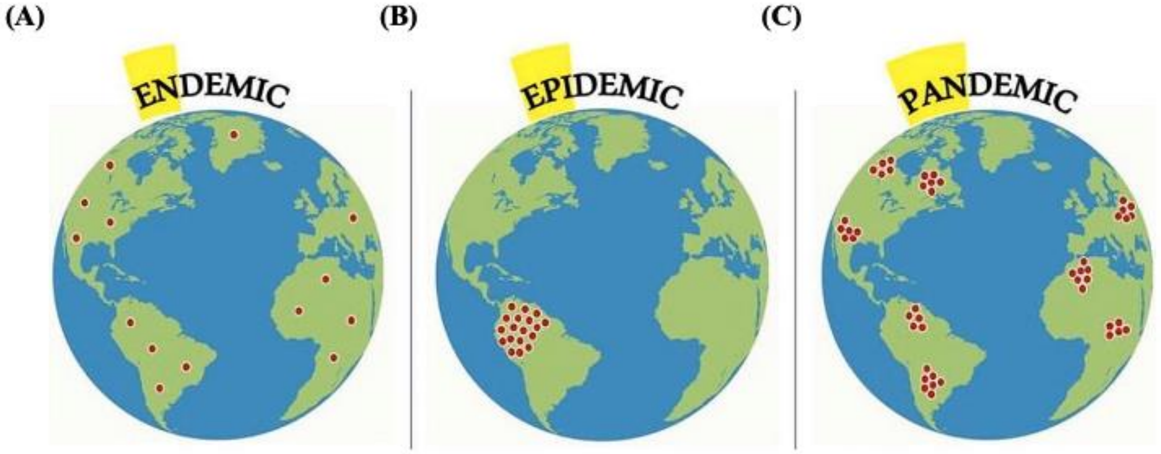

Figure 10: Understanding how to classify a disease based on extend of spreading globally. In situations, occurrence of transmissions is noted but, in (A) an endemic the number of cases remains constant, in (B) epidemic the number of cases increases, in (C) pandemic the number of cases increases and spreading occurs worldwide. (Diagram taken from https://abilenetx.gov/978/Epidemics-and-Pandemics).

Identifying and describing pandemics

Taking into consideration some, amongst many known diseases, including Acquired Immune Deficiency Syndrome (AIDS) caused by infection with the Human Immunodeficiency Virus-1 (HIV-1), cholera, dengue, influenza, plague, severe acute respiratory syndrome (SARS), one needs to identify what these have in common to describe disease. Factors to consider include the following:

geographic extension of the virus, spreading of disease caused by the virus, attack rates and explosiveness, minimal population immunity, novelty of the virus, infectiousness, contagiousness, severity following infection.

a) Considering the **Geographic extension of the virus**, a pandemic can be categorized as being:
   - Trans-regional, where the virus occurs at two (2) or more adjacent regions of the world,
   - Inter-regional, where the virus occurs at two (2) or more nonadjacent regions of the world, and
   - Global, where the virus occurs at most regions around the world.

b) The **spreading of disease caused by a virus** can be via transmission, and can be traced from place to place, as it has been done historically for centuries, including widespread person-to-person transmissions in diseases caused by respiratory viruses, such as influenza, severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS). One should not exclude animal-to-person transmissions, such as in the initial occurrence of SARS and MERS and the Avian Influenza (H5N1), where the disease causative virus is zoonotic, meaning that the virus has an initial animal origin, and this has “jumped” from animal to humans.

c) **High attack rates but also explosive spreads** (that can occur in very short time) comprise some of the characteristics exhibited by identified pandemics. It is important to understand that not every disease spread can be generally called a pandemic, and there are cases of diseases that had not been classified as pandemics presumably because attack rates have been moderate and symptomatic cases have been relatively low.

d) **Minimal population immunity** is a concept that applies to most pandemics, with individuals of the age of 60 and above having a modest degree of protection to existing/ circulating pathogens. Pre-existing immunity drops when it comes to viral pathogens that are characterised by high mutation rates but can also use animals and humans as their hosts. In such cases, such as influenza and corona viruses, one’s immune system constantly requires “updating”.

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e) **Novelty of the viruses** arises for those pathogens that can undergo frequent antigenic shifts, and therefore continually alter their genetic makeup, making it difficult for the immune system to keep up with such changes. Examples of pandemics arising from new variants of such viruses include the reoccurring of influenza and corona viruses, the emergence of HIV/AIDS when it was recognized back in 1983, and the historical epidemics of diseases, such as plague.

f) **Infectiousness** of a viral pathogen is an important parameter to consider, as this may result in possible high rates of transmissibility; in simpler words, the ability of a pathogen to be passed easily from person-to-person, through air or contaminated utensils or food, and induce disease.

g) **Contagiousness** is a term usually used to describe direct person-to-person transmissions.

h) **Severity following infection**, is a common characteristic for pandemics, however, not all pandemics are associated with high death rates and high severity.

Viruses that have staged pandemics over the last century

Knowledge of past pandemics has been constantly ignored and not utilized in ways that would benefit humankind, resulting in repeated failure of attempts to prevent emerging infectious diseases, with the most recent event being the SARS-CoV-2 outbreak. According to Dr Hunasanahally Puttaswamygowda Gurushankara, from the Department of Zoology, School of Biological Sciences, of Central University of Kerala, pandemics' history has highlighted the persistent socioeconomic classes, xenophobia, and pervasive fear of the invisible enemy pathogen (Gurushankara H. P., 2021). As already discussed in section 3.1, animals are the reservoir of vast pandemic disease pathogens and act as vectors for transmission to humans (Table 2). Factors such as urbanization, habitat destruction, habitat loss, and trade and consumption of high-risk, wild animals have been responsible for almost all disease outbreaks. Examples of human viral infectious diseases that have existed for centuries include measles, influenza, smallpox (eradicated in 1980), dengue, HIV, and many others, all of which have originated by animal-to-human host-switching. In fact, human beings are the ultimate cause of pandemics.

During the Neolithic revolution, where humans began to abandon their nomadic hunting and gathering nature, and started settling down in stable locations, growing crops and raising domestic animals for food, labour, and clothing to survive, it is under such conditions of intense human-animal proximity and environmental alterations that enzootic and zoonotic diseases arose. Viral agents that are the cause of many pandemic diseases evolved from animal pathogens that switched hosts to become human infectious agents. For example, the emergence of deadly "bird flu" associated with the poultry-adapted influenza A-viruses H5N1 and H7N9, SARS-Cov-1 that came close to causing a global pandemic in 2002 and 2003, and now in 2019 and 2020, SARS-CoV-2 that has caused the newest pandemic, COVID-19, are all diseases that originated from China's numerous live-animal markets. The establishment of such multiple large live-animal markets in a densely inhabited region, or at least the greatly increased human-wild animal contacts that such markets represent, has within two decades caused the emergence of four fatal zoonotic diseases, including one barely prevented near pandemic (SAS-CoV-1), and one we have clearly failed to prevent (SAS-CoV-2).

The most devastating realization is that the best containment measures that were used in the far past, are the same exact approaches that are currently used in the 21st century to fight the new global disease. As stressed by many scientists, from prehistoric to 21st-century pandemic, humans have not understood many fundamental aspects of emerging infectious diseases, including the origin and evolution of the novel emerging pathogens. It seems that some of these viruses have all the essential components and the ability to directly infect and be transmitted between humans, and, therefore, are poised for human emergence (Morens D. M. et al., 2020). As frankly stated by Morens et al., (2020), since the Athenian plague that was the first, historically identified transregional pandemic, there has been a steady stream of new pandemics of even greater mortality. Confronting them and then quickly forgetting the lessons that they left behind have become a recurring theme in human existence, and repetitive nature of struggles to combat these diseases is illustrated in countless history books, with sometimes striking similarities in avoidance and control strategies across the centuries (Figure 11).

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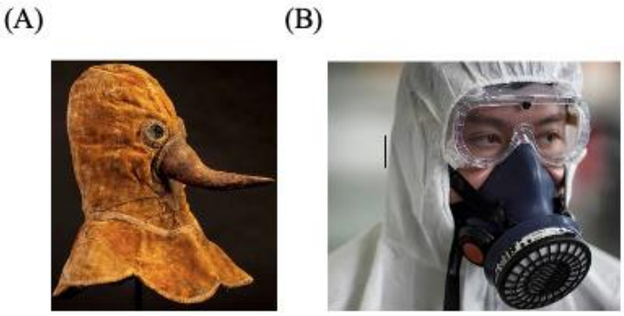

Figure 11: Protection methods used throughout centuries.

(A) Doctors, to protect themselves from highly contagious diseases doctors wore protective hoods like the plague-cotton-velvet mask, that completely covered the face and the wearer breathed through two small holes in the 'beak', which held herbs or sponges soaked in vinegar. (B) Protective mask worn in 2020, during the pandemic caused by SARS-CoV-2. (Images taken from Morens et al, 2020)

Table 2: Comparison of virus related pandemics (Table reconstructed from Roychoudhury S. et al., 2020)

	SARS-CoV-2	SARS-CoV-1	MERS-CoV	Ebola	H1N1	HIV
Outbreak year	2019	2003	2012	1976 onwards	2009 (North America)	1981 onwards
Location first reported	Wuhan, China	Southern China	Saudi Arabia	Central Africa	North America	West-Central Africa
Outbreak countries	More than 215 countries	29 countries	More than 27 countries	Africa, the Americas, Southeast Asia, Europe, Eastern Mediterranean, Western Pacific	Africa, Europe, the Americas, South-East Asia	More than 130 countries
Natural reservoir	Not identified	Bat	Bat	Fruit bats, porcupines, and non-human primates	Human, avian, swine	Chimpanzee
Case Fatality Rate	2–3%	10%	34.4–37%	50–63%	0.02–0.4%	80–90%
Community attack rate	30–40%	10–60%	4–13%	5–30%	10–20%	23%
Clinical symptoms	Fever, Cough, Dyspnea, Myalgia, Malaise	Fever, Cough, Dyspnea, Chills, Diarrhea	Fever, Cough, Dyspnea, Myalgia, Headache	Fever, Fatigue, Muscle pain, Headache, Sore throat, Vomiting, Diarrhea, Rash, Low WBCs and platelet count and elevated liver enzymes	Fever, Chills, Cough, Sore throat, Runny nose, Body aches, Headache, Fatigue, Diarrhea, Nausea, Vomiting	Fever, Cough, Muscle aches, Fatigue, Bloating, Headache, Memory loss, Poor appetite, Diarrhea, Nausea

Educator's implementation guide

The four activities within this learning module have been designed to provide students with the opportunity to explore, research, learn, reflect and peer teach concepts related to the general knowledge of virus pathogens, the general mechanisms viruses use to evade the immune system, and how viruses can be the cause of seasonal epidemics and sometimes pandemics.

The specific assignments are geared toward a general biology course for students within the age range of 12-15 year, but the strategies are applicable for higher A-level, undergraduate and postgraduate level biology classes if the content is scaled up. The order in which they should be applied follows a

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scaffolding approach where students acquire new knowledge at each level via performing their own research and then use this to bridge their understandings to new learning.

This section includes all four proposed learning activities and descriptions of how these could be implicated as an extension to the general biology topics taught at the different stages of education, including lower secondary (12-15 years).

Collaborative poster (Activity-1)

Getting students to work on their collaboration skills through the creation of group posters is a great way to help young minds to structure their understanding in a visual form; using various ways of presenting the information they collect, including tables and timeline diagrams. During this activity students should be guided on how to choose valid resources for extracting information. Creating a poster encourages student's creativity while assisting student's self-assessment via a set of instructions. This strategy is applicable to any topic as well as beneficial for students' use to express creativity and to familiarize students with this type of performance task throughout the year.

The educator initiates students to what they will be teaching through an introductory discussion, using the information of Section 6 "Background Science", and/or by using the additional resources recommended within this learning scenario (video providing an overview of historical pandemics, caused by various pathogen types and not exclusive to viruses, https://youtu.be/B7ivFcGbFJM). Within this video, the pupils are shown a map of the world and are asked to observe to what extend disease spreads in each pandemic example given.

Learning objectives

- gain an overall historical view of general pandemics (via the recommended video resource)
- be able to apply and demonstrate their acquired knowledge via the creation of a collaborative poster, where they will be requested to produce a timeline of pandemics caused specifically by virus pathogens, providing information such as dates, identity of causative pathogen.

Time requirements

- Preparation of students at home, the day prior to the activity, requires a maximum of 20-25 minutes. 15 minutes for watching the assigned video and 5-10 minutes to prepare notes of the names, causative infectious agents, and dates of pandemics.
- The collaborative poster is designed to be implemented over 2 teaching periods (80-100min in total). One teaching period for creating the poster and one for presenting this to the rest of the class.

Description of activity sequence / Educator's Instructions

Prior to introducing activity 1:

- The educator asks all students to watch at home the video of the overview of historical pandemics and record names of disease and dates (give link or send via email).
- For challenging those more able students, the educator could suggest that they could research the individual appearance of each virus they note down.

Application of activity 1:

1. Display the learning objectives of this given activity on the whiteboard.
2. Begin the lesson by displaying Figure 10 (from subsection 4.6.9)
3. Ask the students to explain with their own words the main difference between an endemic/epidemic/pandemic, based on what they observe.

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4 Ask students the question “what do you think are the causative infectious agents of such spreading of diseases?” and get them to think and explain how a spreading of disease can accumulate from an endemic case to an epidemic and a pandemic.

5 Organise students in groups of 3-4 and get them to prepare a collaborative poster, summarising a timeline of all historical pandemics that were associated with viruses. Giving them the time to think about how to represent the information that they have gathered, discuss, and reach a consensus on which information and dates they should include in their poster.

6 As groups plan and create their poster, a set of instructions is essential to ensure that there is a discussion amongst them and that they stay on task and use images and record dates down correctly. Each student in the team uses a single and distinct colour marker, meaning each member uses a different colour to represent his/her work on the poster. Each group member also signs the poster in his/her respective colour when the group agrees that the poster is complete.

7 After the posters are complete, groups present the information to the whole class, or groups share the information in a gallery walk format.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

- Video overview of historical pandemics, caused by various pathogen types and not exclusive to viruses - https://youtu.be/B7ivFcGbFJM (DER1)
- The educator can use and/or give to students:
  - Figure 1 from subsection 4.6.1, for historical sequence of pandemics (DER2: https://trinitonian.com/2020/09/10/a-history-of-sports-and-diseases/)
  - Table 1 from subsection 4.6.1, for reference to time periods of various virus-associated pandemics (DER2)
  - Figure 10 (DLO1: http://abilenetx.gov/978/Epidemics-and-Pandemics) from subsection 4.6.10, as a sketch representation of the differences between the term endemic, epidemic, and pandemic
- For background information on the general scope of pandemics, the educator can refer to subsections 4.6.9-4.6.10.
- For background Information regarding the architecture of virus, the educator can refer to subsection 4.6.3.

Assessment/evaluation of learning outcomes

- Student groups are asked to present their poster to the whole class.
- Student posters are displayed on the class board and groups are allowed to view each other’s work and along with their educator, they ask questions on the presented work.

Immune-response Action Model (Activity-2)

Biology action modelling is a strategy that allows students to participate in active learning where they construct a simple materials model that simulates a dynamic biological process, in this case, the response of the human immune system towards an incoming virus. This approach to learning increases student accountability for their own learning and allows multiple opportunities for the educator to check for understanding of the contents delivered. In addition, the modelling will help students take an abstract concept and make it tangible and concrete to them.
The immune-response action model demonstrates how a virus can initially enter the human body, infecting initially the epithelial cells covering the surfaces of these entry points, and how the different cells of the human immune system will collaborate to mount an effective immune response that will contain the infection and eliminate the pathogen and any infected cells. Students will be able to model the immune-response mechanisms against a virus, from the point of entry into the body, at the different stages of breaching the anatomical, chemical, and cellular barriers of the immune system.

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Learning objectives

- will learn the different routes of entry that viruses use to inter the human body, and how they can infect human epithelial cells found at those entry points.
- will be reminded of and/or reintroduced to the important cell categories of the immune system and their specific functions, and how these interact with each other to bring about an effective immune response.
- will be able to link the different categories of immune cells/components to the three main barriers of immune protection (anatomical/ chemical/cellular).
- will explore how antibodies and different immune cells and immune components help protect against viral pathogen.
- will be able to model the interaction between and incoming virus, epithelial cells, complement proteins, B-cells, antibodies, and T cells to manipulate the fundamental immune response mechanisms triggered when a virus enters the human body.

Time requirements:

- Activity-2 will require a prior introduction to the cells of the immune system and their specific functions (see educator's instructions for more details). This could be a 20-minute session, where the educator will introduce their students to the fundamental barriers of the immune system and the different categories of immune cells/ specific functions. They will also explain the importance of collaboration between these components to ensure an effective immune response against an invading virus.
- Students shall be given printouts of the different categories of immune components and will be asked to cut out to use for constructing their model. This should take 5-10 minutes.
- The actual construction of the immune-response action model should take 20-30 minutes to complete, allowing students to familiarise themselves with the different categories of immune components and their functions towards protection, the interactions between the different cell categories and the outcome leading to immunological protection.

Description of activity sequence / Educator's Instructions

Prior to introducing activity 2:

- Educator needs to familiarise themselves with the theory related to this module by reading through subsection 4.6.6 and 4.6.7 of the current learning scenario.
- Printouts of the different categories of immune components need to be prepared (see relevant appendix section).
- A list of set out steps should be printed for each student groups to help them with the construction of their model (see relevant appendix section).
- Print out of assessment of learning sheet for students to complete at the end of the activity.

Application of activity 2:

1. Educator introduces their students to the fundamental protective barriers (anatomical/chemical/cellular) and the different categories of immune cells, explaining their specialised functions in promoting active immune responses against an incoming virus pathogen. They should follow the suggested sequence of events and refer to Figure 7, in subsection 4.6.7, for their own guidance:
   - A virus entering the human body experiences the first line of defence that involves the anatomical barrier (epithelial cells).
   - The action of the anatomical barrier is further aided by the complementary action of the chemical barrier (mucus, enzyme secretions from the epithelial cells and complement proteins).

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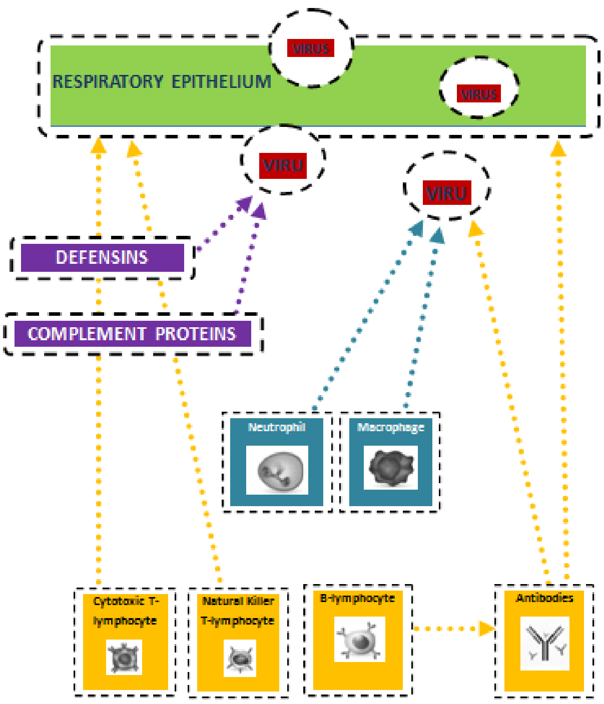
- Even after the collaborative action of these two barriers if a virus succeeds in infecting the epithelial cells, it will have to face the action of the cellular barrier (innate). At this point immune cells known as phagocytic cells will internalise the virus and break it down by internal cellular mechanisms.
- The action of the innate cellular barrier is also aided by the collaborative action of the chemical barrier; chemical complement proteins that bind to the virus better facilitate the actions of phagocytic cells.
- However, if the innate immune cells become overwhelmed by an increasing virus load and cannot clear out the infection, then their actions are re-enforced by signalling the help of the specialised branch of the cellular barrier, known as adaptive.
- The cellular adaptive barrier involves the specialised action of lymphocytes, including both T-lymphocytes and B-lymphocytes.
- T-lymphocytes will regulate the action of immune cells of both the innate and adaptive cell barrier but will also act on their own and eliminate virus infected cells either directly (Natural Killer cells) or via regulation (Cytotoxic T lymphocytes).
- B-lymphocytes are mainly responsible for the secretion of virus specific antibodies. These cells require T-lymphocyte regulation to produce and secrete virus-specific antibodies. Secreted virus-specific antibodies are a component of the chemical barrier of the immune system.

At this point it should be made clear to students that all barriers of the immune system complement each other via their collaborative functions to produce an effective immune response.

2. Educator asks students to colour their cut-outs:
   - Anatomical barrier components in green
   - Chemical barrier components in purple
   - Cellular innate barrier components in blue
   - Cellular adaptive barrier components in orange

3. Educator arranges their students in groups of 3-4 and asks them to use their coloured cut-outs to manipulate the immune response towards an incoming virus, by sticking these on an A3 (or larger) paper. The action of each component should be indicated by drawn in arrows having the same colour as the acting component.



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Educator can assess individual student learning by getting students to complete the assessment of learning sheet at the end of this activity.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

The educator can use and/or give to students:

- Figure 7 from subsection 4.6.7, for reference to the four main barrier of defence towards incoming pathogens
- List of sequence of events from "**Description of activity sequence / Educator's Instructions" (New DLO2)**

For background information on mode of viral infection and the effective mounting of an effective immune response, the educator can refer to subsections 4.6.7 and 4.6.8.

Use of **New LO2** for cut-out prints and assessment sheet (found at the end of Activity-2).

Assessment/evaluation of learning outcomes

1. Guiding questions for the groups should be used to monitor student progress and to check for understanding as students interact with the model. Examples could include:
   - Ask students to decide which virus point of entry they would like to explore.
   - As them to classify their virus (i.e., is this a respiratory, intestinal virus etc)
   - Ask students to identify the anatomical barrier that their virus is encountering at first entry.
   - Ask them to identify the most important cell from the cellular adaptive barrier and explain their choice.
2. At the end of the activity the educator can give out a handout listing the series of events during an effective immune response towards an incoming virus and ask students to number the correct order to assess individual student learning.

Simulation of virus antigenic drifting/shifting (Activity-3)

The presented activity offers a straightforward and efficient way to visualize the mechanisms of antigenic shift and drift in an evolving virus. Pedagogically, the influenza virus proposed by Marintcheva B. (2016) is an excellent choice for demonstrating these concepts in the classroom (LO3). Antigenic drift and shift are central to understanding viral diversity and evolution and the occurrence of re-infections and have direct application to vaccine design and development. Students often struggle to fully understand how both phenomena of viral drift and shift work mechanistically and thus have limited opportunity to gain an appreciation of the scientific principles behind a vaccine's development and its effectiveness. Marintcheva has developed a simple exercise using conventional LEGO bricks to physically model antigenic shift and drift to aid student understanding. The exercise can be executed in any type and level of classroom for about 10 minutes. The material used for this activity is economical and easy to store in the classroom. During this activity, students work in pairs and take turns manipulating the LEGO bricks and recording their data. The example of the virus used is that of Avian Influenza and for keeping the activity simple, this model of virus has only three genome segments, each visualized by a LEGO brick of a different size. A small non-transparent box is used to model the host cell. The educator needs to first explain to the students the concepts of antigenic shift and drift be referring to subsection 4.6.8 (could also use Figure 9, to explain this is in a graphical way).

In short, **antigenic drift** is defined as a random genetic mutation occurring in an infectious agent such as a virus, resulting in **minor changes in proteins called antigens**, expressed on its surface, which stimulate the production of antibodies by the immune systems of humans and animals. A proportion of human/animal populations will have immunity to these minor changes of viral antigens. On the other hand, **antigenic shift** is defined as a genetic alteration occurring in an infectious agent that causes a

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dramatic change in an antigen on its surface, which stimulates the production of antibodies by the immune systems of humans and other animals. Pre-existing immunity to such a dramatic antigenic change is minor and the newly emerged viruses have the potential to cause epidemics or pandemics, since very few, if any, humans possess immune memory cells that can protect them against the new antigens.

From the antigenic shift modelling activity, students will realize that roughly only 25% of their constructed brick-viruses are non-recombinant (of single colour) and 75% are recombinant (having different combinations of the two colours). If the newly acquired fragment (i.e., the one with a different colour) is significantly different from its predecessor and antibodies with different specificity will be required to neutralize the virus, then the re-assortment event results in antigenic shift. From the antigenic shift activity, student will randomly choose which studs to colour, and the class ending up with a considerable variety of mutated versions of the genomic fragments and creating a powerful visual of how diverse the progeny of a single virus can be. Over time viruses could mutate significantly by accumulating multiple small mutations, to the point that antibodies that used to neutralize them will no longer be effective. The newest version of a virus comes to existence via antigenic drift. Considering the actual size of the influenza genome (~14,000 nucleotides long) and the error rate of the influenza RNA polymerase, students can appreciate the magnitude of the diversity that can be observed in influenza viruses.

Learning objectives

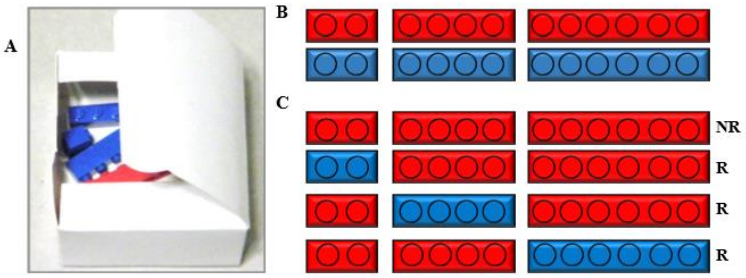
- will be able to understand viral diversity and evolution using a simple hands-on activity.
- will be able to appreciate how a virus requires host cells and multiple hosts to evolve into a pathogen that can be linked to a pandemic.

Time requirements

- The educator will need to introduce the activity to their students explaining the concepts of antigenic drift and shift. This should require 15-20 minutes of lesson time.
- The LEGO activity is a 10–15-minute activity.

Description of activity sequence / Educator's Instructions

1 Educator delivers a short presentation introducing the concepts of antigenic drift and shift as important evolutionary mechanisms of viruses.
2 Students are asked to work in pairs and take turns manipulating the LEGO bricks and their recording data. The **LEGO bricks of two different colours** are given in a non-transparent bag/box/container, representing the infected host cell.



Antigenic shift is modelled using a non-transparent box (panel A) as an infected host cell and two sets of Lego® bricks with different colour (panel B) representing the genomes of distinct Influenza strains replicating with the same rate. Recombinant genomes (R) and non-recombinant genomes (NR) are shown in panel C.

Modelling **antigenic shift** of a virus within a host cell:

3 Each pair of students is given a box with two viral genomes in different colours. The box represents a host cell harbouring two different strains of influenza virus.

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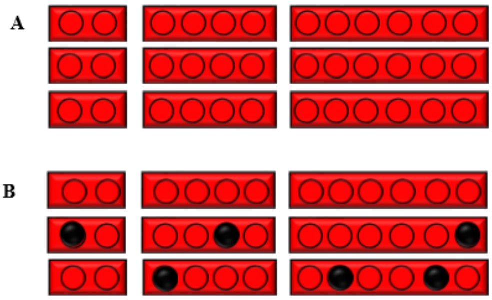
4 The students are asked to construct a virus by assembling a full set of genomic fragments (as shown above) without peeking in the box, and to record the genetic makeup of the constructed virus by describing the fragment colours.
5 Once done with recording, the LEGO bricks are returned to the box and the task repeated to construct ten viruses and to report the number of recombinant and non-recombinant viruses.

Modelling **antigenic drift** of a virus in a host cell:

6 Each pair is given three viral genomes of the same colour and a permanent marker. Students are asked to keep one genome as a reference and to "generate" two new copies, considering the error-prone nature of the **RNA polymerase that makes three errors for every 10 nucleotides copied**.
7 Each pair of students is asked to randomly colour three LEGO studs in two of their genomic virus sequences. Every stud of a LEGO brick is to be considered a nucleotide and every mutation is to be "recorded" by colouring the "mutated stud" with a permanent marker (as shown below).



Panel A shows the three viral genomes given to students, panel B shows a non-mutated genome on the top, and two randomly mutated genomes below (for each viral genome there should be **three black-coloured studs** of LEGO).
8 All students are asked to display their mutated genomic sequences and the educator records all possible new combinations of mutations generated by the whole class. More able students within the class can be challenged further by being asked to connect antigenic shift and drift to vaccine development and effectiveness.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

- Figure 9 from subsection 6.8, for reference to the strategies of viruses for evading immune defences.
- References of **Armitage, H**. (2015), (**DER3:** http://news.sciencemag.org/biology/2015/08/universal-flu-vaccine-horizon) and **Hannoun, C.,** (2013) (**DER4**: www.medscape.com/viewarticle/812621), , to introduce recent developments in the search for a universal flu vaccine in contrast to the established procedure for selecting the composition of the yearly vaccine.

Assessment/evaluation of learning outcomes

To assess the students understanding the educator can pose the following questions during this activity:

- Would one observe antigenic shift if antigenic drift does not take place?
  Answer: If antigenic drift did not happen, it is very likely that antigenic shift would not be observed either. The re-assorted fragments would be very similar, and the same antibodies would likely be able to neutralize the original and the recombinant viruses.

Discussion and proposal of possible strategies for dealing with future pandemics (Activity-4)

This final activity comes to conclude on the sequence of all previous activities, where the educator poses the question of what could be a proposed strategy for dealing with a future virus pandemic, bearing in mind both positive and negative impact on the human population, at local community, at national and international level. For this activity, the educator needs to refer to subsections 4.6.9 to 4.6.10 and consider the objectives and outcomes of the previous activities performed with their students.

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Activity-4 is a concept mapping engaging activity that helps students tackle complex course concepts and promotes problem-based learning, where students acquire knowledge by devising a solution to a real-world problem, in this case how should future pandemics be dealt with. As they do, they can apply their acquired knowledge, as well as work on their communication and collaboration skills.

Learning objectives

- will apply their acquired knowledge from activities 1-3 to come up with proposals and strategies for dealing with future virus-related pandemics.
- will improve their collaboration and communication skills by working with their peers.
- will develop and improve their critical thinking by being applying acquired and existing knowledge.

Time requirements

- The educator introducing their students to this new activity and providing them with a set of instructions ensuring that they keep to task requires 10 minutes.
- Student discussions within their allocated groups and recording of their ideas and suggestions require 20 minutes.
- The remaining lesson time, 15-20 minutes, the educator collects each groups ideas and records a proposed strategy plan on the whiteboards including of the positive and negative outcomes to the subjects of the community to which this is applied (i.e., school community, national, international)

Description of activity sequence / Educator's Instructions

Prior to activity 4:

- The educator needs to review the theory of this learning scenario and the objectives and outcomes of the previous activities that they have performed with their students.
- They could prepare a presentation summarising all learning outcomes from the three activities performed.

Application of activity 4:

1 Educator presents a summary of all acquired knowledge from previous three activities
2 Educator divides the class into teams and presents them with a course-related problem.
3 One team member writes down a solution and a problem and passes the sheets of paper along to the next team member, who builds upon that idea and then passes it along to the rest of the team.
4 In the end, a spokesperson can present their ultimate solution.
5 Meanwhile the educator records the outcomes on their whiteboard as the teams get to express their solutions to the whole class.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

The educator can refer to the theory (section 4.6) of the current learning scenario, to the previous activity descriptions and to the suggested list of references for information to structure their summary presentation.

Assessment/evaluation of learning outcomes

- The educator can assess their students' individual learning by asking them to prepare an essay with the title "History of pandemics: what do we know about powerful viruses and their impact?" using the outcomes all four activities that they have participated in.
- The selected parts of the work of the students can be edited into a single article by their teacher and published in the school's newsletter, as well as on their school website, but also on the local

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pedagogical website paideia-news.com, were the work of the students can be access and read by parents, all education level professionals and stakeholders in the educational field.

School Research Project for Educational Scenario:

Research management, design, and administration:
This final research project comes to conclude on the sequence of all previous activities, where the educator poses the question of:

"What could be a proposed strategy for dealing with a future virus pandemic, bearing in mind both positive and negative impact on the human population, at local community, at national and international level."

Methodology/Implementation:

Session 1:

Challenge: Creating a historical timeline of past virus-associated pandemics

- Preparation of students at home, the day prior to activity 1, where the need to watch the assigned video and prepare notes of the names, causative infectious agents, and dates of pandemics.
- The collaborative poster is designed to be implemented over 2 teaching periods (80-100min in total). One teaching period for creating the poster and one for presenting this to the rest of the class.

Student groups are asked to present their poster to the whole class, posters are displayed, and groups of students are allowed to view each other's work and along with their educator, they ask questions on the presented work.

Session 2:

Challenge: Constructing an Immune-response Action Model

- Activity-2 will require a prior introduction to the cells of the immune system and their specific functions (see educator's instructions for more details). During this, the educator will introduce the students to the fundamental barriers of the immune system and the different categories of immune cells/ specific functions and explain the importance of collaboration between these components to ensure an effective immune response against an invading virus.
- Students shall be given printouts of the different categories of immune components and will be asked to cut out to use for constructing their model.
- The actual construction of the immune-response action model should allow students to familiarise themselves with the different categories of immune components and their functions towards protection, the interactions between the different cell categories and the outcome leading to immunological protection.

Guiding questions for the groups should be used to monitor student progress and to check for understanding as students interact with the model. Examples could include asking student to:

1. decide which virus point of entry they would like to explore.
2. classify their virus (i.e., is this a respiratory, intestinal virus etc.)
3. identify the anatomical barrier that their virus is encountering at first entry.
4. identify the most important cell from the cellular adaptive barrier and explain their choice.

At the end of the session the educator can give out a handout listing the series of events during an effective immune response towards an incoming virus and ask students to number the correct order to assess individual student learning.

Session 3:

Challenge: Simulation of virus antigenic drifting/shifting

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- The educator will introduce the activity (3) to their students explaining the concepts of antigenic drift and shift.

To assess the students understanding the educator can pose the following questions during this activity:

"Would one observe antigenic shift if antigenic drift does not take place?"

If antigenic drift did not happen, it is very likely that antigenic shift would not be observed either. The re-assorted fragments would be very similar, and the same antibodies would likely be able to neutralize the original and the recombinant viruses.

Session 4:

Challenge: Discussion and proposal of possible strategies for dealing with future pandemics

- The educator reviews the theory of the learning scenario and the objectives and outcomes of the previous activities (1,2 & 3) that they have performed with their students.
- The educator prepares a presentation summarising all learning outcomes from the three activities performed.
- The educator collects each groups ideas and records a proposed strategy plan of the positive and negative outcomes to the subjects of the community to which this is applied (i.e., school community, national, international)

The educator can assess their students' individual learning by asking them to prepare an essay with the title "History of pandemics: what do we know about powerful viruses and their impact?" using the outcomes all four teaching sessions that they have participated in.

The selected parts of the work of the students can be edited into a single article by their teacher and published in the school's newsletter, as well as on their school website, but also on the local pedagogical website paideia-news.com, were the work of the students can be access and read by parents, all education level professionals and stakeholders in the educational field.

Development process:

The project is based on guided research about the History of Viral Pandemics. The four sessions of activities will be supervised by the educator and developed by the students, with scheduled moments for checking their work development.

Teaching-learning process milestones:

- gain an overall historical view of general pandemics (via the recommended video resource)
- be able to apply and demonstrate their acquired knowledge via the creation of a collaborative poster, where they will be requested to produce a timeline of pandemics caused specifically by virus pathogens, providing information such as dates, identity of causative pathogen.
- will learn the different routes of entry that viruses use to inter the human body, and how they can infect human epithelial cells found at those entry points.
- will be reminded of and/or reintroduced to the important cell categories of the immune system and their specific functions, and how these interact with each other to bring about an effective immune response.
- will be able to link the different categories of immune cells/components to the three main barriers of immune protection (anatomical/ chemical/cellular).
- will explore how antibodies and different immune cells and immune components help protect against viral pathogen.
- will be able to model the interaction between and incoming virus, epithelial cells, complement proteins, B-cells, antibodies, and T cells to manipulate the fundamental immune response mechanisms triggered when a virus enters the human body.

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- will be able to understand viral diversity and evolution using a simple hands-on activity.
- will be able to appreciate how a virus requires host cells and multiple hosts to evolve into a pathogen that can be linked to a pandemic.
- will apply their acquired knowledge from activities 1-3 to come up with proposals and strategies for dealing with future virus-related pandemics.
- will improve their collaboration and communication skills by working with their peers.
- will develop and improve their critical thinking by being applying acquired and existing knowledge.

Teaching-learning process for school project (summary):

1. Prior overview of historical pandemics and record names of disease and dates, as well as research the structural appearance of every individual virus they record.
2. Creation of a historical timeline of past virus-associated pandemics.
3. Construction of model of the immune-response mechanisms against a virus, from the point of entry into the body, at the different stages of breaching the anatomical, chemical, and cellular barriers of the immune system.
4. Simulation and visualization of the mechanisms of antigenic shift and drift in an evolving virus.
5. Discussion and proposal of concept map that proposes possible strategies for dealing with future pandemics.

Organization of the open schooling event:

The educator will ask students to prepare an essay with the title "History of pandemics: what do we know about powerful viruses and their impact?" using the outcomes all four sessions they were involved. The selected parts of the work of the students can be edited into a single article by the educator or an appointed editorial group of students and published in the school's newsletter, as well as on their school website, but also on the local pedagogical website paideia-news.com, were the work of the students can be access and read by parents, all education level professionals and stakeholders in the educational field.

Data Analysis and Reporting

- Scientific Content analysis.
- Creation of a historical timeline of past virus-associated pandemics
- Construction of an Immune-response Action Model
- Virus antigenic drifting/shifting results analysis
- Development of collaborative poster, write up of a scientific review article and publication to intraschool and external educational resources

Target Audience for Recommendations

- ➢ Parents, science educators, local community – public.

<u>List of Digital Learning Objects (DLO) and Digital Educational Resourses (DER)</u>

	Activity/Lesson No.	*Digital Learning Object (DLO)*	*Digital Educational Resource (DER)*
Educational Scenario 4:	1-Creating a historical timeline of past virus-associated pandemics	**LO1**:http://abilenetx.gov/978/Epidemics-and-Pandemics	DER1:https://youtu.be/B7ivFcGbFJM DER2:https://trinitonian.com/2020/09/10/a-history-of-sports-and-diseases/
	2-Constructing an Immune-response Action Model	**New LO2**: Immune-response Action Model (found at the end of Activity-2)	

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	3-Simulation of virus antigenic drifting/shifting		DER3:http://news.sciencemag.org/biology/2015/08/universal-flu-vaccine-horizon DER4:www.medscape.com/viewarticle/812621
	4-Discussion and proposal of possible strategies for dealing with future pandemics		

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Educational Scenario Impact Assessment Questionnaire

Context: The knowledge of historical virus-related pandemics sheds light on powerful viruses and their impact on aspects of health, society, economy, and governance. The scenario complements the teaching of the existing curriculum of general biology of the immune system in schools, for students of 3rd grade in lower secondary education, between the ages of 14-15 years old, and is designed to provide them with the opportunity to explore, learn, and peer teach concepts related to more specialized functions of the immune system against invading viral pathogens, aiding them to build on prior learning and develop further skills and attitudes.

Meanwhile, educators will be supported with further inside related to the topic, provided with ideas, activities and tools to support the learning of their students, supporting acquire transferable skills such as critical thinking, problem solving, analysis, reasoning, interpretation, adaptive learning, creativity, continuous learning, self-direction, responsibility, perseverance, self- regulation (metacognition, forethought, and reflection), integrity, self- monitoring, self- evaluation, self- reinforcement, and apply all these to their everyday life within their community.

Additional information: the topic is provided in the specifications of an educational scenario of the “History of Pandemics: what do we know about powerful viruses”.

The questions that follow provide and assessment for the impact of the given learning scenario on the pre-existing knowledge of the students, the skills that they have acquired throughout the teaching of this topic and the effect of this on their beliefs, attitude, and behaviour.

As part of acquired knowledge students can:	
1. Identify the history of Pandemics is mostly associated with the evolution of viral pathogens.	1.1. What are the main causative agents of historical pandemics? A. Viruses B. Bacteria C. Fungi 1.2. Which pathogen has always been in the spotlight as the cause of most major pandemics? A. Influenza B. Corona virus C. Human Immunodeficiency virus (HIV)

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2. Understand the nature/architecture of viruses and how this changes to allow for evolution	2.1. Viruses are: A. Non-living, intracellular parasites, requiring the use of the host cell's biochemical machinery to replicate and create new infectious virus particles. B. Living, intracellular parasites, requiring the use of the host cell's biochemical machinery to replicate and create new infectious virus particles. C. Non-living, intracellular parasites, that do not require the use of the host cell's biochemical machinery to replicate and create new infectious virus particles. 2.2. Which virus is the smallest in diameter? A. Picornavirus B. Human Immunodeficiency Virus (HIV) C. Influenza virus 2.3. SARS-Cov-2 has a: A. helical form B. complex polymorphic form C. icosahedral form 2.4. Which of the following is not a natural way leading to the evolution of a virus? A. the prolonged use of anti-viral drugs B. escape of potentiator viruses from the human immune system C. base substitution mutations
3. Understand the strategies used by viruses to evade the human immune system.	3.1. SARS-CoV-2 typical infection involves the initial attachment of the virion to the cell membrane of its target via the virus's A. spike protein B. gp120 receptor C. $CD4^{+}$ receptor 3.2. Which virus can persist within the host's tissues in a non-infectious (latent) form following acute infection recovery and reactivated under low immune surveillance to produce new infectious virions? A. Herpes simplex virus (HSV) B. SARS-CoV-2 C. Influenza virus
4. Explain how the immune system responds to current and novel invading viruses.	4.1. The human immune system comprises of a: A. 2 – level barrier B. 3 – level barrier C. 4 – level barrier 4.2. Which is not part of the cellular-innate barrier of the human immune system? A. Natural killer cells B. Macrophages C. B – cells 4.3. The ability of a virus to radically changing its surface antigens thus resulting in the generation of novel strains is termed: A. Antigenic drift B. Antigenic shift C. Antigenic mutation
5. Define, identify, and describe pandemics	5.1. What is the difference between pandemics and epidemics? A. In both an occurrence of transmissions is noted but, in an epidemic the number of cases increases, whereas in a pandemic the number of cases increases and spreading occurs worldwide. B. In both an occurrence of transmissions is noted but, in an epidemic the number of cases remains constant, whereas in a pandemic the number of cases increases but remain local. C. In both an occurrence of transmissions is noted but, in a pandemic the number of cases increases, whereas in an epidemic the number of cases increases and spreading occurs worldwide. 5.2. Spreading of disease must not consider which of the flowing?

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	A. Human-to-human transmissions B. Animal-to-human transmissions C. Animal-to-animal transmissions 5.3. Considering the Geographic extension of the virus, a pandemic can be categorized as being Global when: A. the virus occurs at two (2) or more adjacent regions of the world B. where the virus occurs at two (2) or more nonadjacent regions of the world C. where the virus occurs at most regions around the world
As part of skills being gained/developed students can:	
1. Select appropriate sources to extract valid historical information regarding pandemics and the spreading of disease	1.1. Which data sources may we use to extract historical information regarding pandemics? A. Centre of Disease Control and Prevention (CDC) and WHO database B. Data retrieved by google searches C. Data extracted from Historical online resources
2. Select appropriate sources to explain the historical course of viral pandemics in a scientific perspective.	2.1. To find scientific information about the historical course of viral pandemics I should consult the following sources. A. researchers, scientific publications, CDC database B. newspapers, google, YouTube C. friends, journalists, Facebook
3. Select appropriate scientific data and information to describe the historical course of viral pandemics.	3.1. I feel able to identify scientific sources to describe the historical course of viral pandemics. 1) strongly disagree… 5) strongly agree. 3.2. I know the main sources to consult to assess the progress of viral pandemics. 1) strongly disagree… 5) strongly agree
4. Propose plausible actions towards promoting protection from possible viral infections in his/her lifestyle.	4.1 Which individual actions can be taken to help containment of a spreading virus within your school community? A. Notify your school community of your unwellness and take a leave to stay home until you recover, while arranging to participate in lessons online. B. No need to notify your school community and go to school as normal. C. Notify your school community and go to school and try and keep a mask on at most times. 4.2 Which individual actions can be taken to help containment of a spreading virus in the vast community? A. Seek the advice of your personal doctor and contain yourself until you are free of all symptoms, and you are no longer infectious to others. B. If feeling that your symptoms are milt, continue to interact within your community. C. Continue to interact within your community, ensuring that you follow precautions such as the use of a face mask.
5. Influence the adoption of choices by others (e.g., their family, peers, friends etc.).	5.1 I feel able to influence the adoption of actions that help achieving the prevention of a future pandemic, including my family, fellow students, and friends. 1) true... 5) false. 5.2 I will try to influence the adoption of actions that help achieving the prevention of a future pandemic, including my family, fellow students, and friends. 1) true... 5) false
6. Selects appropriate scientific data and information to describe the progress of a pandemic	6.1 I feel able to identify scientific sources to describe the progress of a future pandemic. 1) strongly disagree… 5) strongly agree.

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	6.2 I know the main sources to consult to assess the progress of a future pandemic. 1) strongly disagree… 5) strongly agree.
7. Selects appropriate sources to characterize a pandemic in a scientific perspective.	7.1 To find scientific information about pandemics I should consult the following sources. A. researchers, scientific publications, WHO and CDC data bases. B. newspapers, google, YouTube C. friends, journalists, Facebook, other social media.
8. Identify the problems and challenges of their community in relation to a pandemic and find the relevant resources to address them.	8.1 I feel able to identify the main problems my community faces in relation to a pandemic situation. 1) false… 5) true. 8.2 I can understand how the challenges my community faces are related to health and well-being outcomes. 1) false... 5) true. 8.3 I feel capable of proposing actions that address how to prevent the spreading of a pathogenic virus in my community. 1) true... 5) false.
As part of Beliefs, Attitudes and Behaviour, there are no correct or incorrect answers; we are only interested in knowing the students' perspective on the topic introduced.	
1. Believes that is important to contribute to global efforts for tackling future pandemics.	1.1. My participation and actions will increase the chances of success of the global efforts for preventing a future pandemic. 1) strongly disagree… 5) strongly agree. 1.2. I am physically and financially capable of adopting actions that contribute to the efforts of tackling the spread of disease that can lead to a future pandemic (i.e., contain myself if I am feeling unwell, follow rules and regulations regarding health measures recommended, etc.). 1) extremely unlikely... 5) extremely likely. 1.3. My family and friends think that I should adopt actions that contribute to the global efforts for tackling future pandemics. 1) Extremely unlikely... 5) Extremely likely.
2. Believes that learning about the history of past pandemics and about powerful viruses associated with the spread of disease can lead to positive outcomes at the community level when it comes to handling the spreading of communicable disease more effectively.	1. To learn about the history of past pandemics and the causative viruses that lead to the spread of disease will lead to positive outcomes at my community. 1) strongly disagree… 5) strongly agree. 2. My community thinks that learning more about past pandemics will bring positive outcomes 1) Extremely unlikely... 5) Extremely likely.
3. Believes that it is crucial to identify obstacles and problems faced by communities regarding the handling of communicable disease.	1. The identification of obstacles and problems that my community faces are crucial for solving them. 1) strongly disagree… 5) strongly agree. 2. It is possible to identify obstacles and problems that my community faces regarding the dealing with the spread of infectious disease 1) strongly disagree… 5) strongly agree.

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	3. It is common knowledge that it is necessary to identify obstacles and problems that the community faces for solving issues regarding communicable disease. 1) strongly disagree… 5) strongly agree.
4. Has intention to perform sustainable behaviours in his/her/their lifestyle.	4.1. I will try to update myself with current/new information regarding highly contagious viruses. 1) Extremely unlikely... 5) Extremely likely. 4.2. I plan to incorporate health hygiene (i.e., washing my hands often, containing myself if unwell until my symptoms reside) in my day-to-day life. 1) Strongly disagree... 5) Strongly agree.
5. Attitude toward learning about past pandemics and how powerful viruses spread in a community.	5.1. For me to achieve such knowledge is: Harmful : _____:_____:_____:_____:_____: beneficial Pleasant : : : : : : unpleasant Good : : : : : : bad Worthless :_____ :_____:_____:_____:_____: valuable Enjoyable : : : : : : unenjoyable

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5. Specifications for an educational scenario on the topic "Workings and malfunctions of human Immunological memory"

Introduction to the module

This topic sheds light onto the concepts of long-lasting immunological memory and protective immunity, to simplify and improve the understanding of a challenging subject such as Immunology. Educators and students of ages 12 – 15 years old (preferably 15-years of age), are therefore given the opportunity to expand their knowledge by learning about important concepts in Immunology, such as the innate and adaptive arms of the human immune system and the cellular components involved in the establishment of immune memory and the interactions that bring about protective immunity and preventing re-infections. An insight is also given on how immune memory is independent of the frequency or persistence of re-infection, being a long-lasting feature involving both specialised cells of the adaptive and innate immune systems, but also depending on all the rest of the cells of the human body.

Using differentiated instructions to teach immunological concepts related to immunity against infections to a diverse group of learners, of various ages, provides a comprehensive learning module designed to expose high school students to immunological concepts related to the immune memory mechanisms. Such mechanisms are in place to minimise and preventing the spreading of disease and cause of epidemics and possible pandemics. The present learning scenario uses active hands- and minds-on teaching strategies, where students are also introduced to the consequences following malfunction of immune memory mechanisms.

This module includes and proposes the following:

Activity 1: Flipped-classroom activity introducing primary and secondary innate and adaptive immune memory.

Activity 2: In-class short presentation of collaborative work on a selected topic involving immune memory.

Activity 3: Building concept maps of the events leading to established innate and adaptive immune memory.

Expected student prior knowledge

Students should have a basic Cell Biology knowledge of the characteristics and the Variety of living organisms, including:

- ✓ knowledge and ability to describe the common features shown by eukaryotic organisms (i.e., animals, fungi and protoctists, and prokaryotic organisms such as bacteria),
- ✓ an understanding of the term pathogen and know that pathogens may include fungi, bacteria, protoctists or viruses,
- ✓ knowledge of structures within living organisms and their associated functions (i.e., the bone marrow enclosed withing the spinal cord comprises the lymphopoietic organ of the human body, lymphoid tissues such as the thymus gland and peripheral lymph nodes are organs where immune cells differentiate and develop into specialised cells) including levels of cell organisation, cell structure, biological molecules (including proteins, enzymes, DNA, RNA),
- ✓ an understanding of the different ways of transport of substances in and out of living cells, with emphasis on receptor-mediated transport processes.
- ✓ an understanding of cell membrane features such as the presence of surface bound receptors that can be associated with cell-to-cell interactions, or receptor mediated antigen binding and presentation, (i.e., T-cell and B-cell receptors, the Major-Histocompatibility-Complex, MHC, found on all cells of the body an associated with the presentation of internal and external antigens) etc.

Expected outcomes

Learns will have the opportunity to acquire new knowledge and enhance their understanding, about:

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- ✓ The two arms of the immune system: the innate immune responses are non-specific and general against groups of pathogens, whereas the adaptive immune responses are highly specific against given structural motifs of a given pathogen,
- ✓ The cellular and molecular components of each arm of the immune system: this includes the cells and molecules involved in innate and adaptive responses,
- ✓ The interactions between the immune cells and molecules: chemical and molecular interactions including, signalling, activation, proliferation, differentiation processes, to trigger immune memory mechanisms and protection against re-infection,
- ✓ The problems arising from malfunctions in immune memory: such issues may lead to lack of protection and in some case the trigger and initiation of autoimmune disease, whereby the immune system turns against its own cells and molecules.

Learners will also acquire the use of transferable skills such as critical thinking, problem solving, analysis, reasoning, interpretation, adaptive learning, creativity, continuous learning, self-direction, responsibility, perseverance, self-regulation (metacognition, forethought, and reflection), integrity, self-monitoring, self-evaluation, self-reinforcement, and apply all these qualities to their everyday life within their community.

Relation to other topics

This module could complement the teaching of the existing general curriculum in biology that focuses on the immune system. The activities included are designed to give students the opportunity to explore, learn, and peer teach concepts related to more specialised functions of the immune leading to immunological memory to past infections. The specific assignments are geared toward a general biology course, but the strategies are applicable for higher-level biology classes (A-level, undergraduate classes) if the content is scaled up appropriately. The order in which these activities should be applied follows a scaffolding approach where students uncover new knowledge at each activity level and then use it to bridge their understanding to new learning.

Pedagogical methods utilised in the teaching of this module

The objective linked to this module is to help students build on prior learning and develop further skills and attitudes. Meanwhile, the current knowledge of their educators is also enhanced, enabling them to present the given module in a way that is relevant to their students' needs.

A range of different pedagogical methods are implemented through all different activities, catering for a broad range of different learners. The current learning module is based on the pedagogical approach of inquiry-based learning, where students are encouraged to ask questions and complete research while learning various concepts of basic immunology associated with immunological memory. In this way, individual learners acquire the skills necessary to develop their own understanding, as well as question themselves and group members in a constructive way.

The initial flip-class room activity investigates primary versus secondary innate and adaptive immunity, whereby students are asked to watch a series of related online videos and are given a set of pre-lesson questions that they are to complete prior to the actual lesson. This provides an excellent tool that improves tremendously the in-class time with their educator, making the delivery of a lesson more productive. The additional workload imposed by the pre-class activities is worthwhile, as it helps students in their understanding through reinforcement of pre-class material in class, allowing them to adapt an incremental work ethic as opposed to memorising and cramming of information. Additionally, the student responses are used by the educator to provide whole-class feedback and to better focus the in-class plan on the collective needs of the students, transforming the classroom from educator-dominated to student-centered, allowing for bidirectional constructive feedback, creating thus an information loop where in-class and outside-of-class work is highly connected allowing for exploration, collaboration, and interaction among students, while the educator is consistently given feedback of the level of their understanding.

The in-class short collaborative presentation activity follows the "peer instruction" active learning strategy where students are given a narrow list of topics and asked to sign up for a topic of their choice,

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prepare and present this to their class or in small groups. This approach is particularly useful as this will involve the breaking down of the presented topic into smaller parts, and each student groups will be presenting information about a different part. This approach helps the students to associate cells and molecules and their interactive processes, with different people, therefore acting as an aide memoire for their benefit. This approach also encourages interaction and trust-building between students, being especially important at a time where a portion of learning may take place online while students will be researching on their selected topics.

The final learning activity of building a concept map of the events leading to established innate and adaptive immune memory comes to sum up the previous activities, providing students with a framework within which to organize their newly acquired knowledge, without becoming overwhelmed from all the information involved. This learning technique is particularly well-suited for teaching challenging topic such as immunology-based topics, as students must master an impressive number of new words and concepts in a short period of time. Assigning concept maps after studying a chapter that is particularly jargon-heavy is quite successful and works well in-class group and individual activities, as well as a take home study tool. Assigning students to work on creating concept maps in groups of three or four, also decreases the grading burden, allowing the educator to give more thoughtful feedback to their students, but it also allows students the benefits of discussing with each other what belongs where, and why, and how processes can be interlinked. Thus, in the process of constructing the map, the students are highly engaged in peer-instruction and metacognition learning.

Background science

What is immunological memory?

Immunological memory is an important evolutionary feature that improves host survival upon re-infection with pathogens. This means that immune cells of the human body can retain memory of past infectious agents and their associated antigens and responds fast and efficiently to any reencounters.

An antigen is basically a molecular structure that can stimulate an immune response. It is important to note that not all molecular structures are antigens, as many will not activate the immune system against them. Immune memory provides a characteristic acknowledged within both the innate and adaptive cellular barriers of the human immune system. Although the mechanisms and properties through which innate and adaptive immune memory induction occur are distinct, their combined effects improve host defence towards pathogenic intruders. Initially, immunological memory was tightly connected to the actions of the cells of the adaptive arm of the immune system, which includes the B and T cell populations. However, since 2013, innate immune memory, otherwise termed "trained immunity", has been explored during vaccine adjuvant development (Vasiliakos P. J., 2013, Basto P. A., et al., 2014, Töpfer E. et al., 2015) and has been acknowledged as an important supportive component of the protection provided by the cellular adaptive barrier.

This topic reviews the main effector components of the human immune system and provides a clear insight to how the two arms of the immune system collaborate to bring about immunological memory to all past but also newly emerging invaders.

The cell players of Immune memory.

The human immune system is comprised by a distinct population of cells along with a vast number of molecular components that all work together to orchestrate an effective protection against any foreign entity that enters the human body. To ensure understanding of all the complicated interactions and mechanisms that take place during an immune response to bring about immune memory, one needs to become familiar with the very basics of immunology.

Starting from fundamental knowledge, all the cells of the human immune system are generated in the bone marrow from progenitor stem cells (Figure 1), some of which develop and differentiate locally, whereas others that require unique environmental conditions migrate to other tissue of the human body to do so. A helpful example is that of B and T lymphocytes, with the latter migrating to the thymus gland to develop and differentiate into mature, specialized T cell populations that can respond to non-

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self-antigens. There are two main lineages from which immune cells are derived, these being the myeloid and lymphoid progenitors from which innate and adaptive immune cells, respectively, arise (Figure 1). The cells of the innate immune arm are derived from myeloid progenitor cells, the most important being:

- mast cells, mainly associated with responses to allergens
- myeloblasts, including:
  - monocytes that give rise to macrophages and dendritic cells, these being the major antigen presenting cells of the immune system, and mediators of the adaptive immune arm,
  - eosinophils and basophils, mainly associated with parasitic infections,
  - neutrophils, important phagocytic cells involved in the elimination of bacteria and fungi.

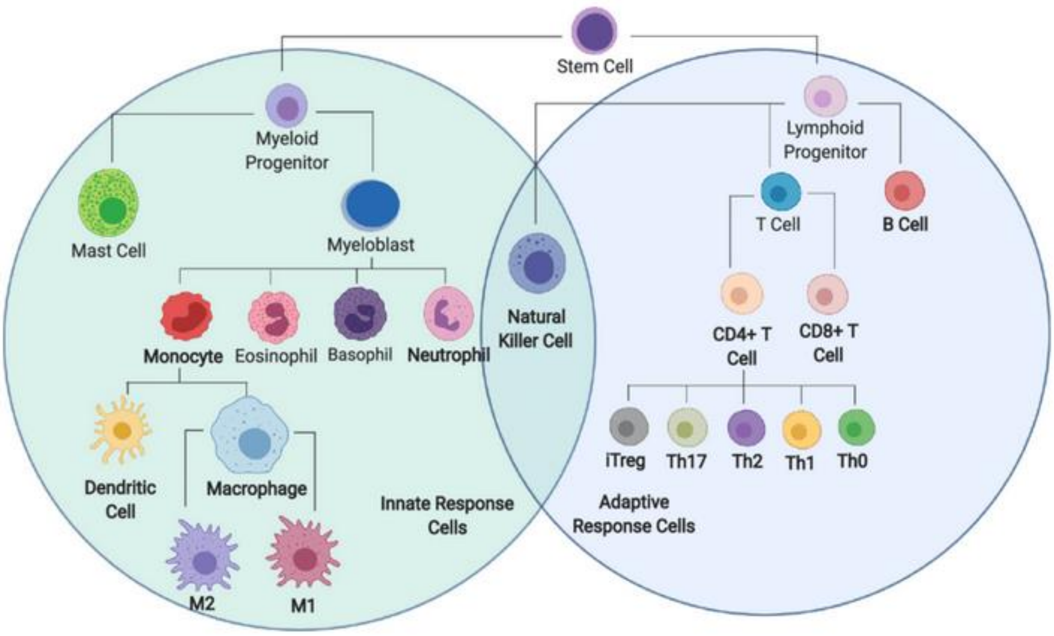

Figure 1: Representation of cells of the immune system.
Immune cells are derived from hematopoietic stem cells in the bone marrow and differentiate into lymphoid and myeloid progenitors that further branch out to differentiate into more specific cell types associated with adaptive and innate immunity. (Figure taken from Torang A., et al., 2019)

The cells of the adaptive immune arm include the T and B lymphocytes, both assigned to pathogen-specific responses and initially linked to long term immunological memory. To our current knowledge, both innate and adaptive immune cells comprise important mediator of immune memory and this topic examines both categories, to explain how memory is implemented and how this can sometimes malfunction to results in re-infection and possible development of disease.

Each immune cell serves a given purpose, this being either auxiliary or specific. However, immune memory is associated with specificity to a given pathogen and is directed against both external and internal molecular pathogen-associated structures, i.e., external surface molecules and/or internal genetic material. Lymphocytic cells of the immune adaptive arm have evolved to directly identify specific pathogen-associated molecular motifs via specialised receptor molecules expressed on their cellular membrane. Activation of B lymphocytes via their B-cell receptor (BCR) leads to the secretion of pathogen-specific antibodies. In a similar way, activation of T lymphocytes via their T-cell receptor (TCR) leads to direct cytotoxic elimination of pathogen and/or the initiation of orchestrated T-cell-mediated responses against it, involving both adaptive and innate arms of the immune system (Figure 2). The action of both B lymphocytes and innate cells is directed against specific external molecular pathogenic motifs, whereas the T lymphocyte-associated immunity is mostly directed towards internal

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molecular pathogenic motifs (Figure 3), that are exposed following pathogen internatisation, processing and presentation by specialised antigen-presenting cells, such as macrophages, dendritic cells, and organ/tissue specific epithelial and endothelial cells. It is important to note that phagocytic cells are equipped with specialised receptors, known as Toll-like-receptors (TLRs) that are expressed both on their cell membrane but also within their cell cytoplasm and involved in the identification and binding to conserved (unchanged) pathogen-associated motifs. This feature enables phagocytic cells to "remember" conserved molecular patterns expressed by a variety of pathogens, an ability that has been acquired through evolution and continuous exposure to pathogens.

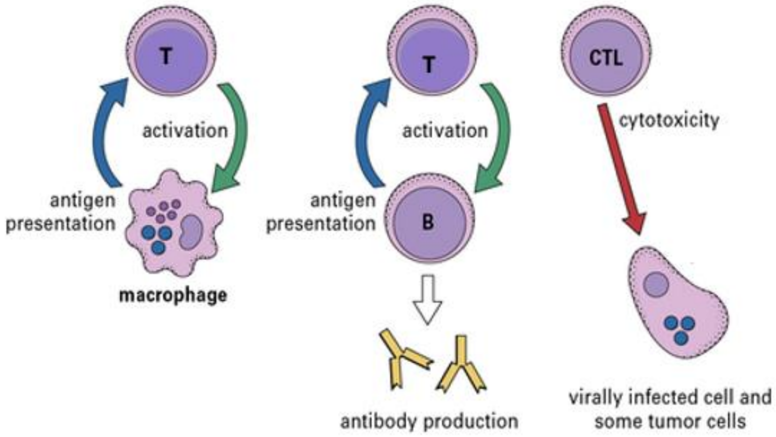

Figure 2: T lymphocyte orchestrated immune response against pathogen.
T lymphocytes can be specifically activated, via their pathogen specific TCR, by a specialised antigen presenting cell (APCs) such as macrophages and dendritic cells, presenting them with the exact specific pathogen antigenic motif, highly compatible to their TCR. An activated T lymphocyte will in turn secrete specific cytokines enhancing the action of antigen presenting cells, as well as the activation of pathogen-specific B lymphocytes and the secretion of pathogen-specific antibodies. Additionally, pathogen-specific cytotoxic T lymphocytes can directly identify and eliminate pathogen via their toxic secretions.

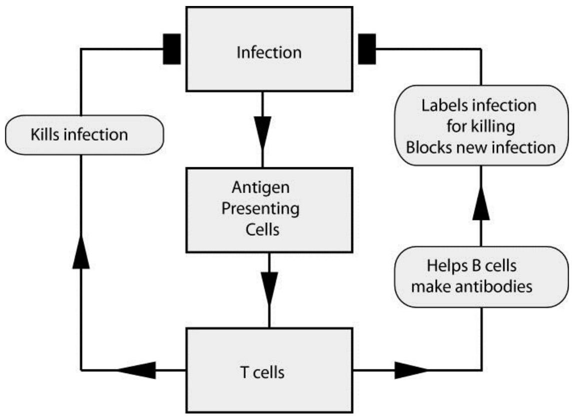

Figure 3: **The adaptive immune response to infection**

Infection, detected by APCs, triggers specific T lymphocytes that co-ordinate killing and antibody production, which stop the infection. (Diagram taken from Nicholson B., 2016)

Activation of immune memory following re-exposure to pathogen.

As already mentioned, immune memory is the ability of the immune system to quickly and specifically recognise an antigen that the body has previously encountered and initiate an analogous immune response against it. Generally, memory responses are rapid secondary, and tertiary subsequent responses to this same antigen, or very similar forms of it. To understand immune memory, one would first need to understand what a primary immune response is. A primary immune response is regarded as the outcome following the first encounter of an organism with a pathogen, and it primarily involves

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the initial non-specific actions of the chemical and cellular innate barriers of the body's immune system, followed by more efficient and specific immune responses of the adaptive system.

Non-specific innate memory:

The complement system is composed of about 20 proteins that circulate in the blood and tissue fluids and provides an essential feature that complements the action of innate immune responses. Most of its proteins are normally inactive, but in response to recognition of molecular features expressed on microorganisms, these proteins become sequentially activated in an enzyme cascade where the activation of one protein enzymatically cleaves and activates the next protein in the cascade, resulting in the targeted killing of bacteria. Additionally, complement components will flag and give away pathogens, thus enhancing the phagocytic action of macrophages and neutrophils that patrol sites of usual pathogen entry. These phagocytes engulf and digest flagged pathogen, that they can also identify via TLRs expressed on their cell surface. The combined actions of the complement and the innate immune cells is almost immediate and only requires up to twelve hours to ensure control of pathogen invasion.

Studies show that innate memory is achieved via TLR-pattern-recognition, and molecular mechanisms underlying its establishment show strong involvement of transcriptional and epigenetic reprogramming of innate cells, including histone acetylation, methylation, and modulation of miRNAs, which can be shaped by environmentally induced metabolic changes (Saeed S., et al., 2014). The fact that most cells of the human body express TLRs on their surface indicates that innate memory is not a privilege attributed only to immune cells. In fact, epithelial stem cells have been also shown to retain memory of previous inflammatory challenges by displaying an enhanced wound healing capacity upon skin damage (Naik S., et al., 2017) providing scientists with important proof that innate memory is not restricted to immune cells, and that most components of the body can remember past "events of invasion".

Highly Specific adaptive memory:

In situations whereby the innate arm of the immune system is unable to establish control following the entry of a pathogen, an inflammatory response takes place during which phagocytes as well as pathogen infected cells secrete a variety of soluble chemical factors, known as chemokines and cytokines, that are respectively associated with the recruitment and activation of adaptive memory cells (T and B lymphocytes). One comes to question from where these pathogen-specific memory cells originated. At this point it is important to note that all sites of the human body are drained by the lymphatic system, that allows for antigen presenting cells (APCs) to travel to peripheral lymph nodes where they get to present encountered antigens to pathogen-specific T and B lymphocytes. Additionally, antigen can also enter peripheral lymph nodes, where it is captured by local APCs and presented to adaptive cells within the node. Figure 4 provides a diagrammatic summary of the stages following antigen entry and the launching of a specific immune response against it. A typical lymph node is divided into areas of naïve T and B cells. T cells are initially presented with antigen by incoming or local APCs, these being of macrophage or dendritic cell origin. These T lymphocytes possess TCRs that firmly binds to the antigen presented to them in context with the Major Histocompatibility Complex-II (MHC) molecule, expressed on the surface of any APC. Upon interactive binding, a T cell becomes successfully activated and in turn enables the activation of a naive antigen-specific B cell, that is located at adjacent germinal centers within the lymph node's architectural structure. Note that cells need to directly interact with each other, at the barriers of the different regions of the lymph node, and their activation is also facilitated by the secretion of various essential cytokines.

In continuation, an activated B cell will undergo somatic hyper-mutation and re-structuring of their BCR (also known as surface bound antibody receptor) to ensure maximum compatibility (affinity) to the antigen that was presented to them, and will differentiate into a:

- short-lived plasma cells, released into circulation and maintained for a several weeks, producing and secreting antigen-specific antibodies,
- long-lived plasma cells, deposited in the bone marrow throughout life and recruited during memory responses, and

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- memory B cells, acting as surveillance cells that circulate throughout the body in a quiescent state until specific antigen is re-encountered and triggers a potent secondary immune response.

These memory B cells respond to antigen much faster (within less than 12h), requiring lower amounts of antigen, and can even be induced in its absence by soluble cytokines secreted by other cells at a site of inflammation, in part because their BCR is already localized on rafts on their cell membrane. Subsequently, just like naïve B cells (these being cells that have not encountered their antigen yet), memory B cells can ingest antigen and express it onto their cell surface, presenting this to helper T cells, receiving thus activation and the ability to undergo expansion and differentiation into antibody producing plasma cells.

Just like memory B cells, T cells also can retain specific memory to incoming pathogens. These memory T cells can thus cut short the 'stealth phase' of pathogen replication that occurs before the initiation of antiviral responses, and mediate extremely potent effector responses, providing thus strong protection upon re-infection, even in the absence of neutralizing antibody.

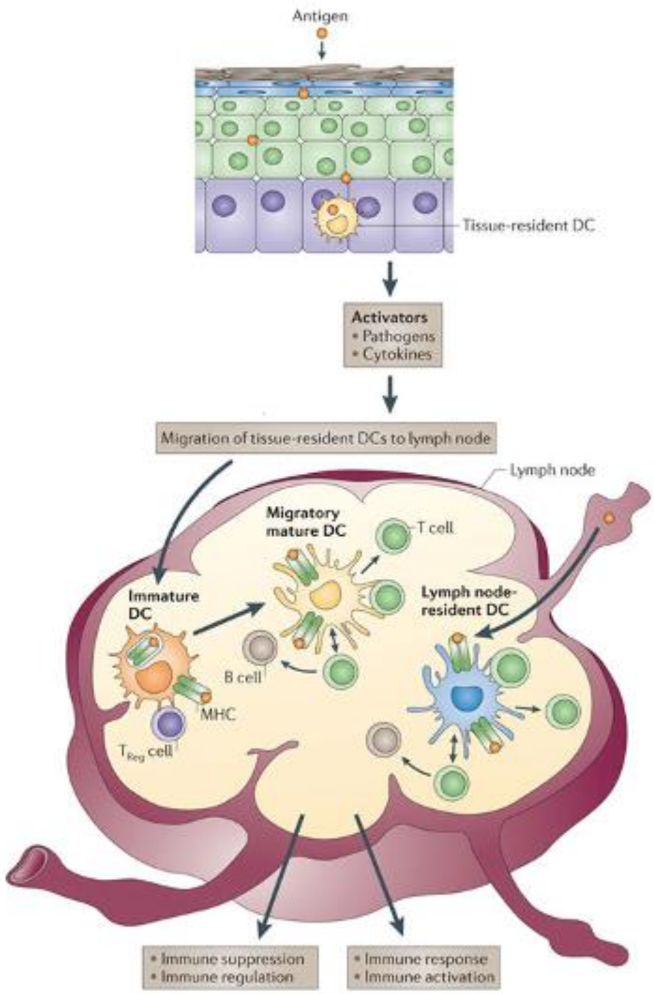

Figure 4: Launching an immune response against an incoming pathogen.

Antigens can enter lymph nodes via the lymphatics, where the antigen is captured by lymph node-resident DCs and macrophages or via tissue-resident DCs and macrophages that in turn migrate to local lymph nodes. DCs and macrophages display antigens in the context of major histocompatibility (MHC) class I and MHC class II molecules or in the context of non-classical CD1 molecules, which allow the selection of rare antigen-specific T lymphocytes (NK T cells). Activated T cells drive DCs towards their terminal maturation, which induces further expansion and differentiation of T lymphocytes into effector T cells.

(Figure from Palucka K., et al., 2012)

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Immune Memory is long-lasting.

Protective immunity is defined as the resistance to re-infection, following natural exposure to an infectious agent, or artificial exposure via vaccination. It is therefore a consequence of both innate and adaptive immunity, operating through the epigenetic changes occurring in most cells of the human body and the clonal selection of T and B lymphocytes, respectively. Protective immunity does not depend only on preformed antibody and armed effector T cells. It also depends on the establishment of a population of T and B lymphocytes that mediate long-lived immunological memory, and the given capacity of these cells to respond rapidly to re-exposure to the same antigen or newly altered antigen, that can be also transferred to naive recipients.

Memory T and B lymphocytes can be distinguished by changes in specialised receptor genes, these being their TCR and BCR respectively, due of somatic hyper-mutation, and secondary and subsequent immune responses are characterized by cells expressing surface receptors with increasing affinity for the given antigen. This is termed affinity maturation and summarised in Figure 5. Additionally, memory B lymphocytes will also give rise to antibodies with a similar increasing affinity towards the specific antigen during secondary and subsequent responses (Figure 6). It is important to note that protective immunity does not depend on, nor maintains itself through the numerous re-exposures or persistence of the same pathogen. This is most clear in examples of individuals who were themselves previously exposed to a given infectious agent and are therefore immune. Their memory is not dependent on repeated exposure to infection because of contacts with other infected individuals.

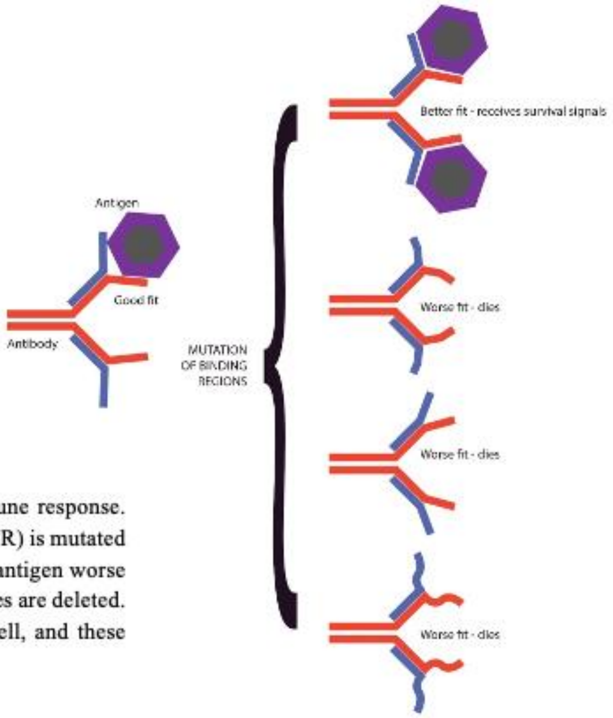

Figure 5: Affinity maturation.

Antibodies that fit the best are selected early in the immune response. The antibody receptor otherwise termed B-cell receptor (BCR) is mutated within daughter B-cells. Many of these mutations bind the antigen worse than the parent antibody, and cells producing these antibodies are deleted. Some antibodies bind the antigen better than the parent cell, and these cells are positively selected.

This was established by observations made on remote island populations, where a virus such as measles would cause an epidemic, infecting all people living on the island at that time, after which the virus seemed to have disappeared for many years. On re-introduction from outside the island, the virus would not affect the original population but causes disease in those people born since the first epidemic that have not been previously exposed to measles. Vaccination provides a means of ensuring that those circulating memory cells are updated to the new "versions" of a pathogen, while been given a head start to undergo somatic hyper-mutation to maintain their alertness to future pathogen encounters.

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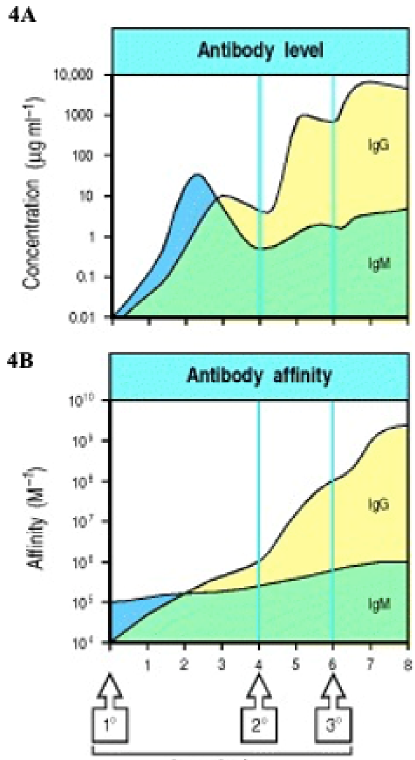

Exposure to the specific antigen

(Weeks after exposure)

Figure 6: Both antibody affinity and the amount of antibody generated increase with subsequent exposure to the same pathogen-related antigen.

Graph 4A shows the increase in the concentration of antibody with increasing time after primary, followed by secondary and tertiary, exposure (immunisation or natural re-exposure) to the same pathogen-related antigen; Graph 4B shows the increase in the affinity (strength with which an antibody binds it compatible antigen) of the antibodies produced following each exposure. This increase in affinity is seen largely in IgG antibody (as well as in IgA and IgE, which are not shown) coming from mature B cells that have undergone isotype switching (have changed antibody class from IgD which is the initial membrane bound antibody seen on naïve B cells, to either IgG, IgM, IgA or IgE) and somatic hyper-mutation (changes in the gene locus associated with the fragment of antigen binding region of an antibody) to yield higher-affinity antibodies. Although some affinity maturation occurs in the primary antibody response, most arises in later responses to repeated antigen exposure.

(Figure taken from, Janeway C. A. Jr., Travers P., Walport M., et al., 2001)

Malfunctions to Immunological memory.

When an antigen is encountered more than once, the adaptive immune response to each subsequent encounter is faster and more effective. This is a crucial feature of protective immunity, also known as immunological memory, and it is specific towards a particular antigen, as well as long-lived. As previously mentioned in subsection 6.4, immunological memory involves both the adaptive and innate arms of the human immune system, but also involves the trained memory of most cells of the human body.

For an immune system to be effective it must be able to interpret changes in the environment around it and respond appropriately, by solving various issues arising (Nicholson L. B., 2016). For instance, our whole existence depends on the ability of our immune system to be able to discriminate against self and non-self-antigens. The inability to do so efficiently may lead to all sorts of issues like autoimmunity and the development of cancer. Flexibility is another characteristic of an effective immune system, allowing adaptation to strange environmental changes to effectively tackle issues such as infections and cancer that may arise at any point during cell renewal processes and can lead to the development of random unpredictable mutations that will transform a normal cell into a cancer cell. Infectious agents replicate much more rapidly than their hosts and can change their appearance to allow evasion of recognition mechanisms. An effective immune system must be alert and able to always cope with such unpredictability.

One other important feature of the human immune system is its ability to manage infections, and this is achieved through the development of protective barriers. For a pathogen to gain entry it must first breach the innate anatomical and chemical barriers that cover and protect all entries to the human body. When pathogens succeed in penetrating these defences, seeking to cause harm or co-existence with the host organism, they pose many threats, from quiet co-existence to full-blown cell destruction and death. However, the most significant feature of an immune response is the ability to retain memory of previous

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infections. This both protects from re-infection and limits the spread of infection within a community. Immune memory can be long-lasting and decays so slowly, with a half-life of approximately 3000 years, which goes well beyond life-long protection.

Rarely, but frequently, individuals are born without an effective immune system. This arises when uncommon mutations prevent immune cells from maturing, and in such cases, individuals have a very limited life expectancy. Less dangerous, but still severe, are mutations that cripple a particular arm of the immune system. There are also situations that an immune system is partly defective, for instance, individuals whose complement proteins do not operate suffer from repeated infections, or those with deficiencies in the action of their natural killer cells are highly susceptible to herpes-virus infections, those who have macrophages that cannot digest bacteria that they encounter develop recurrent abscesses and so on. The importance of efficient innate immune responses is to slow infections down, giving the rest of the immune system time to catch up, readapt and respond appropriately. Such malfunctions of innate immune response will cause "auto-inflammatory" diseases, often manifesting as spontaneous spells of illness and fever.

All above mentioned situations may lead to a defective trained-innate memory. Most common though are defects that arise in B lymphocytes, the cells solely responsible for the production of antibodies. These conditions are often X-linked, meaning that they are encoded on the female X chromosome and therefore are more common in men rather than women. There are also situations that a "stronger-responding" immune memory may lead to complications such as autoimmunity. This is observed in situations involving infections that contain cross-reactive antigens, i.e., pathogen-related antigens that mimic self-antigens, and where tissue damage is caused as immune memory is built against such cross-reactive antigens, therefore posing a threat against the organism's own organs and tissues.

Educators' implementation guide

The three activities within this learning module have been designed to provide educators and their students with the opportunity to explore, research, learn, reflect and peer teach concepts related to the general knowledge regarding innate and adaptive immune responses, the cellular and chemical components comprising each arm of immune system and how these components come to interact as to bring about immune memory and resistance to re-infection. Students are allowed to explore and understand possible undesirable outcomes of malfunctions in immune memory leading to repeated re-infections and likely outcomes of autoimmunity. The proposed learning activities are geared toward the topic of immunity, which comprises part of a general biology class for students between the age range of 12-15 year, but these proposed strategies are applicable for higher A-level, and undergraduate level biology courses if the content is scaled up. The order in which these activities should be applied follows a scaffolding approach where students acquire new knowledge at each level via performing their own research to present their peers with new concepts, and then use this to bridge their understanding to new learning.
This section includes all three proposed learning activities and descriptions of how these could be implemented as an extension to the general biology topics taught at the different stages of lower secondary education. These include:

- a Flipped-classroom activity introducing primary and secondary innate and adaptive immune memory,
- an in-class short presentation of collaborative work on a selected topic involving immune memory,
- the building of concept maps of the events leading to established innate and adaptive immune memory.

All three activities will ensure that students achieve a basic understanding of the different components of the immune system that are associate with immune memory and how these interact with each other to bring about fast and effective memory responses following re-encounter with the same or mutated pathogens.

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Flipped-classroom activity: introducing primary and secondary innate and adaptive immune memory.

Learning and understanding immunology require the engagement of educators and students with new vocabulary and some examples of challenging biological concepts. Stranford A. S. et al., (2020) have found that biology students who regularly spend time before class dealing with new terminology and challenging concepts come to class more prepared to ask interesting, good questions, practice their skills, and apply their self-acquired new knowledge in higher-level thinking endeavours. Students participating in well-designed, pre-class preparation activities, results in being more productive during their class experiences when presented the given topic by their educator. Furthermore, the Flipped-classroom approach aids students in their understanding of challenging concepts, through the reinforcement of pre-class material in class, and helps to entrain an incremental work ethic as opposed to the usual cramming observed amongst young learners.

In this first learning activity, students are provided with a series of online video links to watch prior their actual class introduction, related to the concepts of immune memory. This constitutes their preparation for answering questions shortly before class, where they are requested to submit their answers to these pre-class questions online, 24 hours prior to the class meeting (Stranford et al., 2020). The student responses are used by the educator to provide whole-class feedback and to better focus the in-class plan on the collective needs of their students, transforming their classroom from educator-dominated to student-centred (Simkins S. M. M. et al., 2010). In this way, bidirectional feedback occurs to suitably address the material that is delivered, generating an ideal feedback loop where in-class and outside-of-class work is highly connected, and where the educator is consistently aware of the level of student engagement and understanding. The learning activity assignments can vary, from questions that probe basic vocabulary or the application of concepts, to real-world problems or queries about the assigned online videos. It is ideal to include questions that highlight common confusion and misconception so for the educator to be able to diffuse any issues during the actual delivery of the topic. Examples of such are provided in the section that follows.

<u>Learning objectives</u>

- Learn about the two arms of an effective immune system, innate and adaptive,
- learn about the cellular and molecular components of each arm,
- be able to identify the important cellular and molecular components in each,
- be able to identify and recall the function of each of these components and how they come to interact to bring about immune memory and prevent reinfection,
- be able to explain in simple terms how immune memory arises following primary exposure to a pathogen and how this takes over following future exposure to the same or similar forms of pathogen.

Time requirements

- Students are provided with three online video links to watch, a day prior to their introduction to this activity. Each video is approximately 9-minutes long, requiring from the students approximately 30-minutes time to watch.
- After watching the related series of online videos, students are requested to answer a series of targeted questions and submit their answers online prior to their next day's lesson. This should take no longer than 15 minutes.
- The educator needs to prepare an online questioner for their students, following a selection of the suggested questions found within this activity. These could be in the form of multiple choice or structured questions or a combination of both. Students should be provided with these questions 24h prior to their classroom activity.

Description of activity sequence / Educator's Instructions

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- The educator asks all students to watch at home a series of three online video links or listen to a podcast

  (**DER5**: https://www.exploratorium.edu/audio/drama-immune-system). All these explain the concept of innate and adaptive immunity, how the arms of innate and adaptive immunity work together to protect against infection and how immune memory is established to prevent re-infection.

- The educator prepares a series of questions that will allow them to assess their students' level of outside-classroom learning and understanding on the given topic.

- The educator constructs their lesson plan based on the student needs arising from the outcome of their assessment.

Examples of pre-class questions that can be used for this activity:

For 1st online video: Emergency immune response

1. (True/False) Innate immunity involves soluble products and is a part of humoral (antibody-associated) immunity, while adaptive immunity involves the work of B and T cells, or cell-mediated immunity. Please provide a brief rationale for your choice.
2. (True/False) Adaptive immunity is engaged during both a primary and a secondary immune response. Please provide a brief rationale of your choice.
3. (True/False) All antibodies produced during an immune response can stop a virus from entering the bodies epithelial cells. Please provide a brief rationale of your choice.
4. (Optional) Do you have any questions from this part of the viewing preparation for class? Please be as specific as possible.

For 2nd online video: Do cells remember?

1. (True/False) Immune memory is only linked to the adaptive immune system, which includes T and B cells. Please provide a brief rationale of your choice.
   * For this question students will not be aware on the memory mechanisms of the innate immune system. This can be introduced by the educator as part of their lesson planning.
2. (True/False) Adaptive immune memory requires the combined action of both memory T and B cells. Please provide a brief rationale of your choice.
3. (True/False) Immune memory can be only achieved through the concept of vaccination, using either fractions of a virus or an attenuated (weak form) of this virus. Please provide a brief rationale of your choice.
4. (Optional) Do you have any questions from this part of the viewing preparation for class? Please be as specific as possible.

For 3rd online video: Why do immune systems forget?

8. (True/False) The immune system of elderly people forgets of past infections. Please provide a brief rationale of your choice.
9. (True/False) Immune memory is short lived and needs continuous boosting. Please provide a brief rationale of your choice.
10. (True/False) Viruses can escape immune memory by mutating their genetic makeup. Please provide a brief rationale of your choice.
11. (Optional) Do you have any questions from this part of the viewing preparation for class? Please be as specific as possible.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

From the website of British Society of Immunology:

- Online Video 1: Emergency response

  DER6: https://www.youtube.com/watch?v=g_RZWDBFJjI

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- Online Video 2: How do cell remember?
  DER7: https://www.youtube.com/watch?v=IUEWpHAbAGE
- Online Video 3: Why do immune systems forget?
  DER8: https://www.youtube.com/watch?v=kN0WROnxaCg
- Other online useful links:

  DLO3: https://www.playfactile.com/
  DLO4: https://www.gingerlabs.com/
  DER9: https://www.khanacademy.org/science/high-school-biology/hs-human-body-systems/hs-the-immune-system/a/intro-to-viruses
  DER10: https://www.exploratorium.edu/search/immunity
  DER5: https://www.exploratorium.edu/audio/drama-immune-system

Assessment/evaluation of learning outcomes

- Student groups are asked to answer a series of pre-class questions and provide a simple explanation of the rationale for their choice of response.
- Student answers are assessed by their educator prior to the introduction of the topic allowing them to assess the level of learning and understanding during this outside-classroom activity.
- The educator can plan their teaching of the topic, focusing more on the challenges and needs of their students.

In-class short presentation of collaborative work on a selected topic involving immune memory.

This learning activity, that continues from the previous Flipped-classroom activity, requires that the lesson time is divided into sections, with the educator sharing some in-class presenting time with their students. For instance, the educator might set the stage for the topic to be presented entirely by their students, who shall be in groups and given some of the material to deliver to their peers. Sometimes, the educator will need to interfere to emphasize the main points that have been made by each student group and offer a summary of conclusions. This approach is particularly useful when the subject involves presenting information in the form of a sequence of similar, but slightly different cells and molecules or events occurring during immune memory mechanisms. When student groups are responsible for different parts of the lesson the perceived “sameness” of the material is broken up, helping the students to associate cells, molecules, and biochemical events with different people, and acting as an aide memoire (Stranford A. S. et al., 2020).
The educator could introduce the overall concept of innate and adaptive immunity and then delved into a discussion of how cell members of the two arms of the immune system work together to bring about immune memory. Student groups can then take up the story and present their selected subtopics sharing their acquired knowledge with the rest of the class, referring to concepts of:

- Components of the innate immune system
- Components of the adaptive immune system
- Primary immune response against first encounter with a pathogen
- Secondary immune response following re-infection
- The time span of immune memory to an invading pathogen

Designing and delivering these mini lectures gives the students (usually much needed) additional experience and confidence that they have grasped the newly acquired knowledge, that are able to present to a group of peers. Students should be introduced to different presenting approaches to demonstrate their acquired learning towards the given topic, including preparation of a poster, use of short video, structuring of lists, diagrams, and other creative approaches, other than just PowerPoint presentations that most times are misused by students who get carried away by mechanically copying and pasting information of the internet. This will also help the educator to assess the individual and overall level of understanding of their students.

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Learning objectives

- Learn how to perform their own research on their chosen topic and prepare for it before they enter the classroom.
- Learn to summarise and present important facts regarding immune memory.
- Will be able to develop a skill set for effective presentation and communication of their acquired knowledge.

Time requirements

- Student groups should be given a week to prepare for their chosen presentation topics, allowing for required communication and collaboration with their peers.

Description of activity sequence / Educator's Instructions

The educator should provide their students with a list of topics to choose from and to prepare short 5–10-minute presentations (poster, lists, diagrams, video, etc.)
The topics provided to students should be relevant to the previous activity, focusing on the mediators of innate and adaptive immunity and how are these collaborate and are associated with the establishment of immune memory.
Examples of topic presentations could include:

1. Introducing the cells and molecules of the innate immune system
2. The cells and molecules of the adaptive immune system: how these are involved in primary immune responses.
3. Innate immunity and emergency responses
4. Primary versus secondary immune response
5. Innate versus adaptive immune response
6. Immune memory is linked to secondary response
7. The innate immune response and how this adds to the establishment of immune memory.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

Online links that could be send to students:

- Fighting infection by clonal selection:
  DER11: https://youtu.be/HUSDvSknIgI
- Immune encounters: **DER12:**
  https://www.immunology.org/sites/default/files/Immune%20Encounters.pdf
- Educational illustrations: **DLO5:** https://www.immunology.org/public-information/immunology-related-activities-and-resources/infectious-educational-illustrations

Assessment/evaluation of learning outcomes

- Student presentations are assessed by their educator prior to the lesson allowing them to assess the lever of learning and understanding during this outside-classroom preparation activity.
- The educator can prepare a series of questions to assess the level of understanding of their students following each group's presentation.
- Following assessment of the presenting material, all groups are asked to collaborate to come up with one final presentation that they are to present during a science forum organised at their local school community, including peers, teachers, parents and selected academic specialists in the fields, leading to an open discussion on the topic.

Building concept maps of the events leading to established innate and adaptive immune memory.

When studying any discipline for the first-time students lack cognitive tools that they could use to "manage" the new facts and ideas they encounter. Lacking a framework within which to organize their new acquired knowledge, students can become overwhelmed and feel like they are swaying in a sea of unrelated facts. The use of concept maps has always been a first-time challenge to most students, but in

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fact, mastering the correct use of this approach is proven to be extremely helpful in students being able to synthase and model their recently gained knowledge, to merit continued use in science related classes. A concept map typically represents each idea, for instance an organ such as the lymph node, a cell such as a lymphocyte, or a secreted molecule such as an antibody, as a shape, joined to other shapes by lines that indicate the conceptual connection between them. These lines can be labelled with phrases that are used to describe the relationship between the linked shapes. For example:

1. an epithelial cell infected with a viral pathogen
2. will secrete appropriate chemokines
3. to signal for the recruitment of neutrophils
4. and macrophages to the side of infection,
5. which would in turn phagocytose the pathogen
6. and present to antigen-specific memory T helper cells
7. that would activate antigen-specific memory B cells
8. to secrete antigen specific antibody.

This provides a single chain of events following infection with pathogen (Figure 7). Such a technique is particularly well-suited for teaching challenging concepts to students, such as immune memory, that include various cells, molecules, and difficult terminology. Students could be provided with a list of term from which they could select the most appropriate terms to generate their concept maps.

Learning objectives

- Be able to manage their newly acquired knowledge from previous activities 1 and 2 into a simple structured concept map, summarising the main points.
- Be able choose correct terms and action phrases from a list to construct their own concept maps of innate and adaptive immune memory responses against re-invading pathogen, following subsequent re-infection or/and vaccination.
- Develop collaborative and communication skills as they will have to work within groups.

Time requirements

- This could be a 30-minute classroom activity. Students can be provided with the list of terms to either copy or cut out and use to construct their concept maps.

Description of activity sequence / Educator's Instructions

The educator should provide their students with a list of terms and action phrases to use to construct their concept maps. For example:

Cells:

Plasma B-cell | Memory T-cell | Macrophage | Epithelial cell | Neutrophil
Natural Killer cell | Naïve B-cell | Helper T-cell | Memory B-cell
Dendritic cell | Naïve T-cell | Pathogen

Molecules:

Cytokines | Chemokines | Antibodies | Degrading Enzymes | T-cell Receptor
B-cell Receptor | Toll-like Receptor | Antigen: MHC-Receptor complex

Action phrases:

Antigen presentation to | Phagocytosed by | Activation of | Differentiation into
Proliferation | Migration to | Leading to innate Immune memory | Signalling for
Secretion of | Leading to adaptive Immune memory | Recruitment of
Infection of | Opsonisation of

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Students are asked to colour the terms and action phrases of the innate and adaptive immune memory with a different colour.
Arrows connecting terms of the same arm of immune system (i.e., innate components) should be in the same colour as that initially selected. Arrows interconnecting innate with adaptive immune memory components should be drawn with a different colour.
Completed concept maps can be displayed withing the classroom, allowing peer review and discussion.

Digital Learning Objects (DLO) / Digital Educational Resources (DER)

- Fighting infection by clonal selection:
  DER11: https://youtu.be/HUSDvSknIgI
- Immune encounters: **DER12**:
  https://www.immunology.org/sites/default/files/Immune%20Encounters.pdf
- Educational illustrations: D**LO5**: https://www.immunology.org/public-information/immunology-related-activities-and-resources/infectious-educational-illustrations

Assessment/evaluation of learning outcomes
Educator can visually assess the understanding of their students.

School Research Project for Educational Scenario:

Research management, design, and administration:
This final research project comes to conclude on the sequence of all previous activities, where the educator poses the question of:

> "Does long-lasting immunological memory provide protective immunity, following subsequent virus reinfection?"

Methodology/Implementation:

Session 1:

Challenge: Flipped classroom introducing primary and secondary innate and adaptive immune memory.

- Students are provided with three online video links to watch, a day prior to their introduction to this activity, and requested to answer a series of targeted questions and submit their answers online prior to their next day's lesson.
- The educator prepares an online questionnaire for their students, following a selection of the suggested questions found within activity 1. These could be in the form of multiple choice or structured questions or a combination of both.

Student answers are assessed by the educator prior to the introduction of the topic allowing them to assess the level of learning and understanding during this outside-classroom activity. This allows the educator to plan their teaching of the topic, focusing more on the challenges and needs of their students

Session 2:

Challenge: In-class short presentation of collaborative work on a selected topic involving immune memory.

- Students are allocated into groups and are given a week to prepare their chosen presentation topic, allowing for required communication and collaboration with their peers.
- The educator provides the students with a list of topics to choose from and to prepare short 5–10-minute presentations (poster, lists, diagrams, video, etc.)

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The topics provided to students are relevant to previous activity 1, focusing on the mediators of innate and adaptive immunity and how are these collaborate and are associated with the establishment of immune memory. Examples of topic presentations could include:

a) Introducing the cells and molecules of the innate immune system
b) The cells and molecules of the adaptive immune system: how these are involved in primary immune responses.
c) Innate immunity and emergency responses
d) Primary versus secondary immune response
e) Innate versus adaptive immune response
f) Immune memory is linked to secondary response
g) The innate immune response and how this adds to the establishment of immune memory

Student presentations are assessed by their educator prior to the lesson allowing them to assess the lever of learning and understanding during this outside-classroom preparation activity. The educator can prepare a series of questions to assess the level of understanding of their students following each group's presentation.

Following assessment of the presenting material, all groups are asked to collaborate to come up with one final presentation that they are to present during a science forum organised at their local school community, including peers, teachers, parents and selected academic specialists in the fields, leading to an open discussion on the topic.

Session 3:

Challenge: Building concept maps of the events leading to established innate and adaptive immune memory.

- Students are provided with the list of terms to either copy or cut out and use to construct their own concept maps.

Cells:

Plasma B-cell | Memory T-cell | Macrophage | Epithelial cell | Neutrophil
Natural Killer cell | Naïve B-cell | Helper T-cell | Memory B-cell
Dendritic cell | Naïve T-cell | Pathogen

Molecules:

Cytokines | Chemokines | Antibodies | Degrading Enzymes | T-cell Receptor
B-cell Receptor | Toll-like Receptor | Antigen: MHC-Receptor complex

Action phrases:

Antigen presentation to | Phagocytosed by | Activation of | Differentiation into
Proliferation | Migration to | Leading to innate Immune memory | Signalling for
Secretion of | Leading to adaptive Immune memory | Recruitment of
Infection of | Opsonisation of

This way, the educator can visually assess the understanding of their students.

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Development process:

The project is based on guided research about the workings and malfunctions of human immunological memory. The three sessions of activities will be supervised by the educator and developed by the students, with scheduled moments for checking their work development.

Teaching-learning process milestones:

- Learn about the two arms of an effective immune system, innate and adaptive,
- Learn about the cellular and molecular components of each arm,
- Identify the important cellular and molecular components in each,
- Identify and recall the function of each of these components and how they come to interact to bring about immune memory and prevent reinfection,
- Explain in simple terms how immune memory arises following primary exposure to a pathogen and how this takes over following future exposure to the same or similar forms of pathogen.
- Learn how to perform their own research on their chosen topic and prepare for it before they enter the classroom.
- Learn to summarise and present important facts regarding immune memory.
- Develop a skill set for effective presentation and communication of their acquired knowledge.
- Manage newly acquired knowledge from previous activities 1 and 2 into a simple structured concept map, summarising the main points.
- Choose correct terms and action phrases from a list to construct their own concept maps of innate and adaptive immune memory responses against re-invading pathogen, following subsequent re-infection or/and vaccination.
- Develop collaborative and communication skills as they will have to work within groups.

Teaching-learning process for school project (summary):

1. Learning and understanding new vocabulary and some examples of challenging biological concepts
2. Bidirectional feedback between the educator and the students to suitably address the material that is delivered.
3. Generation of an ideal feedback loop where in-class and outside-of-class work is highly connected, and where the educator is consistently aware of the level of student engagement and understanding.
4. Introduction to different presenting approaches
5. Students demonstrating their acquired learning towards the given topic, including preparation of a poster, use of short video, structuring of lists, diagrams, and other creative approaches, other than just PowerPoint presentations that most times are misused by students.
6. Construction of concept maps

Organization of the open schooling event:

Following completion of the second session and assessment of all presentation material, all groups will be asked to collaborate to come up with one final presentation that they are to present during a science forum organised at their local school community, including peers, teachers, parents and selected academic specialists in the fields, leading to an open discussion on the topic.

Data Analysis and Reporting

- Demonstration of acquired knowledge from being exposed to specific material prior to teaching
- Collaborative work and preparation of in-class presentations
- Collaborative work and presentation of final presentation material during a formal school science forum
- Final topic-specific open discussion.

Target Audience for Recommendations

- peers, teachers, parents and selected academic specialists in the fields

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List of Digital Learning Objects (DLO) and Digital Education Resources (DER)

	Activity/Lesson No.	Digital Learning Object (DLO)	Digital Educational Resource (DER)
Educational Scenario 5: Workings and malfunctions of human Immunological memory	1-Flipped-classroom activity introducing primary and secondary innate and adaptive immune memory	**LO3**: https://www.playfactile.com/ **LO4**: https://gimgerlabs.com/	DER5:https://www.exploratorium.edu/audio/drama-immune-system DER6: https://www.youtube.com/watch?v=g_RZWDBFJjI DER7:https://www.youtube.com/watch?v=IUEWqHAbAGE DER8: https://www.youtube.com/wtach?v=kN0WROnxaCg DER9: https://www.khanacademy.org/science/high-school-biology/hs-human-body-systems/hs-the-immune-system/a/into-to-viruses DER10: https://www.exploratorum.edu/search/immunity
	2-In-class short presentation of collaborative work on a selected topic involving immune memory	**LO5**: https://www.immunology.org/public-information/immunology-related -activities-and-resources/infectious-educational-illustrations/	DER11: https://youtu.be/HUSDvSknIgI DER12: https://www.immunology.org/sites/default/files/Immune%20Encounters.pdf

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Educational Scenario Impact Assessment Questionnaire

Context: Basic knowledge of long-lasting immunological memory and protective immunity provides an essential means of simplifying and improving the understanding of challenging topics such as the spreading of communicable disease and prevention of pandemics. The topic of "Workings and malfunctions of human Immunological memory" provides educators and their students with the opportunity to expand their existing knowledge by learning about important concepts in Immunology, including the innate and adaptive arms of the human immune system, the cellular components involved in the establishment of immune memory, and the interactions that bring about protective immunity and preventing re-infections. The topic clarifies how immune memory is independent of the frequency or persistence of re-infection, being a long-lasting feature involving both specialised cells of the adaptive and innate immune systems, that also depends on all the rest of the cells of the human body. High school students are therefore exposed to immunological concepts related to the immune memory mechanisms in place to minimise and prevent the spreading of disease, preventing thus the occurrence of epidemics and possible pandemics.

Additional information: the topic is provided in the specifications of an educational scenario of the "Workings and malfunctions of human Immunological memory".

The questions that follow provide and assessment for the impact of the given learning scenario on the knowledge acquired and skills acquired by the students throughout the teaching of this topic and the effect of this topic on their beliefs, attitude, and behaviour.

As part of acquired knowledge students can:	
1. Identify immunological memory and its importance in ensuring survival upon reinfection.	1.1. What is immune memory? A. The ability of immune cells to retain memory of past infectious agents and their associated antigens and respond fast. B. The ability of immune cells to retain memory of past infectious agents and their associated antigens and respond slow. C. The initial ability of immune cells to respond to new infectious agents and their associated antigens and respond fast. 1.2. An antigen: A. is a molecular structure that will always stimulate an immune response B. is a molecular structure that will sometimes stimulate an immune response C. is a molecular structure that will never stimulate an immune response 1.3. An effective immune response against a pathogen is achieved: A. by the combined action of both acquired innate and adaptive immune memory. B. primarily by the acquired adaptive immune memory C. primarily by the acquired innate immune memory
2. Recognize the key cell players of immune memory	2.1. Which comprise cells of the adaptive immune system, involved with specialised responses against specific antigens? A. T cells and B cells B. T cells, B cells and macrophages C. Macrophages 2.2. Immune memory is: A. Specific to a given pathogen B. General to all pathogens C. General to a group of pathogens 2.3. Immune memory is brought about by: A. The direct action of pathogen-specific antibodies only B. The direct action of pathogen-specific antibodies and pathogen-specific cells C. The direct action of pathogen-specific cells only 2.4. Phagocytic cells can also remember past pathogens by identifying: A. Conserved molecular structures on the surface of a groups of pathogens. B. Conserved molecular structures on the surface of a specific pathogen only C. Altered molecular structures on the surface of a group of pathogens.

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3. Understanding how immune memory is activated and brought about	3.1. Immune memory can be: A. Innate B. Adaptive C. Both 3.2. Which of the following is true about innate immune memory? A. innate memory involves immune cells and other body cells B. innate memory is restricted to immune cells only C. innate memory is restricted to body cells only 3.3. Antibodies responsible for bringing about immune memory are secreted by which type of cell: A. B cells B. T cells C. Macrophages 3.4. Immune memory to incoming pathogens begins: A. the lymph nodes that are local to the side of infection B. the bone marrow C. the blood circulation 3.5. Immune memory is: A. Long lasting B. Temporary C. Does not exist
4. Understanding the issues of immune memory malfunctions	4.1. Which is not considered an immune memory malfunction? A. Hypercholestolaemia B. Autoimmune disease C. Natural killer deficiency
As part of skills being gained/developed students can:	
1. Identify the two main arms of the immune system involved in immunological memory and their cellular and molecular components	1.2. Immune memory depends on: A. The innate arm B. The adaptive arm C. Both the innate and adaptive arm 1.3. Innate immune memory involves the action of: A. Macrophages/ dendritic cells/ epithelial cells B. Macrophages/ B cells/ epithelial cells C. B cells/ T cells/ epithelial cells 1.4. Cells involved in adaptive immune memory include: A. B and T cells B. B cells only C. T cells only 1.5. Specific immune memory involves the: A. Secretion of pathogen specific antibodies by B cells and the specific direct killing by T cells B. Secretion of pathogen specific antibodies by B cells and the specific direct killing by phagocytic cells C. Secretion of non-specific antibodies by B cells and the specific direct killing by T cells
2. Identify and recall the function of each of the components of the immune system and how they come to interact to bring about immune memory and prevent reinfection	2.2. The cells of the innate immune system include: A. Macrophages, dendritic cells, Natural Killer cells, basophils, eosinophils, neutrophils B. Macrophages, dendritic cells, Natural Killer cells, basophils, eosinophils, B cells C. Macrophages, dendritic cells, Natural Killer cells, basophils, T cells, B cells 2.3. The cells of the immune system responsible to produce pathogen specific antibodies are: A. B cells B. T cells C. Macrophages 2.4. The complement system is a component of the innate immune system, composed by 20-proteins that can: A. Stick to the pathogens surface and promote the targeted killing of a pathogen B. Activate the cells of the adaptive immune system C. Are expressed on the surface of immune cells

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	2.5. Toll-like receptors are involved in immune memory and are found on the surface of: A. All cells of the body B. Only on macrophages and dendritic cells C. Only on B and T cells 2.6. Immune memory to a specific pathogen is: A. Long lasting throughout lifetime B. Short lived and up to 6 months C. Short lived and up to a few weeks
3. Identify that immune memory arises following primary exposure to a pathogen and this results in faster and stronger immune responses to the same pathogen.	3.1. Following primary exposure to a pathogen, re-exposure will result in: A. Faster and stronger immune responses B. Slower and weaker immune responses C. Slower and weaker immune responses
4. Perform own research on their chosen topic regarding immune memory, learn to summarise and present important facts regarding immune memory.	4.1. I feel able to identify scientific sources to use in my research 1) strongly disagree… 5) strongly agree. 4.2. I feel confident to prepare a poster/power point presentation of my chosen topic involving immune memory. 1) strongly disagree… 5) strongly agree 4.3. I can confidently summarise the important facts related to immune memory and present these to my peers 1) strongly disagree… 5) strongly agree
5. Demonstrate understanding and being able to describe the series of events leading to immune memory towards re-encounter with pathogen.	5.1 I can understand the steps following re-encounter with the same pathogen, and how these can lead to faster and stronger responses as a result to immune memory. 1) true... 5) false. 5.2 I can outline and describe briefly these steps leading to immune memory responses following a second exposure to the same pathogen. 1) true... 5) false
6. Development of research, collaborative, and communication skills	6.1 I feel able to identify scientific sources relevant to the consent of immune memory. 1) strongly disagree… 5) strongly agree. 6.2 I know the main sources to consult about immune memory. 1) strongly disagree… 5) strongly agree. 6.3 To find scientific information about immune memory I should consult the following sources. D. researchers, scientific publications, WHO and CDC data bases. E. newspapers, google, YouTube F. friends, journalists, Facebook, other social media. 6.4 I feel able to identify the main problems my community faces when it comes to understanding difficult concepts such as immune memory and how this is the outcome of less severe symptoms following re-exposure to a pathogen. 1) false… 5) true. 6.5 I feel capable of proposing actions that address how to promote immune memory, either using effective vaccination, or testing for pre-existing memory following natural infection. 1) true... 5) false.
As part of Beliefs, Attitudes and Behaviour, there are no correct or incorrect answers; we are only interested in knowing the students' perspective on the topic introduced.	
1. Believes that is important to contribute to global efforts for tackling future pandemics.	1. My acquired knowledge and understanding of immune memory will increase the chances of success of the global efforts for preventing a future pandemic. 1) strongly disagree… 5) strongly agree. 2. I am physically capable of adopting actions (i.e., school, community presentations) that contribute to the efforts of increasing awareness about immune memory and how this is achieved and can help in decreasing the spread of disease that could lead to future pandemics (i.e., vaccination strategies, testing for specific immune memory against a specific pathogen etc.). 1) extremely unlikely... 5) extremely likely.

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	3. My family and friends think that I should adopt actions that contribute to increase awareness about immune memory and add to the global efforts for tackling future pandemics. 1) Extremely unlikely... 5) Extremely likely.
2. Believes that learning about immune memory and that the human immune system responds fast and effectively to even the most powerful viruses following re-exposure can lead to positive outcomes at the community level when it comes to evaluating severity levels.	4. To learn about how immune memory works and how this could help in protecting people from severe symptoms and prevent the uncontrolled spreading of a disease, will lead to positive outcomes at my community. 1) strongly disagree… 5) strongly agree. 5. My community thinks that increasing awareness about difficult concepts such as that of immune memory and its contribution to lowering disease severity, will bring positive outcomes. 1) Extremely unlikely... 5) Extremely likely.
3. Has intention to perform sustainable behaviours in his/her lifestyle.	3.1. I will try to update myself with current information regarding highly contagious virus variants. 1) Extremely unlikely... 5) Extremely likely. 3.2. I plan to update myself about updated versions of vaccines available for communicable diseases. 1) Strongly disagree... 5) Strongly agree. 3.3. I plan to enforce my immune memory to current communicable diseases by being up to date with my vaccinations. 1) Strongly disagree... 5) Strongly agree.
4. Attitude toward learning about how immune memory works and its implications towards controlling the severity of a communicable disease.	5. For me to achieve such knowledge is: Harmful : : : : : : beneficial Pleasant : : : : : : unpleasant Good : : : : : : bad Worthless : : : : : : valuable Enjoyable : : : : : : unenjoyable

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6. Specifications for an educational scenario on the topic "The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling".

Main partner responsible

University of Ioannina, Ioannina, Greece

Overview

This educational scenario focuses on the mathematical modelling of an epidemic - the SIR modelling in particular - and the importance of non-pharmaceutical interventions for the promotion of public health. Students are initially introduced to the distinction between communicable and non-communicable diseases and express their conceptions about the function and importance of certain non-pharmaceutical interventions. Afterwards, they are concerned with various transmission routes and the way they affect the needed interventions. Through interactive maps and timelines students study the spatial and temporal evolution of endemic, epidemic and pandemic diseases in the past twenty years. Then, students are involved in successive inquiry processes, with a lot of scaffolding at answering the assigned questions at the beginning, but with complete independence in the end. During their inquiries students use three SIR simulations from the simplest to the more realistic one, and they study questions concerning the effect of epidemiological parameters (e.g. infectivity, incubation period, mortality, asymptomatics percentage), societal structure (existence of central locations, travelling and transport, healthcare system capacity) and non-pharmaceutical interventions (social distancing, quarantining, mask use, distance education) on the epidemic curve. Students, then, work in small groups and carry out a three-part school project. The first part is the design of a viable plan for the management of an epidemic outbreak by using the SIR models and authentic epidemic data. The second part concerns the input of authentic COVID-19 data to the SIR models and the comparison between the model outcomes and the real COVID-19 values. The third is the making of a short-scale informative material targeting the general public, regarding the importance of applying non-pharmaceutical interventions during an epidemic. Student groups present their work and findings to one another and discuss about them.

Scientific content and its relevance to public health education

- SIR modelling as a quite common way of describing an epidemic and as a case of a model used in authentic scientific research.
- Visualization and active inquiry of epidemiological parameters such as cases, deaths, asymptomatic cases, infectivity, healthcare system capacity and the epidemic curve, which are commonly referred to in the public sphere, during an epidemic.
- Education on the decisive importance of non-pharmaceutical interventions during an epidemic, for helping the healthcare system, and for the prevention of the spread of communicable diseases in general, as well.
- Understanding of the decisive importance personal behaviour has for the public benefit during an epidemic.

Estimated duration & relevant subjects

14 teaching hours organized in continuous two-hour periods if possible.
Designed for Biology, Science or Math classes of K7-9 grades. The scenario might also be applicable for Computer Science classes.

STEM Content

- Fundamental concepts of biomedical sciences (e.g. communicable diseases, infectivity, epidemic).

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- Function, use and nature of scientific models.
- Introduction to transdisciplinary issues, such as scientific modelling – Convergence of sciences towards handling complex problems.
- Use of mathematics in natural sciences.
- Scientific work on authentic problems.
- Authentic scientific data driven decision making.
- Critical understanding and appraisal of epidemiological issues in the public sphere (e.g. descriptive measures of an epidemic, application of non-pharmaceutical interventions during an epidemic outbreak).
- Creation of positive attitude towards scientific research and progress.

Non STEM Content: *Importance of personal civic actions for public benefit, importance of scientific work for civic decision making.*

Content glossary

Airborne disease: A communicable disease is characterized as airborne if it is transmitted through the air, mainly via tiny droplets produced by exhaling, talking, sneezing and coughing. These droplets come into a person mainly through inhaling. Some examples of airborne diseases are influenza, common cold, the COVID-19 and measles.

Asymptomatic cases: Asymptomatic cases of the disease are called the cases that although infected by a disease they do not show visible disease symptoms. Without biomedical tests they do not know if they are infected, whereas they can often transmit the disease.

Communicable/infectious disease: Communicable diseases are the diseases (which are in turn the harmful unnatural conditions for the human organism) which can be transmitted from one person to another. Communicable diseases are mainly caused by pathogens, such as bacteria, viruses, fungi and protozoa (they can be rarely caused by infectious particles, as in the case of Creutzfeldt-Jakob disease). Disease transmission can be direct (through human intercourse) or indirect (e.g., through insects or infected objects). Some examples of communicable diseases are influenza, chickenpox, malaria and the Ebola disease. On the other hand, there are non-communicable diseases, such as diabetes, phenylketonuria and Alzheimer’s disease.

Endemic disease: A disease is called endemic when it has constant presence in a region or in a population and it stays within the usual number of cases. For instance, chickenpox, rubella and measles are considered endemic in Europe.

Epidemic curve: Epidemic curve is the graphical representation depicting the cases of a disease as a function over time during an epidemic outbreak.

Epidemic/epidemic outbreak: Epidemic or epidemic outbreak is called the sudden and unexpected rise in the cases of a communicable disease within a population in a short period. The term is sometimes used for non-communicable diseases as well (e.g., obesity epidemic). Epidemic often refers to a restricted geographic region. Some recent cases are multiple Ebola epidemics in central Africa, the 2015-2016 Zika epidemic in Latin America and the 2015 MERS epidemic in South Korea.

Healthcare system capacity: Healthcare system capacity refers to the maximum limit of patients of a certain disease who can be hospitalised, or supported in general, by the healthcare system of a region.

Incubation period: Incubation period is the time from the time of infection by a pathogen until the time of the first symptoms appearing. It is the period when the pathogen multiplies within the human body until the

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pathogen population, or its actions cause symptoms. A person may or may not transmit the disease during the incubation period, depending on the disease.

Infectivity: Infectivity is the ability of a pathogen to cause infection to a susceptible person given that they have come in contact with an infected person. Infectivity depends on the biological characteristics of the pathogen and the situation of the susceptible person.

Non-pharmaceutical interventions: As non-pharmaceutical interventions are regarded all actions which can be applied to limit the spread of a disease without including pharmaceutics, like vaccines. Common non-pharmaceutical interventions include quarantining, hygiene rules, use of masks, gloves and condoms, object disinfection and insect killing.

Pandemic: Pandemic is the case of an epidemic that has spread to a great number of countries, or even continents. It usually includes a high number of cases. Resent pandemic examples include the COVID-19 and the H1N1 influenza.

Qualitative variable: A variable is called qualitative when its values are not numerical. Gender is a typical example of a qualitative variable.

Quantitative variable: A variable is called quantitative when its values are numerical. It might take all the possible values between two limits (constant variable) or it might take only certain values (discrete variable). Height is a typical example of a quantitative variable.

Quarantine: Quarantine is the limitation of the contacts of people who are considered to be infected and aims at the slowing down of the spread of the disease.

Scientific model: A Scientific model is the representation of a natural or social structure, phenomenon or process that some characteristics of the original are included in the model whereas some others are omitted. A model is less complex than the original structure, phenomenon or process, but has significant scientific or educational value. It is common for scientific models to incorporate some kind of mathematical formulation of the original. Well-known examples of scientific models are the atom models, the meteorological models and epidemiological models.

SIR (Susceptible, Infected, Recovered) modelling: SIR modelling is a very common mathematical description of an epidemic outbreak with significant predictive value. In SIR modelling the population is divided into susceptible (people who have not been infected), infected and recovered (people who have been infected and recovered). Dead are usually incorporated to recovered. The values of these three variables change through time, according to appropriate mathematical functions, and their values stand for the epidemic situation. SIR models often include a graph depicting the S, I and R variables over time.

Social distance: By the term social distance we refer to a group of non-pharmaceutical interventions and measures taken for slowing or hindering the spread of a communicable disease. Social distance includes interventions such as keeping spatial distance, hand washing and remote working.

Transmissibility: Transmissibility is the ability of transmission of a pathogen from an infected person to a susceptible, given that they have contact. Transmissibility depends on various factors including the pathogen characteristics, the situation of the susceptible person and external conditions.

Transmission route: Transmission route are the ways through which pathogens are transmitted from one person to another. Main transmission routes include direct transmission (through direct human intercourse, including sexual intercourse), transmission through infected objects, airborne transmission (through the air) and vector transmission (through animal vectors, like mosquitoes).

Pedagogical glossary

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Assessment rubric: Assessment rubric is a strictly organized assessment system with certain assessment criteria, which is used for the precise quantitative assessment of several features of an answer or a project according to certain criteria and grading scales.

Brainstorming: Brainstorming is an instructional technique with several variations, that might take place within small groups or with the participation of the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning: Collaborative learning is a teaching model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, even rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills.

Digital simulation: With the term educational digital simulations we mean the digital representation of functions, processes and phenomena which have an educational value, but they cannot usually be done in natural conditions at school for practical reasons. Through digital simulations their educative value remains, but the difficulties of their practical application are bypassed.

Inquiry based learning: By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific skills. Students make use of these skills in order to answer scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or be given them already collected. Some common inquiry skills include construction and use of models, carrying out experiments, data collection and organisation, handling of variables, data driven conclusion making and communication about scientific topics.

Models in science education: Models are important in science education and have various meanings. In this scenario we refer to educational scientific models, which are selective representations of the natural world. It is important for the students not to consider the model to be the same with the natural phenomenon represented.

Project based learning: Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, often referring to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Competences / Learning Goals

I. Knowledge (Core Concepts)
a) Transdisciplinary concepts: Scientific modelling, graphs and mathematics in science.
b) Specific content concepts: Communicable diseases, epidemic, pandemic, disease transmission route, SIR (Susceptible, Infected, Recovered) model, asymptomatic carriers, non-pharmaceutical interventions, infectivity, social distance, quarantine.

II. Skills
a) General skills: Critical thinking, reflective thinking, problem solving, decision making, collaboration and communication within small groups, presentation skills.
b) Specific skills: Use of scientific models, scientific data collection, analysis and interpretation, variable distinction and handling, scientific hypotheses testing and question answering, data-driven conclusion drawing, discussing on science topics, presentation and interpretation of scientific conclusions, use of mathematics in scientific contexts, handling of educational simulations.

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III. Attitudes (Affective domain)
a) Attitudes and values: Acknowledgment of the fact that communicable diseases constitute a global and diachronic problem, appreciation of the vital importance of non-pharmaceutical interventions for the limitation of disease spreading, appreciation of the importance of models in scientific research, shaping of positive attitude towards science during a health crisis, roughly empathizing with scientists in terms of the complex nature of their work and the necessary decision-makings, upgrading of the position of science in students' personal value systems, comprehension of the role of discussion and disagreements within the scientific community.
b) Behaviours: Considering the concepts of disease transmission and non-pharmaceutical reasoning to daily health-related decision-making, constant application of simple non-pharmaceutical interventions (e.g. fundamental hygiene rules, face mask use, condom use) for the limitation of communicable disease spread.

Classroom organisation requirements

From the 1st until the 8th teaching hour students work in groups of two, each group working on a computer. These groups are occasionally combined to form four-member groups. From the 9th until the 14th teaching hour students form four- or five-member groups which carry out the school projects.

Prerequisite knowledge and skills

- Microbial nature of contagion of communicable diseases.
- The existence of epidemics and pandemics, e.g. through historical examples, the news or the experience of living during the COVID-19 pandemic.
- Fundamental hygiene rules as non-pharmaceutical interventions for preventing the spread of communicable diseases.
- Ability to interpret mathematical graphs.
- Ease in handling digital simulations (desirable).
- Ease in making digital presentations (desirable).

School research project

Topics

A. How could an epidemic outbreak be represented in a quantitative way?
B. To what degree could a scientific model be efficient in representing precisely and confronting an epidemic?
C. How do characteristics of a communicable disease, citizen behaviour and social organization features influence the progress of an epidemic?
D. What non-pharmaceutical interventions would you choose to restrict an epidemic outbreak?

I. Research management, design and administration
Application of SIR models to propose and test public health interventions for the effective management of an epidemic outbreak.
Input of authentic data into SIR models and comparison between real data and model outputs.
Creation of informative material highlighting the importance of non-pharmaceutical interventions for the promotion of public health.

II. Data analysis and reporting
Use of educational SIR simulations for testing how effective various public health interventions would be, by changing the simulation variables.
Input of authentic data from databases into the SIR models and comparison between model outputs and the authentic epidemiological data.

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Creation of a short informative presentation for the general public, arguing for the importance of non-pharmaceutical interventions for the promotion of public health.
Preparation of a short, written report reviewing the project conclusions and presentation of the conclusion and the material produced to the rest of the class.

III. Target audience for recommendations
The rest of the class, maybe teachers and students of the entire school providing the project is presented at a school event. The parents of the students or even local authorities could also attend the event.
Some of the highest-quality informative material made by the students could be distributed to members of the local community (e.g., health structures, municipal authorities). Some of the informative material and the students' proposed action plan could be communicated via local media (printed or online press), and if the quality of the study of the model precision, or the overall project in general, is high, it could be presented in a student conference.

IV. Public debates and recommendations
Presentation of the project outcomes within a school event. If the quality of the project outcomes is high, they could be communicated through the local media, in health structures, through local governmental, municipal or educational authorities, or in student conferences.

Teacher guidance notes

- Students often underestimate the importance of non-pharmaceutical interventions (e.g. keeping on with hygiene measures, quarantine, social distancing and the use of face masks) as a way of confronting communicable disease outbreaks, and, consequently, not applying them to the degree they ought to. This phenomenon highlights a major deficiency in public health education, thus pointing out a fundamental topic of public health education.
- It is common for students to bear misconceptions concerning the nature and the function of scientific models, a common one of which is to think of the model as an exact representation of the natural phenomenon or function represented. Students often fail to make the distinction between the scientific model and the real world. For confronting such misconceptions, the use of different models of the same phenomenon are recommended as well as the notion of the limitations of each model.
- Students often have difficulties in understanding and interpreting graphs as forms of representations of natural phenomena.
- It is important to practice the ability of student teams to work independently in inquiry-based learning. Novice students may need a lot of scaffolding, but the scaffolding provided should gradually be decreased and students should be in charge of more decision making concerning their work. Different students need a different amount of scaffolding which can be provided by the teacher in the form of meaningful questions.
- Inquiry-based learning is crucial for students to practice scientific inquiry skills, apart from gaining content knowledge. These skills include proper gathering and analysis of data, formulating and testing scientific hypotheses, handling of qualitative and quantitative variables, using of scientific models, using mathematics in scientific contexts, drawing data-driven conclusions, and communicating and presenting scientific ideas.

Assessment activities

The assessment activities act complementarily to one another and aim at the close monitoring of the students' learning procedure. Some activities aim at formative and some others at summative assessment, some assess students in a quantitative and some others in a qualitative way, some aim at conceptual understandings, some at critical thinking skills, some at collaboration and communication skills and some others at affective domain assessment. They all contribute to having a multi-perspective view for each student. The teacher can omit or undermine some of the assessment activities if they think so. Some of the

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assessment actions happen as the lesson takes place without special activities done or special assessment material designed (e.g. observation of students' participation or performance at question-and-answering).

- Initial student assessment (through the first activity) concerning the function and the effectiveness of restrictive measures during an epidemic.
  Diagnostic qualitative assessment aiming at conceptual understanding and logical reasoning.
- Formative assessment of students' worksheets during the entire learning sequence.
  Formative qualitative assessment aiming at conceptual understanding and inquiry skills.
- Formative student assessment through question-and-answering techniques and through observation of student participation, collaboration and individual work.
  Formative qualitative assessment aiming at interest, participation and collaboration skills.
- Summative descriptive and quantitative assessment of the student projects outcomes and presentations according to concrete evaluation criteria (assessment rubrics).
  Summative qualitative and quantitative assessment aiming at conceptual understanding, higher thinking, inquiry, reasoning, collaboration and communication skills.
- Summative quantitative and qualitative assessment of cognitive learning objectives through a short questionnaire with close-ended questions and case studies at the end of the learning process.
  Summative quantitative and qualitative assessment aiming at conceptual understanding and logical reasoning.
- Summative quantitative assessment of students' self-referred beliefs, attitudes and behaviours through a questionnaire with Likert-scale questions at the end of the learning sequence.
  Summative quantitative assessment aiming at affective features.
- Summative quantitative and qualitative assessment of the learning procedure by the students in terms of likeability, interest, difficulty, self-fulfilment, collaboration and time management.
  Summative quantitative and qualitative assessment aiming at self-reflection.
- Reflective and metacognitive discussion with the students on the learning procedure and the final project presentations.
  Summative qualitative assessment aiming at self-reflection.

Teacher professional development actions

Teacher professional development on:
- Inquiry-based teaching and learning in accordance with the learning objective areas involved (content knowledge, inquiry skills, nature of science).
- Issues concerning the use of models in science and STEM education.
- STEM literacy aspects being promoted through the educational scenario (use of scientific models, authentic problem solving, inquiry-based learning, attitudes towards science, science within societal contexts) and the issues of scientific and health numeracy.
- Project-based teaching and learning and principles and techniques of collaborative learning.
- The utilization of Digital Learning Objects in the learning process.

Digital Learning Objects (DLOs)

A. DLOs created specifically for the needs of the PAFSE project

   I. *'Global map of communicable diseases'*
   http://photodentro.pafse.eu/handle/8586/44
   Interactive global map depicting the geographical distribution of specific endemic, epidemic and pandemic diseases during the last twenty years.
   II. *'Temporal and spatial evolution of communicable diseases'*
   http://photodentro.pafse.eu/handle/8586/34

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Interactive global map and timeline depicting the spatial and temporal evolution of specific recent endemic, epidemic and pandemic diseases. Students can study the temporal variance of cases per country for different cases of diseases.

III. *'SIR model of an epidemic'*
Simple SIR simulation, with emphasis on SIR graphs. Students can modify a restricted number of variables (e.g. infectiousness, social distancing, healthcare system capacity) and observe how the SIR graph changes.

IV. *'SIR model of an airborne disease and non-pharmaceutical interventions'*
http://photodentro.pafse.eu/handle/8586/35
Complex SIR simulation of an airborne disease. The epidemic depiction is dynamic and variables can be modified as the epidemic goes on. The SIR graph includes curves for the dead and patients in critical condition. Apart from the graph there is also a realistic graphical representation of the citizens of a city during an epidemic. Students can handle features of the disease (e.g. infectivity, disease duration, incubation period, asymptomatic percentage, mortality), societal features (e.g. healthcare system capacity), and non-pharmaceutical interventions (e.g. quarantine, remote working, remote schooling, mask use).

B. DLOs which have been taken from online resources

V. *'Transmission routes of diseases'*
https://gizmos.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=379
Simulation about transmission routes of communicable diseases. By choosing transmission route and disease infectivity, students observe the rate of infection of people in a closed room. Digital Learning Object made by Gizmos.

VI. *'SIR model of an epidemic and non-pharmaceutical interventions'*
https://prajwalsouza.github.io/Experiments/Epidemic-Simulation.html
Complex SIR simulation, including the graphical representation of people as moving spots in a box. The epidemic representation is dynamic and variables can change even during the epidemic. Students can modify various variables standing for disease features (e.g. infectivity, asymptomatic percentage, disease duration), societal organisation features (e.g. existence of central location, existence of small communities) and non-pharmaceutical interventions (e.g. quarantine, social distance, transport limitation, degree of social distancing). Digital Learning Object made by Prajwal Souza.

Supplementary Educational Resources (SERs)

I. *'Historical pandemics'*
https://www.visualcapitalist.com/history-of-pandemics-deadliest/
Infographics depicting the harshness of certain historical pandemics. Constructed by Visual Capitalist.

II. *'The SIR graph'*
https://cloud.anylogic.com/model/d465d1f5-f1fc-464f-857a-d5517edc2355?mode=SETTINGS
Dynamic visualization of an SIR graph.

III. *'The meaning of the SIR modelling'*
https://www.youtube.com/watch?v=gxAaO2rsdIs
Educational YouTube video about SIR modelling from science communication channel 3Blue1Brown. The rationale behind SIR modelling and the function of an SIR model very similar to DLO VI are presented.

IV. *'Spread of an airborne disease'*

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https://whdh.com/coronavirus/3d-simulation-shows-how-a-single-cough-can-spread-coronavirus-through-a-grocery-store/
Video visualizing the transmission of an airborne disease in a closed place, when a person coughs.

V. *'Face masks against the spread of airborne diseases'*
https://www.youtube.com/watch?v=xEp-Sdgl9AU
Informative YouTube video by Washington Post concerning the transmission of airborne diseases. The air flow coming out when exhaling or speaking is visualized with the aid of an infrared camera, and the importance of face masks for stopping the air flow is highlighted in the same way.

VI. *'Scientific modelling'*
https://www.youtube.com/watch?v=RK9m4OmFAbY
Educational YouTube video about scientific modelling by the science communication channel Tools of Science. The nature of scientific models, their importance for science and the general procedure of creation are described through examples.

VII. *'Global COVID-19 database I'*
https://covid19.who.int/table
Interactive COVID-19 database by the World Health Organisation. Students can find epidemiological data, various indices, vaccination data, and application of precautionary measures for a country and time period of their choice.

VIII. *'Global COVID-19 database II'*
https://covid19.csd.auth.gr/
Interactive COVID-19 database by the Aristotle University of Thessaloniki, Greece. Students can find epidemiological data, relevant social and demographic indices, and application of policy measures for a country and time period of their choice.

Teaching -learning activities

1st teaching hour – Students' conceptions concerning non-pharmaceutical interventions and different transmission routes of diseases

Teaching phase according to the inquiry & project based instructional model: Engagement – Externalization of students' initial conceptions – Initiation of reconstruction/completion of students' initial conceptions

- At first, students are engaged with the topic of the learning sequence by the exemplification of some historical (both old and modern) epidemics and pandemics. At this point infographics from SER I could be utilized.
- During the engagement phase, the distinction between communicable and non-communicable diseases should also be made clear through explicit examples from both categories, which are already familiar to students from their daily life. A short brainstorming could be carried out during which students mention examples of diseases and classify them as communicable and non-communicable. It is stated that the learning sequence will focus exclusively on the case of communicable diseases.
- During the stage of the externalization of students' ideas, they are given some examples of non-pharmaceutical interventions (e.g., quarantine, use of face masks, social distancing, lockdowns, travelling limitations, use of condoms, disinfections and disinfestations) that have been applied as precautionary measures in real cases of epidemics and pandemics. Non-pharmaceutical interventions are emphasised because they can be applied at every case of communicable disease regardless of the biomedical progress has been made. Students express their ideas on paper about the possible way each intervention works and their estimation on how effective and realistic it would be. In order to save time, each student can be assigned just with a few interventions and not with all of them.

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- Next, the phase of inquiry begins aiming at the completion and reconstruction of students' initial conceptions. They use DLO V to study the effect transmission route has to the infection rate through structured inquiry. After choosing transmission through food or human-to-human transmission they note the time needed for 50% and 75% of people to get infected. Each try is carried out in three repetitions. They also study the cases of a disease with low in contrast to a disease with high infectivity. Students are introduced to experimental inquiry with the aid of a digital simulation and the notions of independent and dependent variables.
- Afterwards, the entire class participates in a brainstorming process mentioning different disease transmission routes, other than the ones covered by DLO V. The teacher adds routes that have not been expressed (e.g., by air, by respiratory droplets, by water, by animals, by human contact, by sexual intercourse, by common use of objects and by body fluids). Then, each group is assigned to propose possible non-pharmaceutical interventions for the limitation of two transmission routes by brainstorming. The results from all teams are announced to the rest of the class and their classification in a table reveals that even if some measures are common for all routes (e.g., quarantine), the transmission route is a decisive factor determining which interventions are proper for each case (e.g. use of face masks and condoms).

2nd teaching hour – The spread of recent epidemics and pandemics
Teaching phase according to the inquiry & project based instructional model: Continuation of the inquiry phase

- During this hour students try to answer questions on the temporal and spatial evolution of epidemics and pandemics. They use an interactive global map (DLO I) to study the geographical presence of selected communicable diseases (endemic, epidemic and pandemic) during the last 20 years. Students choose each disease from a list, and they distinguish epidemics from pandemics according to their geographical distribution. Moreover, they recognize cases of communicable diseases that have hit Europe and the 'western world' in general, during the past twenty years and they consequently conclude that communicable diseases still pose a serious threat for public health in spite of the biomedical progress has been done. They also note the unequal geographical distribution of communicable diseases on the globe and draw conclusions on the areas that are more severely hit by communicable diseases, making speculations on the possible causes of this situation.
- Afterwards students use DLO II which includes an interactive timeline with the aid of which they can watch the temporal evolution of selected communicable diseases (endemic, epidemic and pandemic) on the globe. By studying authentic epidemiological data in a visual and interactive form of representation, students understand that the same disease can reappear at different times and on distant places, thus conceptualizing what an epidemic outbreak is. They point out and note cases of disease outbreaks by using the timeline and the map, and specifically cases of outbreaks with large spatial or temporal distance, or outbreak of diseases often considered belonging to the past, are emphasized. It is shown that epidemic outbreaks are not restricted to developing countries but appear in so-called developed ones, as well.
- The following activity focuses on the temporal evolution of diseases, with the aid of DLO II. Authentic disease case studies reveal how a disease spreads, evolving gradually to an epidemic or a pandemic. Students note how quickly a pandemic escalates and formulate hypotheses on possible factors defining whether a disease is going to cause a pandemic or stay geographically more restricted. They recognize the vital role of nowadays travelling and transporting in disease spreading and compare to the role they had in past ages. They also argue why travelling is strictly restricted during epidemics and pandemics.
- Having studied the spread of communicable diseases students focus on ways for the restriction of disease spread. Through DLO II they study countries and areas where cases seem to get decreased. They correlate these cases either to the strict application of non-pharmaceutical interventions or the administration of mass vaccination programs. Examples of diseases that were dramatically restricted through vaccination programs introduce students to the notion of communicable disease eradication.

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Cases of real disease outbreaks in countries where mass vaccinations already take place are used by students in order to explain why vaccination is necessary even if the diseases do not pose a visible threat at the time. Inquiry and case studies activities are heavily based on DLOs I and II during the entire teaching hour.

3rd teaching hour – An introduction to SIR modelling
Teaching phase according to the inquiry & project based instructional model: Main inquiry

- For the following teaching hours (3rd to 8th) students use educational SIR simulations to explore through active learning research questions on the possible correlations between the relevant variables. As the learning sequence evolves, students are responsible for making more decisions concerning the inquiry process and they work more and more independently. Every two teaching hours they change the SIR simulation they work on, gradually moving from the simpler to the more complex and realistic one. The SIR models they use are DLO III, VI and IV. At all inquiry processes students are trained in the distinction between dependent and independent variables and between qualitative and quantitative variables. They are also assigned to interpret why during each question testing all the other variables, apart from the independent ones being tested each time, should remain as constant as possible.
- Students begin by using a rather simple SIR model (DLO III) in order to get used to this way of representing an epidemic. With the aid of SER II and worksheets students are trained to understand and interpret a SIR graph and explain what the shape of each SIR curve means. They are given some SIR graphs and they have to extract numerical data and more general conclusions about the situation of the epidemics represented, according to the curves' shapes.
- Afterwards, students use DLO III through successive inquiry processes to test how disease transmissibility and infectiousness affect the evolution of an epidemic outbreak. After estimating the outcome of the testing and reasoning about their estimations, they change the transmissibility value -keeping infectiousness constant- and describe the changes of the epidemic situation qualitatively and quantitatively, according to the graph. The dependent variables that students measure are the epidemic duration, the cumulative percentage of infected and the maximum percentage of infected cases. They repeat the inquiry steps by changing infectiousness values and keeping transmissibility constant.
- Students go on examining qualitatively and quantitatively the relationship between sociability and the dependent variables previously referenced. It is clarified that by the term 'sociability' we refer to extended social intercourse without precautionary measures depending on the disease transmission route. Students mention examples of 'sociability' behaviours and the correspondent precautionary interventions depending on the transmission route.

4th teaching hour – Using an SIR model to examine why it is important to 'flatten the curve'
Teaching phase according to the inquiry & project based instructional model: Main inquiry

- Students continue the inquiry-based learning process by using the DLO III. They choose the healthcare capacity to be appeared on the SIR graph and explain what would happen if the infected curve exceeded the healthcare capacity limit during the epidemic. They evaluate which of the 3 epidemiological variables mentioned before is the most critical when handling an epidemic crisis and are assigned to explain where the public call for 'flattening the curve' refers to. In order to evaluate each parameter (epidemic duration, cumulative infected percentage and maximum infected percentage) students write down within small groups what would happen to society if each parameter intensified and how important these consequences would be.
- Students, subsequently, modify the disease severity and healthcare system capacity and note down how the epidemic impact would be affected.
- A discussion with the entire class follows concerning the inquiry that proceeded. They classify DLO III variables into independent and dependent and they explain whether each variable depends on disease biological factors, citizens' behaviour and society organization. They argue on which of these variables can get modified during an epidemic, which cannot change, and which have to have been modified

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before the epidemic burst out. Then, the profiles of a ‘severe’ and a ‘light’ epidemic disease are outlined based on the previous activities and students’ own ideas.

- Finally, students form 4-member groups. Each group is assigned a problem of an epidemic due to a hypothetical disease (the values of transmission routes and biological parameters are given). Each group has to input the given values to the model and try to modulate the rest of the variables to proper values. According to their choices, the students propose a viable non-pharmaceutical intervention plan to the rest of the class. A discussion on the proposed plans follows.

5th teaching hour – Using a more complex SIR model to study how decisive social distancing is during an epidemic

Teaching phase according to the inquiry & project based instructional model: Application of new knowledge and skills through inquiry

- With the contribution of a more complex SIR simulation (DLO VI) students continue the inquiry process for the following two teaching hours, by applying and expanding their attained knowledge and skills. DLO VI allows the modification of much more variables, provides a visual representation of people during an epidemic, shows the epidemic progress in real time and incorporates a kind of indeterminism as the input of the same variable values does not lead to unchangeable outcomes. For this reason, whenever the collection of quantitative data is required, a triple repetition of the test is done, and the mean value is calculated.
- In order to get used to the new simulation, the students firstly study the impact of some variables that they have already tested with the DLO III. The variables of the simulation are set to some given initial values and asymptomatic percentage is set to 0%. Students modify successively the infection radius (similar to infectiousness of DLO III) and infection duration parameters and note what they expect to happen. Then, they observe what happens at the two modes of representation (people and graph). They note down the variables of epidemic duration, cumulative infected percentage and maximum infected percentage three times for each case and extract the means. They also try to discover correlations between the studied variables.
- Furthermore, students change variables being inaccessible in the previously used DLO III, and variables representing the application of various non-pharmaceutical interventions in particular. Having as reference values the ones attained from the absence of all precautionary measures, they test how social distancing affects the epidemic spread. Low infectious radius is chosen to represent a disease of low infectivity. They organize the collected data in tables and contrast them with the reference values and with a hypothetical limit of healthcare system capacity.
- Afterwards, students select a high infection radius value to represent a highly infectious disease. They repeat their testing through the SIR model and note down the results. They calculate how much the value of social distance should be in order to achieve a result compatible with the healthcare system capacity. They compare their results with the ones of a highly infectious disease and no social distancing, and the ones with the presence of social distancing with a low infectious disease. Conclusions are drawn on the effect of infectivity on the degree of precautionary interventions needed to be taken.
- As a last phase of inquiry on social distancing, students study the parameter of the degree of application of social distancing. Students change the percentage of citizens applying social distancing for the cases of a low infective and a high infective disease and draw conclusions on the importance of applying social distance interventions during an epidemic. Then, they are given certain percentages of obedience to social distancing and students have to find exactly how strict the social distancing measures have to be in each case, again for two different infectivity values. A certain maximum infected percentage representing maximum healthcare system capacity is given to students to carry out all the necessary tests. A short discussion follows on the inquiry conclusions and relevant students’ experience from the COVID-19 pandemic with the participation of the entire class.

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6th teaching hour – Using an SIR model to examine how quarantining, central locations and interconnected communities affect the progress of an epidemic

Teaching phase according to the inquiry & project based instructional model: Application of new knowledge and skills through inquiry

- After having studied the effect of social distancing, students study the effect of quarantine. At this point they are assigned with much more decision-making and initiative-taking concerning the design and application of inquiry, in a way which inquiry-based learning moves from structured inquiry to guided inquiry. Students are from now on responsible for proper variable handling, data gathering and analysis, the selection of appropriate reference values, proper comparison making and conclusions deduction. In order to save time, students do not have to repeat each test in triple any more, but one repetition is considered sufficient, instead.
- The first inquiry question that students are assigned to answer with the aid of the simulation is how effective quarantine would be in comparison to complete absence of measures. They are hinted to distinguish two cases: a disease with low infectivity and a disease with a high one. Next, they are assigned how asymptomatic patients influence the quarantine effect. Students are told to compare the effectiveness of social distancing alone, of quarantine alone and of quarantine together with social distancing. A discussion about the results and the comparisons between measures is conducted in the class regarding the benefits, the difficulties and the consequences each measure has in social life.
- During the following inquiry stage, students choose the central location mode of the simulation, and observe how the simulation outcomes change. They give examples of cases of central location in a society and argue on which of them they regard as unavoidable during an epidemic and suggest ways of avoiding crowding. By using DLO VI students test how lowering the frequency of visits to the central location, quarantining and social distancing could help with the management of the epidemic. The test aims at the general overview of the epidemic and does not have to be as exhaustive as the previous tests. It is discussed which SIR version (with or without central location) is closer to real life during an epidemic and which version is, consequently, further from reality.
- Finally, students opt for the simulation mode of multiple communities (e.g. multiple cities) and observe how different interrelated epidemic outbreaks happen in different communities. They test whether limiting inter-community travelling can guarantee the existence of communities completely free of the disease. They make different tests for a low infectivity and a high infectivity disease. Then, the importance of travelling and transporting in the spread of an epidemic is discussed in the class.

7th teaching hour – Using an SIR model to examine parameters affecting the spread of an airborne epidemic

Teaching phase according to the inquiry & project based instructional model: Application of new knowledge and skills through inquiry

- During the following inquiry phase, students continue the inquiry processes working more independently and being responsible for much more decision making. They make use of the last SIR model they are going to handle, which is DLO IV.
- In order to get the students familiarized with the new simulation environment, the simplest initial conditions of the simulation are selected. No precautionary intervention is chosen, the values of asymptomatic, hospitalization and mortality are set to zero, and infectivity, illness duration and incubation period are set to low values. Students observe how the pandemic evolves through the graph and the graphical representation and it is highlighted that citizens' behaviour reflects a more realistic lifestyle than in the other two SIR simulations. Students locate different locations in the simulation within which citizens move (houses, workplaces, schools, parks and hospital).
- Afterwards, students study the degree to which four non-pharmaceutical interventions (remote work, remote schooling, quarantining, using of face masks) could limit the epidemic outcome given the initial conditions mentioned before. The effectiveness of the interventions is compared to one another, and students try to interpret the differences. It is made clear that this specific SIR model simulates airborne

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diseases particularly, which are transmitted through the air or through respiratory droplets. To promote the comprehension and meaningful learning concerning the airborne diseases, the visualization SER IV could be utilized. SER IV shows how easily an airborne disease may spread, which cannot be easily understood without some kind of visualization. Students observe that the use of face masks can dramatically drop the spread of the disease. At this point SER V could be shown, which reveals how a mask can disrupt the flow of exhalation and respiratory droplets, with the aid of an infrared camera.

- Then, students choose hospitalization and mortality percentages in the simulation to appear and turn the relevant choices on the graph on. They explain what 'critical' and 'dead' stand for in the graph and observe the visual representation of hospitalization in the hospital building. They repeat the test of the effectiveness of the four non-pharmaceutical interventions and compare the number of deaths in each case.
- Students are assigned to study how asymptomatic percentage, infectivity, incubation period and disease duration affect the effectiveness of each one of the non-pharmaceutical interventions. Students are completely responsible for the test designs, and variable handling. They assess the effectiveness of each intervention in each case, they carry out comparisons, correlate variables, extract and interpret the results. This process might need to be continued to the following hour for some student groups.

8th teaching hour – Using an SIR model to take policy decisions for a hypothetical epidemic
Teaching phase according to the inquiry & project based instructional model: Application of new knowledge and skills through inquiry

- After each group has finished the tasks assigned to them, they can freely carry out investigation with simultaneous changes on more than one variable based on research questions they have posed themselves. This activity is optional and targets only for the groups that have finished their tasks earlier than the others.
- Students discuss in class about the inquiries they have made. Each research question is discussed successively. For each research question, each group shortly presents the test design they applied, the results they found and the conclusions they drew. The methodological options, the results and the interpretations of each group are discussed. Differences among groups and alternate approaches or interpretations are emphasized. In this way, it is attempted to approach the complex nature of scientific study, which does not necessarily fall into unique or absolute research administrations.
- Next, each group is assigned a problem which they have to cope with. Each group chooses variable values of an authentic communicable disease in the simulation (infectivity, mortality, incubation period etc.) and they have to design a viable series of non-pharmaceutical interventions in order to minimize the harsh effects of the epidemic. They have to reason on every decision they take, and they are urged to opt for a realistic solution avoiding extreme ones. On the contrary, they have to simulate a real epidemic management by the state, for example the enforcement of looser measures as the first cases appear, or the avoidance of adopting unnecessary measures, in order to promote the functionality of society. They have, also, to evaluate which precautionary measures will be lifted first and which last. Students are made clear that this is the first problem of such a case they cope with and that they will administrate a similar problem afterwards, much more extensively. Each group shortly presents their plan to class and hands it to the teacher, who returns it to them with comments for further improvement.
- As an ultimate part of the application of knowledge and skills through inquiry with SIR models, students are introduced to the notion of scientific modelling. They note down the similarities and dissimilarities the three SIR models they used have with the real world, as well as the advantages and disadvantages each model has when compared to one another. They explain in what ways an SIR model could be useful for scientists, and if an SIR model totally same to the real world could exist, or even if it would have any meaning at all. The topic is discussed in the class and students mention examples of models used in natural sciences. Moreover, it is discussed whether mathematical models are flawless and if a flawless model would ever be possible. Students express themselves whether the integral uncertainty of a model cancels its predictive or even its scientific value. The video SER VI is presented

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and commented in a final conceptualization of the nature, the function and the usefulness of a scientific model.

9th teaching hour – Trying to use SIR models in order to make viable policy decisions in order to cope with a case of an epidemic (School project)
Teaching phase according to the inquiry & project based instructional model: Project initiation – project development

- The 9th teaching hour aims at the initiation of the school project by the students. In order to make connections to the previous instructional phase, students comment in small groups, and later in the entire class, on news from the recent COVID-19 pandemic which refer to behaviours that burden public health (e.g. avoidance of spatial distancing and mask use, transportations among places, overcrowding in central locations, avoidance of quarantining). Students argue on the reasons why this kind of behaviours put a burden on public health, by using what they have already learnt.
- The main activity of the 9th hour follows, which is the first part of the three-part school research project. Four- or five-member groups are formed and each one gets a card with the biological and epidemiological features of the recent COVID-19 pandemic for a certain area in a certain period of time. Students enter the relevant data into the three SIR simulations they have used (DLOs III, IV, VI) in the way they judge to be closer to reality. They are also given an upper limit of the healthcare system capacity. Each group uses the three simulations complementarily, in a way that the pros of each simulation outweigh the cons of another. Students act as scientists and policy makers during an epidemic crisis, the COVID-19 in particular. They are assigned to use the simulations in order to test the outcome of the epidemic under various conditions and choose through this way a series of non-pharmaceutical interventions in the form of precautionary measures protecting public health. They have to minimize the harmful consequences of the epidemic, as well as to balance between the enforcement of strict measures and a proper function of the society. It is made clear, that the suggested plan must be functional and viable under real circumstances. Students are urged to use the SIR models, but not to get stuck on them. The ultimate target of their plan is a real society, not a model. So, they ought to think of other interventions not included in the models, modify and specify the interventions of the simulations, and, also, take into consideration the special features and the inhomogeneous nature of a real society. The teacher monitors students' work and often scaffolds students' ideas and work through appropriate questions, depending on each group's choices. The project development begins in this hour but will be continued for the following two hours.

10th teaching hour - Examining how close SIR models are to real epidemic cases (School project)
Teaching phase according to the inquiry & project based instructional model: Project development

- At the beginning of the 10th hour each group presents briefly a draft of their plan to the rest of the class. This presentation and the following discussion aim at the exchange of ideas among students and the overcoming of difficulties that some groups might face.
- Then, the first part of the project (design of a plan for the administration of an epidemic crisis) which started during the previous hour is continued by some members of the group. Students navigate in databases SERs VII and VIII, where they can find authentic examples of precautionary measures during the COVID-19 pandemic taken by various governments around the globe, as well as how extensive the application of each measure was. The group members, who continue working on this task, improve their suggested plan based on the previous discussion in the class, the navigation of the databases and further testing with the models.
- The rest of each group leaves the first part of the project and take responsibility for carrying out the second one. This latter part concerns the test of the compatibility of the three SIR models studied (DLOs III, IV and VI) with the real evolution of the COVID-19 pandemic. Students extract the COVID-19 epidemiological data for a certain moment and from a certain area (e.g., the country or province they live in) from databases SERs VII and VIII. The only necessary requirement is the chosen period to be

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before the application of vaccinations against COVID-19 in the area, because this pharmaceutical intervention changed dramatically the pandemic outcome in a way that cannot be represented by the simulation used. Students can find information in SERs VII and VIII about the main precautionary measures that were imposed to the area of study during the period of study. They have to find the appropriate way to input the authentic data to each one of the three models by making the necessary reductions, drawing parallels between real world features and simulation parameters and making appropriate mathematical manipulations. They are assigned to compare the model outcomes to one another, as well as to the authentic data as shown in the databases SERs VII and VIII. The interpretation of the differences by each group is of high importance for this activity.

11th teaching hour – Drawing conclusions based on students' work (School project)
Teaching phase according to the inquiry & project based instructional model: Project development

- During the eleventh teaching hour students continue and finish the progress of the two parts of the project started. At the beginning of the hour students from 2-3 groups having the same responsibility (either the task of epidemic administration or the precision testing of the models) form bigger groups in order to exchange ideas concerning possible difficulties they have found, the approaches they have followed and the first results they have come to. After this short exchange of ideas, the initial groups are formed again.
- The students responsible for designing the administration plan of an epidemic complete their experimentation with the models and the selecetion of precautionary measures. Now, they have to write a report on the conclusions of their study, which represents their group. They compile a text or a diagram which refers in detail to the proposed measures, alternative measures, probable difficulties in the application of the measures, and mainly to the rationale behind each choice.
- The students responsible for the project part regarding the precision of the SIR models complete their study, too, and they are assigned to fill in some worksheets which serve as the final reports of their study. They note down in detail the way they worked, including the handlings and conventions they used during the data input, the models' outcomes, the results from the comparisons and a thorough interpretation of their findings, where they are urged to incorporate as many parameters and ideas as they can think of.

12th teaching hour – Designing an informative campaign concerning the importance of non-pharmaceutical interventions for the promotion of public health (School project)
Teaching phase according to the inquiry & project based instructional model: Project development

- During the twelfth teaching hour students are assigned to carry out the third part of the school project. Each group is responsible for making a short informative campaign for the general public concerning behaviours which promote public health during an epidemic. Each group is given four actions taken at random from a list with non-pharmaceutical interventions (e.g., travel restrictions, quarantining, use of masks, disinfections, use of insectivores against mosquitoes). Each group is tasked to make a short digital presentation with four slides, one for each intervention, by using the appropriate software. Presentation must be concise, without scientific flaws, aesthetically pleasuring and comprehensive for the general public, explaining the scientific reasons for applying each measure, in simple words. Students recall and apply the knowledge they gained through the learning sequence and are urged to utilize all the DLOs and SERs they have used. For instance, they can use disease examples from DLOs I and II, visualizations and images, graphs and numerical data from the SIR models, always accompanied by the necessary explanations.

13th-14th teaching hour – Presentation of the project outcomes (School project)
Teaching phase according to the inquiry & project based instructional model: Project presentation – Final assessment – Self-reflective phase

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- Each group has completed the three project outcomes at this point (plan for epidemic administration, report on the models' precision and informative campaign). The phase of project presentation follows, in front of the entire class.
- Each group successively presents their work and findings. Three presentation rounds are made, one for every part of the project. All the students of each group must take part in the presentation. Each presentation ought to be short (about 5 to 10 minutes) and a discussion among groups follows after each presentation round. Active listening, constructive criticism, interaction and respect among students are promoted during the discussion.
- After all the presentations have finished a more general discussion takes place in class concerning the subject, the learning sequence, the students' impressions and difficulties. This discussion is appropriate for question answering, conceptual clarifications and expansions depending on students' needs and interests.
- Students are given a short questionnaire with a few close-ended questions (about 20) and two short case studies aiming at individual student's assessment of the cognitive learning objectives.
- The presentations and the project outcomes (two reports and one presentation) are assessed by the teacher according to criteria shared for all groups via an assessment rubric designed specifically for each outcome.

Supplementary learning activities

I. Discussion with experts

Some discussions with experts could take place as optional educational activities, which act complementary to the educational activities previously described. They can have the form of a short presentation, a free discussion, an interview or a combination of those and they could take place in the physical presence of the expert or via teleconference. The expert might be a person whose scientific specialization or whose profession closely relates to issues that having been discussed in the classroom during the learning sequence. The students' discussion with the expert has some additive STEM educational value which is summarized with the following points:

- The experts have an advanced scientific or professional expertise, so they have deeper content knowledge and are more suitable to give students a deeper understanding of the scientific contents and answer students' advanced questions.
- Students can see how the content of the learning sequence can be reflected to real world professional specializations. In this way they connect what they learn to authentic contexts and can learn further information about the real work of STEM professionals.
- Students have the opportunity to discuss with STEM professionals, which would otherwise be probably inaccessible to them. They can learn about the real work of scientists and about the real way new scientific knowledge is produced (Nature of Scientific Inquiry).
- Experts can act as role models for some students and trigger them to follow STEM related careers in the future.
- Experts can give students some more specific guidelines or answer advanced students' questions concerning their research project.

It is suggested to have the discussions done after the general activities have been completed and before or at the beginning of the school project (more specifically around the 8th or the 9th teaching hour). In this way students will have a good background in order to discuss and meaningfully understand the topics discussed with the experts and can ask them questions that will help them in decision-making concerning the conduct of the school project. Of course, if the teacher thinks that the discussions are better to take place at a different time they, are free to do so.

Some scientific and professional specializations that could be cases of experts are listed below with some indicative topics for discussion:

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1. Doctors or medical professionals specialized in communicable diseases – They could discuss with students about recent cases of communicable diseases, transmission routes and the importance of non-pharmaceutical interventions.
2. Epidemiologists – They could discuss with students about evolution and features of an epidemic or pandemic, the modelling of an epidemic, the epidemic curve and how to 'flatten' it.
3. Health data scientists or models creators – They could discuss with students about the importance of mathematics and model in medical science, the process of making a model, the function, the precision and the limitations of a scientific model and how models help science advance.
4. Members of public health institutions - They could discuss with students about the importance of non-pharmaceutical interventions for the prevention of spread of communicable diseases, different types of non-pharmaceutical interventions and the importance of everyday habits for infectious disease prevention.
5. Health communicators, specialists in health outreach – They could discuss with students about health communication during COVID-19 and about the features that an effective health communication campaign should have.
6. Academics or university professors with relevant expertise.
7. Members of the PAFSE consortium with relevant expertise.

<u>II. Educational visits</u>
Some educational visits could take place within the context of this learning sequence. In this way the school's educational activities will be complemented with educational activities from other organisations or with visits to authentic places where research or work on relevant topics is being done. It would be preferable to make these visits after the students have examined the relevant issues in the learning sequence so that they will be able to meaningfully conceptualize what they examine during the educational visit. A short discussion before and after the educational visit is also necessary in order to determine and summarise the context of the visit and link it to the learning sequence.
Some suggested places for educational visits are listed below:

1. Medical museum – During this visit, students could probably come across items concerning historical cases of infectious disease outbreaks, epidemics and pandemics and how the different non-pharmaceutical interventions were adopted as medical knowledge has expanded over the ages.
2. Research laboratory concerning medical data analysis or medical modelling – During this visit, students could see the actual work of medical data scientists and model developers, discuss about their work and see the convergence and collaboration of scientists from different fields (mathematics, medical science, biology, computer science etc).
3. Institution of public health promotion or policy making – During this visit, students could get informed about the importance of non-pharmaceutical interventions for the promotion of public health, about the processes that hide behind policy decision making and see informative material from past cases of infectious disease outbreaks, epidemics and pandemics.
4. Institution for health awareness, promotion or education – During this visit, students could take part in educational activities concerning infectious disease transmission routes, disease prevention, non-pharmaceutical interventions and maintenance of hygiene rules.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: “The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling**”**

I. Knowledge	
1. Distinguishes communicable from non-communicable diseases	**Question 1.1:** Which of the following diseases is non-communicable? A) Alzheimer disease B) Influenza C) AIDS
2. Distinguishes among endemic, epidemic and pandemic diseases	**Question 2.1:** COVID-19 has been characterized as a pandemic because … A) a lot of cases have been found in many distant countries B) the disease is highly infectious and causes several deaths C) the disease is a quite new one **Question 2.2:** A disease which exists in an area and has a small number of cases each year us characterized as ... A) endemic B) epidemic C) pandemic **Question 2.3:** In 2012 a lot of measles cases were found in Greece in contrast to previous decades years during which number of cases was low. We can say that … A) measles is endemic in Greece and it had an epidemic in 2012 B) measles had a pandemic in Greece in 2012 C) measles had an epidemic in 2012 in Greece and then it became an endemic disease **Question 2.4:** If COVID-19 transforms from a pandemic into an endemic disease, this means that … A) there will be COVID-19 cases worldwide but their number is going to be small in general B) COVID-19 cases are going to appear rarely and only in a few countries C) despite COVID-19 cases are going to be a lot, deaths are only going to be few
3. Explains different transmission routes of diseases	**Question 3.1:** Communicable diseases are transferred from one person to another because … A) pathogens are transferred from one person to another B) toxic substances are transferred from one person to another C) a healthy person gets close to an infected one **Question 3.2:** A disease can be transmitted between two closely distanced people if the disease is transmitted through … A) respiratory droplets B) contact with infected objects C) insects **Question 3.3:** Which of the following does NOT describe a disease transmission route? A) Through solar radiation B) Through blood transfusion C) Through insects

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4. Exemplifies non-pharmaceutical interventions appropriate for each disease transmission route	**Question 4.1:** Which of the following measures describes a non-pharmaceutical intervention against a communicable disease? A) Use of medical gloves B) Antibiotic prescription C) Mass vaccination of the population **Question 4.2:** Which of the following daily habits is NOT a non-pharmaceutical intervention against the spread of diseases? A) a balanced diet B) The use of condoms during sexual intercourse C) Coughing into an one-use napkins
5. Explains the ways non-pharmaceutical medical interventions work	**Question 5.1:** A non pharmaceutical intervention does NOT hinder the spread of a disease by … A) curing infected people B) preventing a healthy person to catch the disease C) killing pathogen microorganisms **Question 5.2:** Which of the following interventions would be inappropriate against a disease transmitted through respiratory droplets? A) Mass killings of insects B) The use of medical face masks C) Spatial distancing among people **Question 5.3:** Which of the following intervention is suitable against every type of infectious disease? A) Quarantining of the infected B) Spatial distancing C) Disinfection of objects of communal use **Question 5.4:** What is the main advantage non-pharmaceutical medical interventions have compared to pharmaceutical interventions? A) They can be applied in diseases even if no treatment is known B) They are more economical than a lot of expensive pharmaceutical interventions C) They usually are more effective **Question 5.5:** Non-pharmaceutical interventions during an epidemic must be held … A) by everyone in order to slow down the transmission rate of the disease B) only by people in danger of severe disease in order to minimize deaths C) only by people in danger of severe disease and their close contacts in order to minimize deaths
6. Explains the importance of the epidemic curve and ways of handling it	**Question 6.1:** When referring to the 'epidemic curve' we refer to … A) the change of the number of cases over time B) the change of the number of deaths over time C) the change of the number of healthy people over time **Question 6.2:** The number of disease cases during an epidemic is crucial to remain low … A) so as the healthcare system is able to efficiently handle the patients B) so as to end the epidemic as soon as possible C) so as to restrict the overall percentage of the population been infected **Question 6.3:** The strict application of non-pharmaceutical medical interventions during an epidemic contributes to … A) the decrease of cases B) the earlier end of the epidemic C) the increase of the healthcare system capacity limit **Question 6.4:** A high percentage of asymptomatic carriers of a disease … A) makes the restriction of the disease spread more difficult B) makes the restriction of the disease spread easier C) does not influence the efforts of the restriction of the disease

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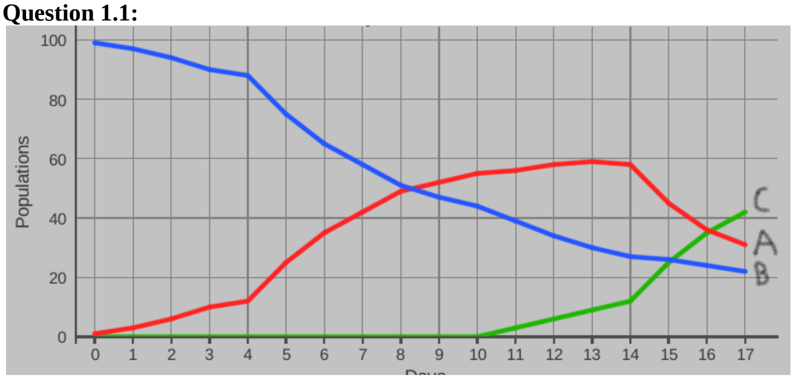
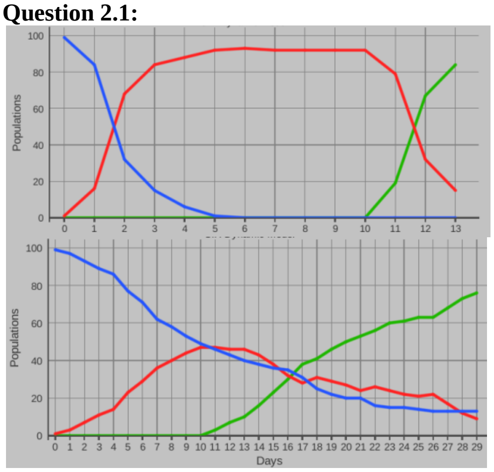
7. Recognises the nature of a scientific model	**Question 7.1:** A scientific model is … A) a selective representation of a natural phenomenon which can contribute to original scientific research B) a selective representation of a natural phenomenon having solely educational value C) a close replication of a natural phenomenon which might have scientific ore educational value
II. Skills	
1. Interprets graphic and numerical SIR data	**Question 1.1:**  The graph shows the evolution of an epidemic. The letters A and B stand for … A) the numbers of infectious and susceptible people respectively B) the numbers of susceptible and recovered people respectively C) the numbers of infectious and recovered people respectively **Question 1.2:** What is the shape of an epidemic curve of infectious people in an SIR graph during an epidemic? A) At first increases and then decreases B) It steadily increases C) It steadily decreases
2. Uses SIR models to interprets the evolution of an epidemic	**Question 2.1:**  These two graphs depict the evolution of two epidemics in the same city. In the upper case … A) the healthcare system might have had more difficulties in dealing with the epidemic B) the epidemic would have lasted last longer C) it is likely to have been enforced stricter measures for the restriction of the disease spread

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3. Uses SIR models to make decisions concerning the handling of an epidemic	**Question 3.1:** In which of the following cases it is necessary to have more extensive or stricter precautionary interventions enforced for the restriction of the spread of the epidemic? A) In a disease having high infectivity, long duration and high percentage of asymptomatic carriers B) In a disease having high infectivity, long duration and low percentage of asymptomatic carriers C) In a disease having low infectivity, short duration and low percentage of asymptomatic carriers **Question 3.2:** Which of the following is preferable in the case of a highly infectious and severe disease in a city with low number of hospital units? A) Keeping the number of cases as low as possible B) Ending the epidemic as soon as possible C) Enforcing a small number of non-pharmaceutical interventions **Question 3.3:** If the epidemic curve starts suddenly increasing it is preferable to … A) Strengthen the precautionary measures before the epidemic curve comes to its maximum B) Strengthen the precautionary measures after the epidemic curve comes to its maximum C) Minimize the precautionary measures applied
4. Designs research plans to test hypotheses	**Question 4.1:** I want to know to what extent the use of medical masks affects the number of seasonal flu cases during an epidemic in a city. Which of the following comparisons would be more suitable to make? A) To compare the cases in a city after the application of wearing masks with the cases of another city of the same country and similar population in which the measure of masks was not imposed B) To compare the cases of flu after the application of wearing masks in a city with the flu with the number of cases in the city before the application of the measure C) To compare the flu cases after the use of medical masks in the city with the influenza cases that appeared in the same city during the H1N1 pandemic, when wearing masks was not mandatory **Question 4.2:** In order to test the effectivity of vaccination against COVID-19 it would be preferable to compare … A) data from unvaccinated and vaccinated populations which are as similar to one another as possible (e.g., in terms of gender, age, health condition) B) data from unvaccinated and vaccinated populations for which I can obtain a big load of data, even if the populations are quite dissimilar C) data from unvaccinated and vaccinated populations for other diseases (e.g., measles, influenza, polio) because they are more easily available and have been studied to much greater extent
5. Gathers and processes mathematical data	**Question 5.1:** I am able to gather and organize numerical data (e.g., put them in appropriate tables) with ease. 1) I strongly disagree … 5) I strongly agree **Question 5.2:** If I am given organized numerical data regarding a research question (e.g., how many were infected when an intervention was applied and when it was not), I am able come to a conclusion quite surely. 1) I strongly disagree … 5) I strongly agree
6. Interprets graphs (self-referred)	**Question 6.1:** I am able to understand what an SIR graph depicts. 1) With great difficulty … 5) With great convenience **Question 6.2.:** I am able to understand if an epidemic gets better or worse by looking at an SIR graph. 1) With great difficulty … 5) With great convenience

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7. Designs a plan for restricting the spread of a communicable disease	**Question 7.1:** I am able to come up with possible non-pharmaceutical interventions which could be applied in the context of an epidemic, regardless how realistic they are. 1) I strongly disagree … 5) I strongly agree **Question 7.2:** I am able to evaluate the applicability of various proposed non-pharmaceutical interventions for the handling of an epidemic and explain which of them would be applied more difficultly and why. 5) I strongly disagree … 5) I strongly agree **Question 7.3:** I am able to propose a concise plan of measures for the administration of an epidemic, which seems to be realistic, but without defining a lot of details. 1) I strongly disagree … 5) I strongly agree **Question 7.4:** I am able to propose an extensive plan of measures for the handling of an epidemic while defining a lot of details and making specializations and seeming to be quite realistic and applicable. 1) I strongly disagree … 5) I strongly agree
8. Handles digital simulations	**Question 8.1:** I am able to handle digital SIR simulations. 1) With great difficulty … 5) With great convenience
III. Beliefs, Attitudes and Behaviours	
1. Recognises the global and diachronic nature of the issue of communicable diseases	**Question 1.1:** Communicable diseases are not a primary health issue for the Western world. 1) I strongly disagree … 5) I strongly agree **Question 1.2:** Epidemics and pandemics belong mainly in the past and there is no great concern about them for the future. 1) I strongly disagree … 5) I strongly agree **Question 1.3:** International cooperations are necessary for confronting with the issues of communicable diseases. 1) I strongly disagree … 5) I strongly agree
2. Appreciates the value of non-pharmaceutical interventions for the administration of communicable diseases	**Question 2.1:** The application of precautionary measures against the spread of a disease is necessary only in urgent cases of health crises. 1) I strongly disagree … 5) I strongly agree **Question 2.2:** The application of non-pharmaceutical interventions is able to lead to the prevention of an epidemic outbreak. 1) I strongly disagree … 5) I strongly agree **Question 2.3:** Small daily habits such as proper handwashing and object disinfections can have great effect in the prevention of a disease outbreak. 1) I strongly disagree … 5) I strongly agree **Question 2.4:** The application of non-pharmaceutical interventions can contribute even to the total eradication of communicable diseases. 1) I strongly disagree … 5) I strongly agree

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3. Appreciates the value of non-pharmaceutical interventions for the effective administration of an epidemic outbreak	**Question 3.1:** The application of non-pharmaceutical medical interventions is totally necessary during an epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.2:** Non-pharmaceutical interventions are always less important than pharmaceutical interventions during an epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.3:** Non-pharmaceutical interventions are sometimes the sole mean of confronting some epidemics. 1) I strongly disagree … 5) I strongly agree **Question 3.4:** Non-pharmaceutical interventions such as quarantining, social distancing and wearing masks during an epidemic can have only small benefit for public health. 1) I strongly disagree … 5) I strongly agree **Question 3.5:** The kind of non-pharmaceutical interventions applied, and the time of their application are quite important for the outcome of an epidemic. 1) I strongly disagree … 5) I strongly agree
4. Recognises the importance of the collective application of precautionary measures during an epidemic	**Question 4.1:** In order to be effective the application of a non-pharmaceutical intervention (e.g. avoiding overcrowding, wearing masks) it must be applied by the majority of the population. 1) I strongly disagree … 5) I strongly agree **Question 4.2:** Even if a small percentage of the population does not apply the precautionary measures during an epidemic, then the effectiveness of the measures might be affected to a great extent. 1) I strongly disagree … 5) I strongly agree **Question 4.3:** The effectiveness of the health measures during an epidemic lies only upon the civic structures and not upon the citizens. 1) I strongly disagree … 5) I strongly agree **Question 4.4:** Non-pharmaceutical interventions during an epidemic (e.g., wearing masks, quarantining, avoiding overcrowding) cannot lead to a big relief of the healthcare system. 1) I strongly disagree … 5) I strongly agree
5. Shapes a positive attitude towards science for the administration of an epidemic crisis	**Question 5.1:** The management of an epidemic ought to rely on scientific data and follow the scientists' guidelines. 1) I strongly disagree … 5) I strongly agree **Question 5.2:** If scientific data and citizens' perceptions referring to the administration of an epidemic conflict, then it is preferable to follow the citizens' beliefs. 1) I strongly disagree … 5) I strongly agree **Question 5.3:** The effective administration of a health crisis can be designed solely upon scientific knowledge. 1) I strongly disagree … 5) I strongly agree **Question 5.4:** The economic and social function of a society ought to keep going during an epidemic even if it is not compatible to scientists' recommendations. 1) I strongly disagree … 5) I strongly agree
6. Recognizes the importance of scientific models for scientific research and decision making	**Question 6.1:** Models have little importance for scientific research. 1) I strongly disagree … 5) I strongly agree **Question 6.2:** Models cannot lead to making new predictions. 1) I strongly disagree … 5) I strongly agree **Question 6.3:** Scientific models are not a trustworthy source for making civic decisions. 1) I strongly disagree … 5) I strongly agree

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7. Applies precautionary personal hygiene rules for the restriction of the spread of communicable diseases	**Question 7.1:** How often do I apply urgent health measures imposed during the COVID-19 pandemic? 1) Never … 5) Always **Question 7.2:** How possible would it be to apply urgent health measures (e.g., overcrowding avoidance) during an epidemic even if this was contrary to my personal desires (e.g., for entertainment). 1) Completely impossible … 5) Completely possible **Question 7.3:** How often do I apply fundamental hygiene rules (e.g., proper handwashing, common-use objects disinfections) when no health crisis exists? 1) Never … 5) Always

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7. Specifications for an educational scenario on the topic “Social determinants of health during an epidemic/pandemic outbreak”.

Main partner responsible
University of Ioannina, Ioannina, Greece.

Overview

This educational scenario focuses firstly on the social determinants of health during an epidemic, and secondly on some environmental issues concerning communicable diseases, with emphasis on the recent COVID-19 pandemic. Initially, students express their views and attitudes towards the social and environmental determinants of communicable diseases via filling in a short questionnaire and constructing a graphic organizer (concept or mind map). A first discussion on students' initial ideas follows. Afterwards, they study the origin of communicable diseases, with emphasis on recent epidemics and pandemics. They realize their animal origin and correlate it to our modern lifestyle. Then, students critically read some selected information sources (texts, videos and infographics) and study the ways in which social inequities lead to health inequities. Students adopt the role of a citizen with specific personal and societal features (e.g., gender, age, profession, educational level etc.) in a role game, in which they apply what they have learnt during the previous teaching phases. The roles that students adopt will probably be quite distant from themselves. They have to describe the role's personal experience of an epidemic, make health decisions and put values in a scale according to the role's experience of the epidemic. Students put the values in a scale according to their personal criteria, as well. Then, they move on to the school project phase, during which they design a questionnaire and conduct a short social research via the Internet on the effect the COVID-19 pandemic had on the local society. They try to bring the citizens' personal experiences of the pandemic to the surface, and especially the way the pandemic affected their way of living. Students design the questionnaire, collect and handle quantitative or qualitative data by using proper techniques and present the project findings in a school festival or even communicate them to the local society.

Scientific content and its relevance to public health education

- It is widely accepted that social parameters and social inequities magnify health inequities among citizens. The concept of health does not only depend on medical and biological factors.
- Social determinants of health during an epidemic or a pandemic are emphasized. They consist of a dimension that is often undermined in science education or STEM courses, although they are, in fact, decisive of one's health condition.
- The comprehension of the connection between science and society, as well as the social embedding of science, is promoted.
- Social inequities pose a serious issue in public health promotion. Students have to be aware of this problem in order to evolve to active citizens.
- The inclusion of social determinants of health in health-related decision-making is necessary for health promotion both in personal and societal level

Estimated duration & relevant subjects

12 teaching hours, organized in continuous two-hour periods if possible. Designed for Biology, Science or Social Science classes of K7-9 grades.

STEM Content

- Promotion of the interconnection among science, technology, society and the environment (STSE).
- Promotion of critical STEM literacy, critical health literacy and critical scientific literacy aspects in STEM instruction with a view to promoting active citizenship.

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- Highlight of the role of science for the establishment of social justice.
- Collection and proper handling of research data, conclusion drawing and appropriate research project presentation by students.

Non-STEM Content: *Conduct of authentic empirical social research by students – students in the role of social researchers under authentic small-scale research conditions, collaborative student work for the design of appropriate social research tools.*

Content glossary

Anthroponosis (pl. anthroponoses): Anhroponoses are the human communicable diseases that are transmitted from human to human through direct or indirect transmission routes. Measles and diphtheria are examples of anthroponoses.

Communicable/infectious/contagious disease: Communicable diseases are those diseases (which are in turn the harmful unnatural conditions of the human organism) which can be transmitted from one person to another. Communicable diseases are mainly caused by pathogens, such as bacteria, viruses, fungi and protozoa (they can be rarely caused by infectious particles, as in the case of the Creutzfeldt-Jakob disease). Disease transmission can be direct (through human intercourse) or indirect (e.g., through insects or infected objects). Some examples of communicable diseases are influenza, chickenpox, malaria, and the Ebola disease. On the other hand, there are non-communicable diseases, such as diabetes, phenylketonuria and Alzheimer's disease.

Data analysis: Data analysis is the phase following data gathering in empirical research. It includes various techniques (e.g. mathematical handling, logical functions, groupings, codification etc.). According to the empiricist view of science the aim of data analysis is to draw conclusions which lead, in turn, to the confirmation or the refutation of the initial research hypotheses, or the formation of a new scientific theory.

Data gathering: Data gathering is the process of recording observations of a phenomenon (natural or social) during empirical research. According to the empiricist view of science, it is one of the first stages of empirical research.

Emerging Infectious Diseases: Emerging Infectious Diseases are the communicable diseases the frequency of which has increased rapidly over the last twenty years and/or have the potential of rapid increase in the near future. Emerging Infectious Diseases are often anthropozoonoses and they are usually the cause or potential cause of epidemics and pandemics. Old diseases which reappear are sometimes included in Emerging Infectious Diseases. Typical cases of emerging infectious diseases are the COVID-19, the Ebola disease, measles and outbreaks of antibiotic-resistant bacteria strains.

Empirical research: Empirical research is the kind of research which is based on the gathering, the analysis, and the interpretation of empirical data. Empirical data are the qualitative or quantitative data which are collected from the observation of a phenomenon by the researcher.

Health disparities/inequities: Health disparities or inequities are the differences in health condition among social groups which are caused by social, economic or environmental differences, and that negatively affect the health of certain social groups. Common causes of health disparities are ethnicity, gender, sexual identity, age, disability, socioeconomic status, and geographical factors. A typical case of health disparity is the high incidence of cardiovascular diseases in African Americans although no biological reason for this difference exists.

One Health: The One Health approach is a transdisciplinary approach that considers human health under a broad context highlighting the direct interconnections with animal health and the environment. Zoonoses,

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vector-transmitted diseases and antibiotic-resistant bacteria strains are common issues dealt with the One Health approach.

Qualitative data: Qualitative are the data which refer to qualitative variables. Qualitative variables have values that are not numerical. The genders or the political beliefs of the people in a population are examples of qualitative data.

Quantitative data: Quantitative are the data which refer to quantitative variables. Quantitative variables have numeric values. They might be able to take all possible values between two limits (constant variables) or it might take only certain values (discrete variables). The heights or the ages of the people in a population are examples of quantitative data.

Research tool: Research tool is the medium which a researcher uses to collect data for empirical research. Questionnaires and interviews are common research tools for social research.

Social determinants of health: Social determinants of health are the non-medical factors which affect the health condition of some people or a population. Social determinants of health usually include factors such as living conditions, working conditions, socioeconomic status, educational level, unemployment, social discriminations and social exclusion. Social determinants of health are often used to explain the disproportionally lower health indices in certain social groups, such as the incidence of communicable and non-communicable diseases, life expectancy and accessibility to the healthcare system.

Social research: Social research is the sum of the different ways of systematic and scientific study of social phenomena. These ways often aim at the detection of mechanisms and the development of models which explain the social phenomena.

Zoonosis (pl. zoonoses): Zoonoses are the communicable diseases that can be transmitted between humans and vertebrate animals. If they are transmitted from humans to animals they are called zooanthroponoses, while the ones that are transmitted from animals to humans are called antropozoonoses. The west Nile fever and brucellosis are typical examples of anthropozoonoses. The transmission of an anthropozoonosis from animals to humans does not exclude human-to-human transmission.

Pedagogical glossary

Assessment rubric: An assessment rubric is a strictly organized assessment system with certain assessment criteria, which is used for the precise quantitative assessment of several features of an answer or a project according to certain criteria and corresponding grading scales.

Brainstorming: Brainstorming is an instructional technique, with several variations, that might take place within a small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning: By the term collaborative learning we refer to a sum of learning techniques, during which students cooperate or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participation and their collaboration and communication skills.

Concept map: Concept maps are a kind of graphic organizers similar to mind maps. They include concepts in frames interconnected with arrows. A verb is written above each arrow which determines the kind of the semantic connection, in a way that the two interconnected concepts and the arrow (verb) form a semantically independent sentence.

Critical health literacy: Critical health literacy is an important dimension of health literacy beyond fundamental literacy and comprehension skills in health contexts. It includes quite useful notions and skills

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for a health literate citizen in modern society. Critical health literacy mainly consists of the critical appraisal of health information, the comprehension of the interconnection between health and society - and the notion of social determinants of health in particular - and the participation in civic actions for the promotion of health.

Critical reading: Critical reading is an instructional technique which consists of the thorough study of an information source (e.g., a text or a diagram). During critical reading, students have to recall, interpret and evaluate information from the source, training the corresponding critical thinking skills.

Graphic organizer: Graphic organizers are a group of various ways of schematic (visual) and diagrammatic representation of the connections among facts, concepts or processes. They can be used as teaching, learning, or assessment tools. Common kinds of graphic organizers are mind maps, concept maps, flow charts and Venn diagrams.

Infographic: An infographic (information graphic) is a kind of multimodal representation of facts and information. It usually forms a broad graphic composition combining short texts, numerical data, graphs, diagrams, sketches, colours, and shapes. The aim of the infographic is to present a big amount of information on a topic in a visual way, making it immediately comprehensible.

Inquiry based learning: By the term inquiry-based learning we refer to the engagement of students in active learning processes during which they practice several scientific skills. Students make use of these skills in order to answer scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some other common inquiry skills include models construction and use, carrying out experiments, data collection and organization, variable handling, data driven conclusion-making and communicating over scientific issues.

Mind map: Mind maps are a kind of graphic organisers which, in their generic form, include concepts in frames which are interconnected with lines. Each line represents a semantic connection between the two concepts it connects. Mind mapping is easy even for novice students. Although showing the existence of semantic connections, it does not clarify the kind of connections depicted.

Project based learning: Project based learning is an instructional approach of active learning having several forms, during which students work in groups on the development of projects, often referring to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Role game: By referring to the term role game in educational contexts we mean a broad spectrum of activities in which one (usually a student) assumes the role of another character, often fictional. The student has to act and express themselves as the character would do, while keeping some kind of distancing from the assigned character, as well.

Values clarification: Values clarification is quite a common technique in values education. At its general form, students have to prioritize values they select from a list, according to their own hierarchical value system, especially in terms of a given decision-making problem. It is a highly self-reflective activity, during which they are concerned about the values they have even if they were not aware of them.

Competences / Learning Goals

I. Knowledge (Core Concepts)
a) Transdisciplinary concepts: Critical health literacy, STSE (Science, Technology, Society, Environment) interconnections, One Health approach, empirical social research.

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b) Specific content concepts: Communicable diseases, zoonoses, anthroponoses, antropozoonoses, emerging infectious diseases, social determinants of health, health disparities, social inequities, social groups.

II. Skills
a) General skills: Critical thinking, reflective thinking, critical reading, decision making, collaboration and communication within small groups, presentation skills.
b) Specific skills: Critical reading of scientific sources (videos, infographics, informative health texts, academic texts), argumentation about the social and environmental dimensions of scientific topics, empirical social research design, questionnaire (research tool) design, gathering of qualitative and quantitative data, statistical analysis of qualitative and quantitative data, drawing data-driven conclusions, presentation of scientific topics, discussing about scientific topics, handling of educational simulations.

III. Attitudes (Affective domain)
a) Attitudes and values: Awareness concerning environmental, social and ethical aspects of an epidemic, recognition of modern civilization as a factor of emergence of new infectious diseases, empathy development towards sensitive social groups, emotion recognition, recognition of the interference of emotional factors in decision making, recognition of the difficulty in decision making and values hierarchy within realistic contexts, values recognition and hierarchical organization, reconsidering of values hierarchies concerning social disparities, awareness about health disparities, recognition of the interconnection between science and society.
b) Behaviors: Health-related decision-making driven by scientific data, civic actions for the limitation of health disparities, health-related behaviour and decision-making with an orientation towards humanistic values.

Classroom organisation requirements

During the 1st teaching hour students work independently on computers. From the 2nd to the 4th teaching hour students work in pairs, having one computer for each pair. From the 5th to the 6th teaching hour students work on pairs on their computers, with a potential of cooperation of two pairs at four-member groups (2+2 technique). From the 7th to the 10th teaching hours students work in small groups, about 3 to 5 members each, the precise number of members depending on the number of sections of the questionnaire. During the 11th and the 12th teaching hours the whole class works collectively.

Prerequisite knowledge and skills

- Existence of communicable diseases capable of leading to pandemic and epidemic outbreaks.
- Examples of historical or recent epidemics and pandemics.
- The students' experience of everyday life during COVID-19 pandemic would be quite useful.
- The notion of social inequities in modern society in relation to various factors (e.g. concerning profession, income, education, origin, gender etc.).
- The existence of questionnaires as social research tools.

School research project

Topics

E. What is the origin of communicable diseases?
F. How can an epidemic crisis affect various social groups?
G. How did the COVID-19 pandemic affect social groups in the local society?

I. Research management, design, and administration

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Research item (questionnaire) design for the conduct of an Internet school research on the effect of the COVID-19 pandemic on the local society. The research focuses on the personal experience of the pandemic by each citizen and the impact the pandemic had on several local society groups.
Conduct of empirical social research in the local society.
Data collection, analysis and interpretation.
Presentation and communication of the research project.
Minor aspects of the project design are going to be determined by students themselves.

II. Data analysis and reporting

Data collection and handling by using proper techniques from the field of descriptive statistics.
Different data handling depending on the data type (qualitative or quantitative).
Calculation of simple descriptive measures for quantitative data, such as mean, median and range.
Grouping of qualitative data into categories and calculation of simple descriptive measures, such as frequencies and relative frequencies.
Depiction of data by simple graphs, such as histograms, bar charts and pie charts.

III. Target audience for recommendations

The rest of the class, maybe teachers and students of the entire school provided the project is presented at a school event. The parents of the students or even local authorities could also attend the event.
Maybe the local society if local media are available (e.g., an informative website for local issues). The outcome of the school research (final report and results) could also be communicated to local authorities (e.g. the municipal section for education or educational structures) or a non-governmental organization, particularly if they have cooperated with the school at during educational visit or a discussion-with-experts event.
If the project quality is high and students would like to, it could be communicated in a student research conference or in a student research journal.

IV. Public debates and recommendations
Presentation of the project outcomes within a school event or in local media. They could also be distributed to the local authorities on to non-governmental organizations. They could be optionally presented at a student conference or in a student journal.

Teacher guidance notes

- Students often find it difficult to acknowledge the importance of social determinants in shaping one's health condition. The notion of health is often seen exclusively from a medical or a biological viewpoint and the impact of social conditions is undermined. Consequently, the social determinants of health are often omitted or severely undermined in the conceptualization of health by students.
- Attention ought to be paid to the careful handling of the issues of social inequities in order not to reproduce stereotypes or have some students become offended. The examples of social groups or social inequities should be carefully selected, since the scope of the learning sequence is to cultivate students' citizenship and critical health literacy skills. The reproduction of commonplace stereotypes might intensify students' bias and easy labeling that do not represent the complex and changing nature of a real society. On the contrary, it promotes a deterministic way of thinking for the students hindering their meaningful critical understanding.
- Teaching ought not to be restricted to the notion of the existence of health inequities due to social inequities. Furthermore, potential actions for bridging the health gaps should be emphasized, especially

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those to which students as potential citizens could contribute. They should realize that health inequities are not irreversible, but they could be in part restricted, through citizens' personal and collective actions.

- Students experientially approach the role of a researcher by designing and conducting empirical research by themselves. The concept, the characteristics, the difficulties and the limitations of research are approached, and students are trained in inquiry skills like gathering, handling, interpreting and presenting data. Moreover, they approach some epistemic aspects of scientific practice, such as the procedure and the way of production of new scientific knowledge, the intrinsic variance of social research, the different interpretations of the same data and the notion of theory-laden practice.

Assessment activities

The assessment activities act complementarily to one another and aim at the close monitoring of the students' learning procedure. Some activities aim at formative and some others at summative assessment, some assess students in a quantitative and some others in a qualitative way, some aim at conceptual understandings, some at critical thinking skills, some at collaboration and communication skills and some others at affective domain assessment. They all contribute to having a multi-perspective view for each student. The teacher can omit or undermine some of the assessment activities if they think so. Some of the learning activities happen as the lesson takes place without special activities done or special assessment material designed (e.g. observation of students' participation or performance at question-and-answering).

- Initial assessment of students' initial conceptions and attitudes in the phase of students' ideas externalization, via a short questionnaire and constructing a concept or mind map.
  Diagnostic quantitative and qualitative assessment aiming at conceptual understanding and affective connotations.
- Formative assessment of students' worksheets during the entire learning sequence.
  Formative qualitative assessment aiming at conceptual understanding, critical thinking skills and affective connotations.
- Formative student assessment through observation of their participation in question-and-answering techniques and in class discussions during the entire learning sequence.
  Formative qualitative assessment aiming at participation, conceptual understanding, reasoning, collaboration and communication skills.
- Formative student assessment through the observation of their participation in the role game and the way they handle their role.
  Formative qualitative assessment aiming at reasoning, communication skills and affective connotations.
- Summative student groups assessment of the quality of the intermediate reports on project data analysis and of the project oral presentation according to assessment rubrics.
  Summative qualitative and quantitative assessment aiming at higher-order inquiry and communication skills.
- Summative assessment of the final project report made collaboratively by the whole class. *Summative qualitative and quantitative assessment at inquiry, communication and self-reflection skills*.
- Summative assessment of students' self-referred beliefs, attitudes and behaviours through a questionnaire with Likert-scale questions at the end of the learning sequence.
  Summative quantitative assessment aiming at affective connotation.
- Summative assessment of the learning procedure by the students in terms of likeability, interest, difficulty, self-fulfillment, collaboration and time management.
  Summative quantitative and qualitative assessment aiming at self-reflection.

Teacher professional development actions

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Teacher professional development on:

- STEM/science/health education for social justice and citizenship through the promotion of critical literacy aspects.
- The use of active experiential learning techniques (role playing, values clarification).
- Project-based learning and collaborative learning techniques.
- Fundamental principles of the conduct of a social empirical research and the design of questionnaires as a research tools.
- Coordination of the conduct of students' empirical research.
- Use of appropriate software for questionnaire design, data analysis (descriptive statistics) and presentation.
- The utilization of the scenario's digital learning objects in the inquiry-based learning process.

Digital Learning Objects (DLOs)

DLOs created specifically for the needs of the PAFSE project

I. *'Concept mapping of the social determinants of an epidemic'*

http://photodentro.pafse.eu/handle/8586/32
Graphic organizer development environment for the externalization of students' conceptions. Students are given the environment to freely design a concept or mind map about the environmental and social aspects of an epidemic. Some guiding core concepts and connections are provided to help students begin the concept or mind mapping activity more easily.

II. 'Global map of the origin of communicable diseases'
Interactive simulation and map software about the chronology (approximate date) and place of origin of recent epidemics and pandemics and past endemic diseases. Students select on a 20th and 21st century timeline dates representing the first description of pathogens which lead to the outbreak of recent epidemics and pandemics. Endemic disease choices are also available next to the timeline. By selecting each disease, the geographical area of disease origin is coloured on the map and a short informative text about the disease and its origin appears.

III. 'Social determinants of health'
Environment for guided navigation and critical reading of adapted texts, short videos and infographics concerning social disparities during epidemics in close relation to the notion of social determinants of health. Two videos, two text excerpts and some small infographics have been selected to be incorporated in the navigation environment. Students critically study the sources above. The DLO environment also provides short explanations for specific terminology used, like a small-scale glossary.

IV. 'The social, emotional and ethical experience of an epidemic'
Experiential three-part role game environment, in which the user (a pair of students) chooses a character to support. During the first part the pair gives one-word-answers (yes/no) to a series of health-related questions according to the role and sees how much 'advantage' they have in relation to the other students' roles. The advantage is visualized in a virtual environment. At the second part some keywords are given to the students, and they have to describe the experience of the character during an epidemic and make health-related decisions on crucial issues. At the third part students have to prioritize conflicting values within an epidemic context, according to the ethical criteria of their role and their own ethical criteria.

DLOs which have been retrieved from online resources

I. *'Health and social inequities among European countries'*
https://health-inequalities.eu/el/toolbox/interactive-map/

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Interactive European map depicting social and financial indices of European counties in relation to health-related indices. The possible correlation among indices is noted and the relation of each country's index to the European mean is presented, as well as index variations among regions within the same country.

Supplementary Educational Resources (SERs)

A. SERs created specifically for the needs of the PAFSE project

I. *'Questionnaire about the environmental and social determinants of health'*
Initial assessment and misconception detection software about the environmental and social dimensions of epidemics in the form of a short quiz with close-ended and short-answer questions.

B. SERs which have been retrieved from online resources

II. *'Health disparities during the COVID-19 pandemic'*
https://www.health.org.uk/news-and-comment/charts-and-infographics/same-ipandemic-unequal-impacts
Comprehensive infographic about the interconnection between health and social inequities during the COVID-19 pandemic.

III. *'The animal origin of epidemics'*
https://www.youtube.com/watch?v=qp5CEcIyk94
Educational YouTube video about the animal origin of epidemics, by exemplifying this with the cases of West Nile virus and Ebola virus.

IV. *'Health inequities in the USA'*
https://www.youtube.com/watch?v=VCnBgaGJMKc
Short news excerpt regarding health disparities during the COVID-19 pandemic in the USA, related to nationality/race and working conditions.

V. *'Types of health disparities during the COVID-19 pandemic'*
https://www.youtube.com/watch?v=6leuxxEDM-E
YouTube video by the World Financial Forum about the ways in which various kinds of social disparities lead to an unequal experience of the COVID-19 pandemic by different social groups (social determinants of health).

VI. *'The causes and consequences of health disparities'*
https://www.cdc.gov/coronavirus/2019-ncov/community/health-equity/racial-ethnic-disparities/index.html
Informative text by the Centre for Disease Control and Prevention about the social determinants of health in the case of the COVID-19 pandemic. In particular, social reasons for health disparities and their health outcomes on citizens are presented and explained.

VII. *'Health disparities during epidemics'*
https://ejournals.epublishing.ekt.gr/index.php/ekke/article/view/23229
Academic paper on social disparities and health disparities during epidemics with emphasis on the case of COVID-19 (in Greek).

VIII. *'Inequities in the Greek society during the COVID-19 pandemic'*
https://www.statistics.gr/el/infographic-menoume-spiti-5,
https://www.statistics.gr/el/infographic-menoume-spiti-2,
https://www.statistics.gr/el/infographic-menoume-spiti-8
Infographics by the Hellenic Statistical Authority concerning statistical data from the COVID-19 pandemic in Greece (in Greek). The chosen infographics highlight residence size, accessibility to the Internet and underlying health condition.

IX. *'Consequences of the COVID-19 pandemic on the society'*

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https://www.youtube.com/watch?v=6vkMJNRJ_NY
Educational YouTube video about the consequences of social disparities and discrimination on the impact the COVID-19 pandemic had on different social groups.

X. *'The social determinants of health'*
https://www.youtube.com/watch?v=8PH4JYfF4Ns
Educational introductory YouTube video about the theoretical conceptualization of the social determinants of health.

XI. *'Questionnaire design software'*
Software for online questionnaire design and distribution, e.g., Google Forms, for making the student questionnaire for the school research project.

Teaching -learning activities

1st teaching hour – What students think about the environmental and social determinants of an epidemic?
Teaching phase according to the inquiry & project based instructional model: Engagement – Externalization of students' initial conceptions

- Students are initially engaged in the learning sequence and are introduced to its main topic, which is the impact of an epidemic crisis to society, and to its different social groups. Some relevant news headlines, infographics or short videos could be used at this stage to spark a conversation in class on the topic. The infographic SER II could be utilized. SER II refers to the COVID-19 pandemic and is quite comprehensive and appropriate to be used in the phase of engagement, preferably translated in students' native language.
- Students continue by externalizing their initial concepts and attitudes regarding a) the origin of communicable diseases and b) the social determinants of health during an epidemic crisis. For this reason, SER I and DLO I are used to help the detection of students' conceptions. Students answer a short digital questionnaire (SER I) of about 15-20 close-ended or short-answer questions regarding their knowledge and attitudes about the origin of communicable diseases and the social dimensions of an epidemic. The questions are meaningful so that they bring core concepts and attitudes to the surface. Students are made clear that the questionnaire is anonymous and that it is not a grading activity.
- Afterwards, they move on to DLO I, where they are assigned to construct a graphic organizer in the form of a mind map or a concept map; they can easily turn a mind map into a concept map, if it is not too confusing for them. They are given some guiding central concepts and connections, as well as some concept options that can orientate students for the initiation of the map construction, about the environmental and social determinants of epidemics. Then, students continue expanding their maps independently by complementing the concepts and connections they desire. They are also told that the maps are anonymous and that they are not going to be used for grading.
- The students' data from the questionnaires and the graphical representations are collected by the teacher who shows the questionnaire results anonymously to the class. The teacher shows the questions one-by-one and the percentages of each answer. Students can explain their rationale if they would like to, and a first classroom discussion on the answers follows. In this way some common misconceptions might arise. However, this instruction phase does not aim to misconception reconstruction but to their expression, their realization, and use of them as a reference level by the teacher for the rest of the learning sequence.

2nd teaching hour – Emerging Infectious Diseases and the animal origin of communicable diseases
Teaching phase according to the inquiry & project based instructional model: Completion and reconstruction of students' initial conceptions through inquiry

- At this phase, students are engaged with the animal origin of most communicable diseases and the effect of the modern way of living, regarding the relationship with the natural environment, on the

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appearance of new Emerging Infectious Diseases ('One Health' approach). DLO II is used for making this approach via structured inquiry within small groups. The inquiry aims at the completion and reconstruction of students' initial conceptions which have been previously shown in the learning sequence.

- DLO II includes an interactive timeline with a world map. Students select points on the timeline that stand for dates of the 20th and 21st century that some epidemic and pandemic causing pathogens were described for the first time (SARS-COV-2, HIV, Zika virus, avian influenza virus, swine influenza virus, SARS virus, MERS virus, Nipah virus, Creutzfeldt Jakob prion, antibiotic resistant bacteria strains, etc.). By selecting each pathogen the area of its origin on the map gets coloured, and some general information on the origin of the pathogen and main features of the disease appear. There are some other choices out of the timeline, as well, referring to common endemic diseases (e.g. measles, rubella, malaria), which appeared mainly for the first time during the agricultural revolution.
- At first, students select several diseases from the timeline trying to answer the question regarding how the communicable diseases originated. They conclude that most of them have come from animal pathogens (anthropozoonoses), which were mutated and turned into human pathogens (anthroponoses). Students also find certain examples of antroponoses and anthropozoonoses in DLO II.
- Then, students use DLO II to match specific human diseases to the animal they came from. They try to detect possible ways in which humans came in touch with the animals of each case, since the animals are in many cases wild. Students exchange their opinions in pairs and then in groups of four.
- Afterwards, students focus on recent cases of contagious diseases (cases from the 20th and 21st century). By selecting the proper options in the learning object, they try to draw a conclusion regarding the geographical origin of recent epidemics and pandemics. Students are given a global climate and a global population map as complements to the map of epidemic origins. They conclude that the diseases often origin from subtropical and tropical areas, and specifically from areas of human expansion towards non-developed natural areas.
- Students brainstorm in groups of four on aspects of modern lifestyle and civilization that intensify the emergence of new infectious diseases, as can be seen in the timeline. The brainstorming is then repeated and enriched by involving the entire classroom and a classroom discussion on these activities follows (city expansion to natural areas, habitat fragmentation, wild animal consumption and trade, intensive farming, overuse of antibiotics etc.). Students conclude that the common denominator of most of these activities is the intense intercourse between human and wild animals.
- As a final recapitulation of the lesson the educational video SER III is suggested to be shown and commented. The video concerns the connection between natural habitat alteration and the increase of emerging infectious diseases, explaining the cases of the Ebola virus and the West Nile virus.

3rd-4th teaching hours – The magnification of health disparities due to social inequities during the COVID-19 pandemic and introduction to the concept of social determinants of health

Teaching phase according to the inquiry & project based instructional model: Completion and reconstruction of students' initial conceptions through inquiry

- At this phase, students work in groups of four and are engaged in critical reading of various information sources with the aid of DLO III. It includes the controlled navigation in certain information sources (short videos, infographics, a public health organisation text and academic text excerpts) concerning the magnification of social inequities during the COVID-19 pandemic. The information sources are adapted according to the learning objectives and the students' abilities and language. The educational resources selected as information sources highlight inequities due to citizens' nationality, gender, socioeconomic status, profession, and health condition. Students have to study critically each source, which means to find, interpret and evaluate the source's information. The central inquiry question of the entire critical reading process (having the form of structured inquiry) is whether an epidemic or a pandemic (bearing in mind the example of the COVID-19) has the same impact on all citizens, which

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means whether all citizens start from 'the same level' when an epidemic crisis, and a health crisis in general, happens.

- Students work in groups following their worksheets and studying successively five sources of informative material (educational resources). The educational resources have been adapted to students' language and to the learning objectives. Each information source sheds light on a different aspect or dimension of the general research question posed to the students. The educational resources that have been incorporated in DLO III are the following sources:
    i. Video SER IV (part of the news referring to the working and racial inequities in the USA in relation to the COVID-19 pandemic. The activation of subtitles is suggested). Students watch the video and have to note down the basic COVID-19 pandemic health inequities in relation to working conditions and race or national descent. They try to detect the reasons leading to these inequities and then, they have to think of what differences would have a cleaner, an open market seller and an office worker in their daily life during the COVID-19 pandemic in regard to the exposure to the virus and the difficulty in the application of precautionary measures. Afterwards, students argue which of these three jobs would be more likely to have an immigrant or an unskilled person. Students answer to the final question whether citizens' health condition depends exclusively on medical reasons, or whether they interfere with social ones as well.
    ii. Video SER V (Short presentation of health inequities during the COVID-19 pandemic in connection to the accessibility of the healthcare system, the economic status of the neighborhood, the accessibility to technology and remote working, and the existence of disabilities). Students are assigned to find the five social parameters, mentioned in the video, which affected citizens' exposure to COVID-19. Then, they attempt to explain and interpret some possible reasons why each of these categories leads to health inequities and to mention some relevant examples. They also completement other possible parameters leading to health inequities and are asked to consider whether some of these parameters affect one another. The guiding inquiry question of this video is which social factors lead to health inequities during the COVID-19 pandemic, and in what ways they did so.
    iii. Public health organization text SER VI (a translated or linguistically adapted form of a text by the Center for Disease Control and Prevention). Students have to find social determinants in the text (e.g., working conditions, income, nationality, education level), leading to health inequities and to interpret the possible reasons for these causative relations. Afterwards, they have to find in the text the different kinds of health inequities mentioned (e.g. exposure risk, hospitalization risk, transmission risk). They attempt to interpret the possible causes of these health inequities and the consequences they would have in citizens' health condition. Students are given two hypothetical cases of citizens and try to analyze, with the aid of their worksheets, the health inequities they would face during an epidemic outbreak similar to the COVID-19. Finally, students try to come up with ways in which a proper health policy could attempt to downsize health inequities caused by one social inequity case mentioned in the text. The guiding inquiry question of the study of this text is the same with the previous one but requires a much greater degree of analysis.
    iv. Academic text SER VII (a translated or linguistically adapted version of text excerpts referring to the intensification of social inequities during epidemic crises). Students read critically some text excerpts, and keeping in mind what they have already seen, they are assigned to summarize and enrich what they have already studied about the consequences of social inequities during an epidemic. They find examples different from COVID-19 in the text, for example the Ebola epidemics in Africa and cases of non-communicable diseases, and test whether the emergence of health inequities due to social inequities took place in these cases as well. They also focus on the issue of access to digital technologies and explain, based on the texts, why the rise of digital technologies magnifies health inequities. They generalize and conceptualize the notion of social determinants of health by using their own examples and attempting to formulate a

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definition for the concept. The study of this text aims to answer the guiding inquiry question whether health inequities due to social inequities appeared only during the COVID-19 pandemic, or whether they are an intrinsic feature of every health crisis.

v. Infographics SER VII (Infographics referring to inequities during the COVID-19 pandemic in Greece concerning residence, health conditions and access to the Internet). Students use the infographics to evaluate to what extent these three parameters would unequally affect the Greeks during an epidemic outbreak. The evaluation is done according to given criteria (e.g. access to health information, infection risk at work, capability for remote working and schooling, quarantine effectiveness etc.). Then, they propose possible interventions for limiting these inequities and assess their applicability. The question studied with these infographics is to what extent health inequities appeared during the COVID-19 pandemic in Greece.

- Students have studied about health inequities within the same society up until now. With the aid of the interactive map DLO V they are now studying about COVID-19 disparities between different societies, and, in particular, among European counties. They select two European countries in the DLO V interactive map; they can optionally select their own country and another of their choice. Students try to find differences in educational level and financial status between the two states by comparing them to a) the European mean, b) one another and c) between different regions of the same country. They test whether a correlation of these indices with health accessibility, life expectancy and self-reported health condition exists. They try to interpret these data and consider how these problems –if found to exist- could be encountered. The inquiry question of this phase is how health disparities differ among European states.
- At the end of the inquiry phase students draw general conclusions on the social determinants of health, based on their study. A short relevant discussion in class may follow.
- The inquiry process up to the critical reading of text (iii) is suggested to be organized for the 3rd teaching hour, whereas the 4th teaching hour is suggested to be dedicated to the critical reading of sources (iv) and (v), and to the study of the map. If time is not sufficient, the study of SER VII (v) can be assigned as homework, as the other activities are estimated to have more educational benefits, yet greater degree of difficulty.

5th-6th teaching hours – The personal experience of the COVID-19 pandemic, emotional and ethical aspects of the COVID-19 pandemic as parameters for health-related decision making

Teaching phase according to the inquiry & project based instructional model: Application of knowledge and skills gained through inquiry

- At this phase, students apply the knowledge they gained during the inquiry phase on the social determinants of health through experiential learning, by playing a role game and getting engaged in values education activities.
- At first, a short recapitulation about the social determinants of health takes place as a connection to the previous teaching section and aiming at the better conceptualization of the issue. The educational videos SERs IX and X are suggested to be shown and commented in a classroom discussion. These are two educational videos appropriate for the clarification of misunderstandings and the furthering of meaningful conceptual understanding of the notion of social determinants of health.
- Then, students participate in a three-part experiential role game in pairs, with the aid of DLO IV. Each pair of students is randomly given a hypothetical person (role) by DLO IV, accompanied with a short description. People from various social groups facing different kinds and different degrees of health disparities during an epidemic or pandemic are represented in the game.
- During the first part of the role game, each pair is assigned to give an one-word answer (yes/no) to some questions concerning exposure risk, healthcare accessibility and health disparities due to social inequities in general, during an epidemic crisis (in this case COVID-19 because of its familiarity) according to the assigned role. Students are given about 15 questions, such as ‘Is remote working plausible?’, ‘Is quarantining within the same house possible?’ and so on. The number of positive

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answers represents the advantage each person has when compared to the others, in terms of protecting their health condition during an epidemic.

- After answers from all the pairs are submitted, the results are presented in the DLO in the following way: each pair's role is represented by a virtual character. Although all characters have started from the same point, every character steps forward as many steps as the number of their positive answers. In this way the health inequities are visualized. A classroom discussion follows, with each pair presenting the rationale behind their answer and commenting on the result.
- Then, each pair deepens the study of their role. Alternatively, two pairs can cooperate having two roles assigned, in total. Each pair has to be put in their character's shoes and attempt to describe the role's personal and subjective experience during an epidemic crisis. Students are given some keywords and parameters by the DLO (such as possible emotions or dimensions they could include in their answer) which could scaffold those students who have difficulties in organizing their answer. The answer can be either submitted in the DLO or be written on the worksheet, for students without the ease of typing fast on the computer.
- Afterwards, students are given some hypothetical cases of health-related decision-making (e.g. the application of strong precautionary measures, the frequency of purchase of healthcare products, the attitude towards vaccination, the degree of getting informed on health topics etc.). They have to take these decisions according to the rationale and criteria they think their role would make use of. It is highlighted that decision making is not always based on pure rational reasoning, and that this has been explained by neurobiological data. Emotional factors usually interfere to a great degree in decision-making, especially for short-term decisions. Students are urged to take the whole emotional state of their role into account in order to make decisions that seem more realistic for their character. It is clarified that correct or wrong answers do not exist and that the prediction of the role's behaviours is based exclusively upon the personal interpretation of the role's features by each pair of students.
- Each pair presents briefly the role's personal experiences and decisions to the class and a short discussion follows about them. Each pair explains the rationale behind the character's presentation and choices. The following discussion focuses mainly on alternative suggestions on the roles' experiences and decisions other than the one presented. It is important these decisions to be supported by arguments, in order to show that each personality is complex and, although affected to a great extent by social circumstances, it cannot be reduced to simple schemes of naïve social determinism, but is, instead, open to different interpretations.
- In the final part of DLO IV, each pair has to put several conflicting values in hierarchy according to some values systems (values clarification). Each pair is given some sentences, each of which represents a different value during an epidemic, such as the funding of medical research, the society's financial activity, the help of sensitive social groups, the environmental awareness regarding the overuse of medical products, etc. The values are given in the form of sentences in order to be more comprehensible for students, since they are expressed through specific examples. Some examples of these sentences could be 'small corporations should continue working even if they mean high intercourse among people', 'it is very important to reduce human intercourse at any cost', 'it is important to make regulations regarding pollution by medical waste', 'fundamental health interventions must be obligatory even for those who do not agree with them', and other similar sentences. The number of sentences is suggested to be around 10 to 15. Each pair has to make three hierarchies of the values, putting them from the most important to the least one. The two hierarchies resemble the personal value systems of the two students, whereas the third resembles the value system of the assigned role. It is made clear again that there are neither correct nor wrong answers, as well as morally accepted or discredited ones. It is also explained that students might find some values equally important, but in emergency cases, like during an epidemic, values have to be scaled, although the value hierarchy and decision-making are much more complex in reality. Students are urged to express themselves freely and sincerely and not to reproduce what it is generally thought to be morally accepted.

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- A class discussion takes place about the many different value systems people might have, the existence of conflicting values by the same person, the importance of values for decision making and the importance of value evaluation for policy making. Different students' values hierarchies are used to exemplify how different values systems lead to very divergent personal behaviours and policy making during an epidemic. The interconnection among values, attitudes, decision making, and behaviours is also highlighted.
- The 5th teaching hour is suggested to be dedicated to the commentary of the videos, the first part of the role game and the beginning of the second part, whereas the 6th teaching hour is suggested to be dedicated for the completion of the second part and the entire third part (values education) of the role game.

7th-8th teaching hours – Development of a questionnaire to study the personal experience and health disparities of the COVID-19 pandemic (School project)

Teaching phase according to the inquiry & project based instructional model: Initiation of the project (research tool design and data gathering)

- Students work on the short project of the learning sequence, which constitutes of the conduct of a short school empirical social research regarding the way citizens of the local society experienced the COVID-19 pandemic. The 7th and 8th teaching hours focus on the design of the social research tool, which is a questionnaire.
- Initially, the teacher outlines the main phases of empirical research and explains the fundamental principles of question selection and formulation, when designing a questionnaire. The generic scope of the questionnaire is to highlight the citizens' personal experiences of the COVID-19 pandemic, the emotions they felt, the changes that happened in their life and the difficulties they faced. Secondly, the questionnaire aims at the detection of health inequity issues and possible correlations to social factors. Students decide on the questionnaire sections, and they are divided in groups equal in number to the questionnaire sections. Each group is responsible for designing one questionnaire section.
- Each group takes responsibility for coming up with and formulating the questions to fill in the assigned section. They are urged to choose explicit and meaningful questions without overlap, and to include both close-ended and open-ended questions in order to allow both the free expression of the citizens and the gathering of quantitative data (e.g., from Likert scales) for the detection of correlations. Each group focuses on the kind of questions which is more appropriate for the kind of data needed.
- When every group has finished the first outline of their questions, another group checks the questions made by the first team in order to suggest enrichments or modifications, which are always made in conciliation with the first group.
- The questionnaire is presented to the entire class and it gets its final version, which is approved by all the students.
- Some students get the responsibility to write the questionnaire in an online form, which allows it to be more easily delivered to its targets. An application such as Google Forms (SER XI) can be used for this purpose.
- The online questionnaire is completed by a sample which has been selected to represent the target population. The sample has to be small in order to make the data analysis easier for students.

9th-10th teaching hours – Analysis of the questionnaires collected (School project)

Teaching phase according to the inquiry & project based instructional model: Continuation of the project (data analysis)

- The questionnaires are going to be filled-in by selected members of students' and teacher's affiliations, as it has been planned by the teacher and the students. The interval for the data collection has been estimated to be about a week between the 8th and 9th teaching hours. If participation is low, the analysis of the questionnaires could begin normally at the 9th teaching hour, but also be expanded for one extra teaching hour until a sufficient number of online questionnaires has been collected. The filled-in

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questionnaires are gathered by the students and this phase of the project is dedicated to data handling and analysis. Each student group is assigned to the analysis of the data of the questionnaire section they had initially made.

- Each group shortly describes the results of its section on paper and uses the appropriate statistical techniques for the analysis and presentation of the collected data (quantitative or qualitative). In the case of quantitative data, simple graphs (e.g., histograms, pie charts, scatter plots) and fundamental descriptive statistics measures (e.g., mean, range, median) are used. On the other hand, qualitative data are grouped in categories and, again, simple graphs (e.g., bar charts, pie charts) and fundamental descriptive statistics measures are used (e.g., absolute and relative frequencies), as well as a selection of specific answers bearing some kind of significance.
- After each group has finished the data description and analysis, it has to draw data-driven conclusions, to make possible interpretations and correlations and to suggest complementary research designs which would shed more light on the research.

11th-12th teaching hours – Presentation and review of the findings of the empirical research (School project)

Teaching phase according to the inquiry & project based instructional model: Completion of the project & final assessment (project presentation)

- During the 11th teaching hour each group presents their research findings and the relevant report the have written to the rest of the class and a class discussion follows among the groups under the teacher's coordination. Students are urged to make arguments in relation to alternate conclusions and interpretations than the ones proposed, and to develop interpretations and correlations among different sections of the questionnaire. The teams are urged to take part in a fruitful dialogue and to exchange opinions instead of an one-sided presentation of the work of each group. The discussion might focus on issues concerning uncertainty, risks and biases in social empirical research. Such issues might be the misinterpretation of data, theory-laden practice, conflicting results, sampling issues and personal biases in social research. The discussion should rely on specific examples from the survey findings and be encouraging to the students, not disapproving. These discussions are important because they highlight important notions of the Nature of Scientific Inquiry and of the Nature of Scientific Knowledge and disprove the common misconception that science has an impersonal and flawless character.
- During the 12th teaching hour, a short report is written based on the results of each team and the discussion that preceded, which is the final report of the school project. It is suggested the students to organise this final report according to the structure of an academic paper (Introduction – Methodology – Results – Conclusions), having discrete roles for each part, which, in turn, define their content.
- The texts of the final project could be communicated in a school festival and/or in local mass media, possibly at some website. If the quality of the work is high and the students are willing to do so, the project could be publicized in a student academic conference or journal.

Supplementary learning activities

I. Discussion with experts

Some discussions with experts could take place as optional educational activities, which act complementary to the educational activities previously described. They can have the form of a short presentation, a free discussion, an interview or a combination of those and they could take place in the physical presence of the expert or via teleconference. The expert might be a person whose scientific specialization or whose profession closely relates to issues that having been discussed in the classroom during the learning sequence. The students' discussion with the expert has some additive STEM educational value which is summarized with the following points:

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- The experts have an advanced scientific or professional expertise so they have deeper content knowledge and are more suitable to give students a deeper understanding of the scientific contents and answer students' advanced questions.
- Students can see how the content of the learning sequence can be reflected to real world professional specializations. In this way they connect what they learn to authentic contexts and can learn further information about the real work of STEM professionals.
- Students have the opportunity to discuss with STEM professionals, which would otherwise be probably inaccessible to them. They can learn about the real work of scientists and about the real way new scientific knowledge is produced (Nature of Scientific Inquiry).
- Experts could act as role models for some students and trigger them to follow STEM related careers in the future.
- Experts could give students some more specific guidelines or answer advanced students' questions concerning their research project.

It is suggested to have the discussions done after the general activities have been completed and before or at the beginning of the school project (more specifically around the 6^{th} or the 7^{th} teaching hour). In this way students will have a good background in order to discuss and meaningfully understand the topics discussed with the experts and can ask them questions that will help them in decision-making concerning the conduct of the school project. Of course, if the teacher thinks that the discussions are better to take place at a different time they, are free to do so.
Some scientific and professional specializations that could be cases of experts are listed below with some indicative topics for discussion:

8. Members of environmental organizations – They could discuss with students about emerging infectious diseases, about the 'One Health' approach and about the way modern practices (environmental degradation, habitat loss and fragmentation, antibiotics overuse, modern farming) can increase the threat of the emergence of new infectious diseases.
9. Researchers on the social determinants of health – They could discuss with students about the way social disparities can lead to health disparities, different kinds and examples of health disparities in modern society and how health disparities were magnified during the COVID-19 pandemic.
10. Members of governmental organizations in charge of social policy – They could discuss with students about the different kinds and examples of health disparities in modern society, about vulnerable social groups that are more in danger of health disparities, actions of the state in order to confront health disparities and examples from the COVID-19 pandemic
11. Members of non-governmental organizations or civic networks against health and social disparities – They could discuss with students about different kinds and examples of health disparities within the state and globally, vulnerable social groups that are more in danger during a health crisis, ways of civic action in order to fight against health disparities, non-governmental organization and civic network actions against health disparities, examples and personal experiences from the COVID-19 pandemic.
12. Social empirical researchers – They could discuss with students about the way social empirical research is done, the phases of social research, the process of sampling, good and bad practices when developing a questionnaire, data analysis and presentation, limitations and bias in social research and examples of authentic cases of social empirical research.
13. Academics or university professors with relevant expertise.
14. Members of the PAFSE consortium with relevant expertise.

<u>II. Educational visits</u>
Some educational visits could take place within the context of this learning sequence. In this way the school's educational activities will be complemented with educational activities from other organizations or with visits to authentic places where research or work on relevant topics is being done. It would be preferable to make these visits after the students have examined the relevant issues in the learning sequence

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so that they will be able to meaningfully conceptualize what they examine during the educational visit. A short discussion before and after the educational visit is also necessary in order to determine and summarize the context of the visit and link it to the learning sequence in school.
Some suggested places for educational visits are listed below:

5. Medical or historical museum – During this visit, students could probably come across items featuring the way historical epidemics and pandemics affected past societies and different social groups and can compare them to the impact of the COVID-19 pandemic.
6. Research laboratory concerning social research on social aspects of the COVID-19 pandemic – During this visit, students discuss about the process of an empirical social research, discuss about the work of a social researcher, and discuss about health inequities, decision making and the personal experience of citizens during the pandemic.
7. Governmental organization concerning social policy against health disparities – During this visit, students could get informed about the extent health disparities have in their society, examples of health disparities, the situation during the COVID-19 pandemic and about the social policies that were launched in order to confront them. They could also see material for such campaigns.
8. Non-governmental organization or civic network against health disparities – During this visit, students could get informed about the extent of health disparities and the relevant actions of the organization or the network, about the situation of the COVID-19 pandemic, and the ways each citizen can take action to help the unprivileged during a health crisis. They could also see the way this organization or network work and coordinates its actions for themselves.
9. Institution for health awareness or promotion – During this visit, students could be informed about health awareness or promotion campaigns delivered especially for unprivileged or marginalized social groups, the specific features and difficulties these campaigns have, and the degree that they have been effective up until now. Moreover, they could see for themselves material from these campaigns.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: "Social determinants of health during an epidemic/pandemic outbreak**"**

Knowledge	
1. Distinguishes antroponoses, zoonoses and anthropozoonoses from one another	**Question 1.1:** Zoonoses are transmitted … A) between humans and animals B) solely among animals C) solely among humans **Question 1.2:** The West Nile virus infects humans and birds and can be transmitted from birds to humans. It is a case of …. A) an antrhropozoonosis B) an anthroponosis C) an endemic disease
2. Recognizes cases and features of Emerging Infectious Diseases	**Question 2.1:** Which of the following diseases is an example of Emerging Infectious Diseases? A) SARS B) Smallpox C) Malaria **Question 2.2:** Which of the following is NOT true about Emerging Infectious Diseases? A) They are decreasing over the last years B) They often cause epidemics and pandemics C) They originate from animal pathogens **Question 2.3:** Which of the following practices does NOT lead to the appearance of new Emerging Infectious Diseases? A) An increase in urban pollution B) The urban expansion in subtropical areas C) The antibiotic overuse
3. Recognizes cases of health disparities	**Question 3.1:** A case of health disparity is NOT … A) the increased frequency of several diseases in elder people due to their biological maturity B) the exposure of a lot of manual workers to chronic physical damages C) the inability of a lot illiterate to get informed about health topics **Question 3.2:** Health disparities … A) exist within every society and among different societies B) pose a problem primarily for developing countries C) are not responsible for variations in life expectancy **Question 3.3:** A disease is observed to infect mainly the migrants of a country as compared to the locals. A) This is a case of health disparity, only in the case no biological susceptibility to the disease underlies in the migrants B) This is definitely a case of health disparity C) This is a case of social disparity and not of a health disparity

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4. Explain how health disparities arise from social inequities during an epidemic	**Question 4.1:** During the COVID-19 pandemic a lot of people working in professions having personal contact with a lot of people (e.g., sellers) obligatorily. This is a social disparity which leads to … A) an increased exposure risk to the disease B) a decreased capability of getting informed about the disease C) an increased risk of having severe complications due to the disease **Question 4.2:** The digitization of several healthcare services (e.g., making appointments) might be an extra obstacle … A) for the elderly B) for those who do not handle the spoken language C) for several manual workers **Question 4.3:** Which of the following social groups might have become victims of extensive misinformation during the COVID-19 pandemic? A) People with low educational level B) Immigrants C) People with low income **Question 4.4:** People with low income might have been more exposed to the disease during the COVID-19 pandemic … A) because they were not able to afford for buying medical and pharmaceutical equipment (e.g. medical masks) B) because they were working in profession having extensive contact with other people C) because they might did not have access to the Internet for health information **Question 4.5:** Quarantining during COVID-19 pandemic was more difficult for … A) members in extended families B) people working in office work C) people with disabilities
5. Describes the notions of health determinants of health	**Question 5.1** Social determinants of health appear … A) within the same country and among different countries B) among different countries C) within the same country **Question 5.2:** Social inequities … A) lead to an increase in health disparities B) lead to a decrease in health disparities C) are not connected to health disparities
6. Recalls the phases of an empirical social research	**Question 6.1:** Which of the following phases is earlier during an empirical research? A) Data collection B) Data analysis C) Data interpretation **Question 6.2:** A common research tool for social research is … A) the questionnaire B) observation making C) the use of digital simulations **Question 6.3:** Which of the following practices is included in the phase of data analysis in a social empirical research? A) The organization of answers collected through questionnaires B) The filling in of the questionnaires C) The questionnaire design **Question 6.4:** In an empirical social research via questionnaires … A) either quantitative or qualitative data can be gathered

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	B) only quantitative data can be gathered C) only qualitative data can be gathered **Question 6.5:** The statement of the limitations and the weaknesses of a research is a very important point because … A) it shows the directions that future research can follow B) explains the reasons why the specific research was difficult C) highlights that the research is not important if the limitations are too many
Skills	
1. States arguments concerning the rise of Emerging Infectious Diseases	**Question 1.1:** In which of the following cases it is more probable for a new infectious disease to emerge? A) In a dense city of Southeast Asia at the fringe of a tropical forest B) In a big and highly polluted city of the USA C) In a rural area of France **Question 1.2:** Why the restriction of intensive farming could hold the prevention of new infectious diseases emergence? A) Through the restriction of over-transmission conditions for animal diseases B) Through the restriction of the intercourse between wild animals and humans C) Through the restriction of the poor-quality diet and therefore the boost of the immune system
2. States arguments concerning the reasons of health disparities	**Question 2.1:** Health disparities are more intense for vulnerable social groups because … A) these groups are already in more margined position in the society B) these groups belong to high risk groups for the disease due to biological reasons C) these groups intentionally select to lead a riskier lifestyle
3. Critically reads health related texts	**Question 3.1:** I am able to watch a news reportage about health topics and understand in detail the topic shown. 1) I strongly disagree … 5) I strongly agree **Question 3.2:** I am able to read a text by a health institute and understand in detail the topic presented. 1) I strongly disagree … 5) I strongly agree **Question 3.3:** I am able to read an academic text about a health topic and understand in detail the topic examined. 1) I strongly disagree … 5) I strongly agree
4. Designs a social empirical research	**Question 4.1:** I am able to design an empirical social research in order to study a social phenomenon. 1) With great difficulty … 5) With great convenience **Question 4.2.:** I am able to outline the limitations of a particular social empirical research. 1) With great difficulty … 5) With great convenience

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5. Makes a questionnaire for the conduction of an empirical research	**Question 5.1:** 'How happy to you believe you are?' This question is unsuitable for a questionnaire because … A) it is unclear B) it is open-ended C) it examines several topics at once **Question 5.2:** 'Do you agree with the new governmental measures concerning education and health?' This question is unsuitable for a questionnaire because … A) it examines several topics at once B) it is open-ended C) it is unclear **Question 5.3:** I am able to design a short questionnaire in order to study a social phenomenon. 1) With great difficulty … 5) With great convenience **Question 5.4:** I am able to suggest improvements for a short questionnaire aiming to the study of a social phenomenon. 1) With great difficulty … 5) With great convenience **Question 5.5:** I am able to evaluate the quality of a short questionnaire aiming to the study of a certain social phenomenon. 1) With great difficulty … 5) With great convenience
6. Gathers and handles quantitative and qualitative data	**Question 6.1:** I am able to select a proper data collection method for a social empirical research in order to study a social phenomenon. 1) With great difficulty … 5) With great convenience **Question 6.2:** I am able to use proper statistical measures and graphs in order to analyze the quantitative data of a social empirical research. 1) With great difficulty … 5) With great convenience **Question 6.3:** I am able to organize and graphically present the qualitative data of a social empirical research. 1) With great difficulty … 5) With great convenience
7. Presents the results of a social empirical research	**Question 7.1:** I am able to use graphs in order to concisely present the results of a study. 1) With great difficulty … 5) With great convenience **Question 7.2:** I am able to summarize the results of a research. 1) With great difficulty … 5) With great convenience **Question 7.3:** I am able to formulate possible conjectures in order to explain of the results of a research. 1) With great difficulty … 5) With great convenience **Question 7.4:** I am able to make a short report describing the methodology, the results and the conclusions of an empirical research. 1) With great difficulty … 5) With great convenience

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Beliefs, Attitudes and Behaviours	
1. Recognizes features of the modern civilization as a factor contributing to the emergence of new communicable diseases	**Question 1.1:** Most communicable diseases originate from animal pathogens. 1) I strongly disagree … 5) I strongly agree **Question 1.2:** The increase in interaction between humans and wild animals will lead to increase in the emergence of new diseases. 1) I strongly disagree … 5) I strongly agree **Question 1.3:** The modern lifestyle contributes to the emergence of new infectious diseases. 1) I strongly disagree … 5) I strongly agree **Question 1.4:** New epidemics and pandemics might appear in the near future as a result of the modern. 1) I strongly disagree … 5) I strongly agree
2. Is aware concerning the lives of vulnerable social groups during an epidemic	**Question 2.1:** All citizens of a society experience an epidemic in the same way. 1) I strongly disagree … 5) I strongly agree **Question 2.2:** All citizens of a society have equal accessibility to the healthcare system during and epidemic. 1) I strongly disagree … 5) I strongly agree **Question 2.3:** All citizens of a society are equally informed about health issues during an epidemic. 1) I strongly disagree … 5) I strongly agree **Question 2.4:** All citizens of a society have equal exposure to the disease during an epidemic. 1) I strongly disagree … 5) I strongly agree **Question 2.5:** Vulnerable social groups (e.g. refugees, people of low educational level, people of low economic background) are at greater risk of getting sick or even dying during an epidemic, as compared to people which are not included in vulnerable social groups. 1) I strongly disagree … 5) I strongly agree **Question 2.6:** In the case of a pandemic, some countries are more advantageous in the administration of the pandemic compared to other countries. 1) I strongly disagree … 5) I strongly agree

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3. Recognises the emotions they feet during an epidemic	**Question 3.1:** I might feel fear during a new epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.2:** I might feel insecurity during a new epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.3:** I might feel despair during a new epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.4:** I might feel pressure during a new epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.5:** I might feel anger during a new epidemic. 1) I strongly disagree … 5) I strongly agree **Question 3.6:** I estimate I will deal easily with my emotions during a following epidemic. 1) I strongly disagree … 5) I strongly agree
4. Recognizes the interference of emotions in health-related decision making	**Question 4.1:** The emotional state of a person does not interfere in their decision making processes. 1) I strongly disagree … 5) I strongly agree **Question 4.2:** During the COVID-19 pandemic I intentionally did acts because I wanted it a lot although I knew was putting myself at health. 1) I strongly disagree … 5) I strongly agree **Question 4.3:** It is easier to get influenced by my emotions during taking a decision which might put me at risk when it is about the near future (e.g., the next hours) than when it is about a long-term decision. 1) I strongly disagree … 5) I strongly agree
5. Recognizes the difficulty in making decisions when different ethical values collide	**Question 5.1:** I often feel a clash among my values when it comes to decision making. 1) I strongly disagree … 5) I strongly agree.
6. Prioritizes values into scale during decision making in the context of an epidemic	**Question 6.1:** If I am invited for entertainment during an epidemic, I might go in spite of the increased risk of exposure to the disease. 1) I strongly disagree … 5) I strongly agree **Question 6.2:** If I work in close contact with a lot of people during an epidemic, I am probably going to continue my work in spite of the increased exposure to the disease. 1) I strongly disagree … 5) I strongly agree
7. Recognizes the interconnection between science and society	**Question 7.1:** The administration of an epidemic can rely exclusively upon the scientists' recommendations. 1) I strongly disagree … 5) I strongly agree

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8. Takes part in civic actions for the elimination of health disparities	**Question 8.1:** It is important to take actions which are going to help to encountering against health disparities? 1) I strongly disagree … 5) I strongly agree **Question 8.2:** How important is it to financially support structures and organizations that support vulnerable social groups during an epidemic? 1) Completely improbable … 5) Completely probable **Question 8.3:** How probable is it to vote political schemes, which try to minimize health disparities 1) Completely improbable … 5) Completely probable **Question 8.4:** How probable is it to take action by helping myself vulnerable social groups (e.g. by taking part in actions of an NGO during an epidemic? 1) Completely improbable … 5) Completely probable

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8. Specifications for an educational scenario on the topic "Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities”.

Main partner responsible

University of Ioannina, Ioannina, Greece

Overview / Context

Scientific literacy development and social skills improvement regarding an epidemic/pandemic outbreak are crucial for students with intellectual disabilities (ID), for them to participate equally in school and society. The current scenario concerns a cognitive approach that used a structured inquiry model with supplemental elements of task analysis, time delay and prompting for small group of students. All the phases of inquiry are applied through a single subject design (baseline, intervention, maintenance, generalization) which is supported through digital educational resources and digital learning objects. Students with ID are introduced in scientific oriented questions regarding infectious diseases. Dynamic simulations contribute to the improvement of students understanding about viruses and vaccination. In addition, students apply social and decision-making skills in a problem-solving experience designed on an educational game. Completing the learning process, students conduct a guided project and produce an infographic presenting and communicate new knowledge and skills.

Scientific content and its relevance to public health education

- Scientific knowledge adequacy and perceived world interaction of students with ID.
- Design and develop of policies and practices based on evidence-practice that contribute to social disparities reduction regarding health.
- Awareness and new standards of social behaviour (social distancing).
- Measures of prevention and reduced anxiety of co-occurring health problems and social isolation for people with ID.
- Science and society promotion, social justice, equal participation, accessibility.

Students with ID experience limited accessibility and they identify their active role regarding awareness and claiming their rights as equal members of the society.

Estimated duration

At least 6 sessions/lessons.
The sessions can be extended in more lessons depending on students’ individualized profile and the availability of lessons at school.

STEM content

- Highlighting STSE interactions.
- Basic concepts of biomedical sciences (e.g., infectious diseases, epidemic, pandemic, virus, etc.)
- Developing the dimensions of STEM, scientific literacy, health literacy and critical thinking related to STEM teaching with the aim of shaping active citizenships.
- Importance of science in order to claim social justice and to participate equally in society.
- Conducting inquiry (role of researcher, enhancing inquiry skills and problem-solving skills)

Content glossary

Epidemic: the large number of cases of a disease in a given period of time.
Host: the person being infected.

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Incubation period: the time interval between infection and the onset of the first symptoms of the disease.
Infection: the entry of a pathogenic microorganism into a host.
Infectious Diseases: can be transmitted from one person to another. They are caused by pathogens such as viruses, bacteria, fungi and protozoa.
Intellectual Disabilities (ID): is a disorder that begins during developmental period and includes not only mental deficits but also deficits of adaptive function in the conceptual, social and practical areas (DSM-5).
Pandemic: the spread of the disease in many countries
Pathogenic: the microorganism that enters a person and causes him a disease.
Quarantine: restricting movement and contact in people considered to be infected with a contagious disease.
Social distancing: the set of non-pharmacological interventions and measures taken to slow the transmission of an infectious disease (e.g., distance keeping, hand washing, teleworking).
Transmissibility: the ability to transmit a pathogen from an infected person to a healthy one.

Pedagogical glossary

Concept map: a diagram that graphically depicts concepts and the correlation between them.
Easy to Read (EtR): adapted text for students with ID, easy to read and understand, which avoids abstract concepts and metaphorical speech, turning the text into plain content.
Inquiry: students' involvement in active learning activities by applying scientific skills. Students use these skills to answer scientific questions, posed by themselves or by the teacher, through the handling of real data, collected by themselves through experimentation or provided to them. Some common research skills include model construction and use, conducting experiments, collecting and organizing data, manipulating variables, drawing inferences based on data, and communicating scientific issues.
Models in science education: concern selective representations of the natural world with the aim of better understanding by students.
Prompting: the provision of partial assistance incorporates appropriate stimuli and their management during teaching.
Simulations: digital representation of functions, processes and phenomena with an educational character. Usually, the simulations cannot be performed in physical conditions for practical reasons.
Single subject design: is an experimental research design that studies the student's self-performance over time.
Structured inquiry: students explore a question posed by the teacher through a defined process, in which they receive clear step-by-step instructions at each stage.
Task analysis: a teaching technique which divides a goal in small stages-learning steps, in order for the students with ID to understand the task effectively.
Time delay: a delay that separates the occurrence of two events.

Competences/ Learning goals

I. Knowledge (concepts)

Infectious diseases, virus, epidemic/pandemic, virus, symptoms, diagnosis, prevention, social behavior, intellectual disabilities, scientific literacy, health literacy, STEM, STSE.

II. Skills

General: inquiry skills (identify relations between variables, describe thinking process, data as evidence, assessment, discussion and communication), scientific content questions engagement, collect data

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Students' profile:
The target group enrols students with intellectual disabilities of secondary education who meet the following inclusion criteria: (i) a diagnosis of mild ID – mental age of students with mild ID concerns typical developing students with chronological age of 9-12 years old (ii) verbal communication, (iii) normal range vision and hearing to interact with materials, (iv) functional reading and writing skills, and (v) basic computer skills (e.g., ability to use the mouse to click on options and follow directional cues).

Objectives:
- follows guidelines
- stays on task
- indicates willingness
- communicates, motivation
- enhances preparedness and adaptability skills
- improves mnemonic skills
- understands information and problem solving
- assessing decision-making / initiative / autonomy / self-care skills
- acquires higher level of academic content
- generalizes, maintains

Specific:
- develops scientific literacy skills (acquire and use basic vocabulary of science, indicate basic understanding)
- describes contents and processes
- identifies causal relations between terms/variables
- assesses the impact of social behaviour in epidemic/pandemic conditions
- selects and applies protection/prevention practices in hygiene, social distancing, vaccination
- develops digital literacy / uses dynamic simulations
- is able to transfer new knowledge to classmates, teachers, parents and caregivers
- develops and apply critical thinking
- set priorities / makes decisions
- designs and develops a project based on structured inquiry.

III. Affective/Attitudes

- strengthens awareness and sensitivity regarding the challenges of public health
- identifies patterns or attitudes of health at risk
- identifies barriers in access health services and information
- develops empathy and equal contributions in health promotion
- identifies science and society relevance
- understands behaviour standards
- understands the difference between opinions/ perceptions based on inadequate information or stereotypes and reliable information
- adopts socially sensitive attitudes towards health.

Classroom organization requirements

During all sessions students work in small groups guided by the teacher.

Prerequisite knowledge and skills

- ➢ Students have experienced diseases, especially the COVID-19 pandemic.

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- Students experience barriers based on their disability, as well as other social disparities regarding human rights (accessibility and equal participation).
- Functioning of basic hygiene rules as a non-pharmaceutical means of prevention of infectious diseases.
- Previous knowledge of structure of matter and molecules would help students to understand viruses.
- Basic computer skills.

School research project

Topics

Main topic: What is an infectious disease?
Specific research questions:

- What is a virus?
- How the vaccination protects from an infectious disease?
- How does a social behaviour affect an epidemic outbreak?

I. Research management, design, and administration
Experimental design of single-subject to assess learning outcomes of students with ID regarding scientific literacy skills, emphasizing on COVID-19 pandemic. Several phases of inquiry in line with single-subject design are conducted by the teacher.

II. Data analysis and reporting

Collect and analyze descriptive statistics data. Visual analysis of individualized graphs of the participants through data referring to level, trend, stability/variability. Descriptive statistical data for baseline and intervention, such as mean, median, range.

III. Target audience for recommendations

Students, parents, caregivers, teachers, local agency, intellectual disabilities associations.

IV. Public debates and recommendations
Publication of research findings at a school event or a local community festival.

Teacher guidance notes

Students present limitations based on the profile of ID which means reduced understanding of cognitive and social skills in health promotion.
Identifying life value helps in new standards of behavior (social distancing, use remote communication, vaccination) for health outcome.
Designs and develops interventions for information access and searches supportive networks.
Handles social disparities carefully to avoid stereotypes or stigmatization of students.
Focus on activities that bridge disparities.
Focus on understanding of inquiry experience through their role as researchers.

Teacher professional development actions

- recognizes disparities and adapt processes to support access and equal participation
- motivates students to engage with STEM
- practical knowhow in STEM/science/health science content applying evidence-based practices (structured inquiry, task analysis, prompting, time delay)
- training in project and infographic implementation

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- foster teachers' skill sets regarding single case research designs

integrating DLOs in inquiry activities

Assessment activities

Initial assessment of prior knowledge and attitudes of students (baseline phase).
Continuous assessment of learning outcomes by applying multiple measurements in each phase of the process.
Assessment of the specific profile of ID though observation.
Assessment of the experience (LOES-S tool concerning learning, quality, experience).
Total assessment.
Students complete the KWL chart and observe the learning process, too.

Digital Learning Objects (DLOs)

All digital learning objects follow the principles of the universal design framework to be accessible by all students with ID. They focus on basic science vocabulary and comprehension about infectious diseases and their correlations (description, symptoms, transmission, and prevention measures).

I. Concept map COVID 19 (http://photodentro.pafse.eu/handle/8586/40).
The goal of the digital learning object is to train students with intellectual disabilities to apply basic vocabulary and comprehension regarding an infectious disease and especially the coronavirus COVID-19. The learning object is consisted of three propositions or statements, that are presented successively based on task analysis steps. Students choose the given words or phrases to complete the propositions. Since each proposition is completed, the learning object provides a reinforcement and a short feedback is presented to the student.

II. Concept map of symptoms COVID-19 (http://photodentro.pafse.eu/handle/8586/41).
The goal of the digital learning object is to train students with intellectual disabilities to apply basic vocabulary about symptoms of an infectious disease. The learning object is consisted of four propositions or statements, that are presented successively based on task analysis steps. Students choose the given words to complete the propositions. Since each proposition is completed, the learning object provides a reinforcement and a short feedback is presented to the student.

III. Concept map of the transmission of COVID-19 (http://photodentro.pafse.eu/handle/8586/42).
The goal of the digital learning object is to train students with intellectual disabilities to apply basic vocabulary and comprehension about transmission of an infectious disease. The learning object is consisted of three propositions or statements, that are presented successively based on task analysis steps. Students choose the given words to complete the propositions. Since each proposition is completed, the learning object provides a reinforcement and a short feedback is presented to the student.

IV. Infographic COVID-19 (http://photodentro.pafse.eu/handle/8586/43).
The dynamic infographic using visual representations and EtR concerns the measures taken to slow the transmission of infectious diseases and especially the coronavirus COVID-19. The goal of the DLO is to familiarize students with prevention measures and to enhance decision making skills during a pandemic outbreak. The learning object is consisted of twelve spaces, that are colored green (measures to protect) or red (measures against the protection) in line with the given images. Students choose the given images to complete the boxes.

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Supplementary educational resources (SERs)
The following SERs have been retrieved from online resources

I. https://www.rch.org.au/ccch/covid-19/ (translated infographic about COVID-19)
II. https://www.youtube.com/watch?v=MVvVTDhGqaA (translated video about COVID-19, Eurac Research)
III. https://www.unicef.org/greece/en/stories/day-school-during-covid-19 (video A Day at school, Unicef)
IV. https://www.youtube.com/watch?v=6lJQ123_4e8 (All about Coronavirus: A Video for Kids and Their Families | University of Michigan School of Public Health)
V. https://www.youtube.com/watch?v=GFm45J8d7HI (video about viruses)
VI. https://www.youtube.com/watch?v=oCelMyMtRCk (video about viruses)

Teacher-learning activities

Principal target
Biology, Physics and Chemistry classes (students with mild intellectual disabilities, secondary education: 14-25 years old students)
At least 6 sessions/classes of 20-30 minutes
Science teachers in Greece are specialized in Physics, Chemistry, Biology and Geography due to teacher branch in secondary education. To increase interdisciplinary, other scientists/colleagues could be integrated in the enactment of the scenario, especially in the school research project evaluation (e.g., doctors or microbiologists). As the scenario will be applied in a special education school, all teachers are qualified in special education practices.

Training phase
Students' training based on DLOs implementation with simple task analysis steps.

Lesson 1 (Baseline: orientation phase)

Students are informed about their optional participation and the possibility to withdraw of the research at any time. In addition, students are informed that the questionnaires or worksheets are anonymous without any type of grading.

- Orientation phase is started by the main question of the whole scenario "what is an infectious disease?". Two short videos (SER II https://www.youtube.com/watch?v=MVvVTDhGqaA, SER III https://www.unicef.org/greece/en/stories/day-school-during-covid-19) increase curiosity and interest of students around the COVID-19 pandemic and its impact to daily life. The aim of the current phase it to get the learner started with a new topic for investigation and engage them in a debate on the question with guidance and prompting.
- After the completion of the first activity, students are informed about the objectives of the lesson and apply their initial knowledge and attitudes around the infectious diseases, correlating viruses, symptoms, and protection. The first activity encourages students to explore the educational material (e.g., videos) through relevant questions and share ideas in small groups with guided learning.
- DLO I (http://photodentro.pafse.eu/handle/8586/40),DLO II (http://photodentro.pafse.eu/handle/8586/41), and DLO III (http://photodentro.pafse.eu/handle/8586/42) are applied for students to complete the three conceptual maps with a set of concepts related to infectious diseases and their correlations (symptoms, transmission, prevention) and a short infographic respectively. The topics are supported by task analysis steps, reinforcements are activated after each mastery step, as well as feedback through visual representations, to support learning and reduce reading comprehension difficulties, as well as to increase motivation.

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- Students gather and organize their responses at the first and second columns *What I Know* and *What I want to Know* of the graphic organizer.

Lesson 2 (Intervention: main inquiry – conceptualization – investigation)

- The second phase of inquiry concerns the conceptualization of main inquiry which starts with the questions "what is a virus?" which is linked to the previous session. During this initial investigation, students are engaged in an inquiry identifying that a virus is too small and can be seen only with a microscope. Students describe the virus, emphasizing on coronavirus, and identify that a virus is microscopic.
- Completing this module, students are expected to use the scientific vocabulary for viruses and understand their interfaces, acquiring basic understanding (what is a virus, which is its structure, how it could be seen , how a virus is transmitted, which symptoms can a virus cause). At this activity the goal for students is to make meaning.
- DLO I (http://photodentro.pafse.eu/handle/8586/40), DLO II (http://photodentro.pafse.eu/handle/8586/41) and DLO III (http://photodentro.pafse.eu/handle/8586/42) describe how an infectious disease emerges.
- Brief review of new information contributes to students' understanding are asked to try to predict ways to protect themselves from viruses based on their experience with the COVID-19 pandemic. Students work in pairs, are encouraged by the teacher, and summarize on the graphic organizer. They complete the concept maps with an appropriate sequence of instructions and recall and comprehension questions for the evaluation of the teaching unit.
- Assessment could include questions as follows:
  1. What is a virus?
  2. Why cannot we see a virus?
  3. How can you see a virus?
  4. How can a virus infect an organism?
  5. How the virus is called when it can cause a disease?
  6. How can a virus be transmitted?
  7. how the situation in which a virus has infected too many people around the world is called?

Lesson 3 (Intervention: main inquiry – conceptualization – investigation)

- The current phase focuses on ways of prevention and protection towards COVID-19 pandemic highlighting vaccination. Students are asked to identify the importance of reliable information in contrast with daily experiences or attitudes concerning stereotypes or misinformation. A lot of students with ID usually face co-occurring health problems, experience high levels of anxiety and present social isolation behaviors.
- Students are expected to understand that vaccine functions protecting people, emphasizing vulnerable groups. In addition, students may recognize the importance of taking on a responsibility as an equal member of the society and adopt social skills in line with public health promotion. Students may enforce high levels of cognitive skills, as they are trained in critical thinking, decision making and reasoning.
- DLO IV (http://photodentro.pafse.eu/handle/8586/43) is designed to help students acquire information regarding the prevention measures, such as vaccination and adopt attitudes in line with scientific explanations.
- Students summarize new skills and new terms at the graphic organizer. They answer relevant worksheets by following guidelines. Students have an overview of major acts that prevent the emergence of infectious diseases and their evolution through epidemics to pandemics.
- Assessment could include questions such as:
  1. How can you protect yourself from being infected with a virus (e.g., coronavirus?)

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2. What is a vaccine?
3. How does the vaccine work?
4. How can we acquire immunity?
5. Does vaccine protection last forever?
6. What can you do to stay safe longer?
7. Can you get sick after the vaccination?

Lesson 4 (Intervention: applying new knowledge and skills)

- Students apply new terms and skills on a social behavior problem. Initially, it is suggested students to watch a short video (SER IV https://www.youtube.com/watch?v=6lJQ123_4e8) and discuss on it. Then, students play an educational game with social-communicative challenges to apply scientific terminology of health.
- By this session, students are expected to follow cognitive processes, be trained in metacognitive skills, such as critical thinking, reasoning, and assessment regarding a problem (students with ID usually meet a lot of barriers in these types of skills).
- A couple of students interact with DLO IV (http://photodentro.pafse.eu/handle/8586/43) and collaborate to take on a role (a girl or a boy) and make decisions independently. The specific process includes a route with or without taking protective measures which concludes to a friendly meeting during a pandemic outbreak.
- Completing the task, students communicate their conclusions and highlight the importance of individual and societal responsibility during a pandemic outbreak.
- Assessment could include questions, such as:
  1. How could the outbreak of COVID-19 infection be overcome?
  2. What are the precautionary measures?
  3. How can everyone take decisions to prevent the spread of an infection?
  4. What does it mean that it is my social responsibility to spread the pandemic?
  5. What does social distancing mean?
  6. During a pandemic you can mention prevention measures?
  7. What is quarantine?

Lessons 5 - 6 (Maintenance – Generalization: applying new knowledge and skills – Conclusions)

- This section concerns the maintenance and the generalization phases of the acquired knowledge of students with ID. Completing the third column named *What I learned* of the graphic organizer, students are asked to use their knowledge and new skills about infectious diseases and relevant determinants through a research project, which reaches the production of an infographic. They develop an accessible, relevant, and curiosity-driven action with guidance, which frames the flow of the initial proposed idea to termination, keeping in view all the phases of the previous sessions. The teacher coordinates, explains, facilitates, cooperates, and encourages.
- Students are separated in groups to collaborate and justify an inquiry task, including the phases of engagement, conceptualizing, inquiry, and conclusions. They are expected to apply inquiry skills. For example, they formulate questions and hypotheses, describe the thinking process, analyze, and interpret data and evaluate the outcomes in relation to the research question and hypotheses. Finally, they can communicate their knowledge in a schooling event.
- DLO I (http://photodentro.pafse.eu/handle/8586/40), DLO II (http://photodentro.pafse.eu/handle/8586/41), DLO III (http://photodentro.pafse.eu/handle/8586/42) and DLO IV (http://photodentro.pafse.eu/handle/8586/43) help students to build and present a static infographic about infectious diseases and relevant determinants.

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- The students create an infographic, which describes the whole project and presents the outcomes. Discussions among students and other engaged groups which attend the open schooling event (teachers, parents, caregivers, community members) contribute to knowledge diffusion towards the school and community. The final deliverables are proposed to be made public within a school event and / or in the local community through a local media, possibly online.
- The assessment could use the "Learning object evaluation survey—students" (LOES-S questionnaire) in 5 item Likert scale.

  Learning
  1. Working with the learning object helped me learn
  2. The feedback from the learning object helped me learn
  3. The graphics and animations from the learning object helped me learn
  4. The learning object helped teach me a new concept
  5. Overall, the learning object helped me learn

  Quality

  6. The help features in the learning object were useful
  7. The instructions in the learning object were easy to follow
  8. The learning object was easy to use
  9. The learning object was well organized

  Engagement

  10. I liked the overall theme of the learning object
  11. I found the learning object motivating
  12. I would like to use the learning object again
  13. What, if anything, did you LIKE about the learning object?
  14. What, if anything, did you NOT LIKE about the learning object?

<u>Supplementary learning activities</u>

I. Video watching and discussion

- It is suggested to enrich the previous learning activities with two videos in line with the description of viruses, their structure and reproduction. This section could be conducted within the generalization phase of the intervention, after the completion of the designed sessions and during the school project. The teachers in cooperation with special educators could present to the students the two videos:
  SER V: https://www.youtube.com/watch?v=GFm45J8d7HI
  SER VI: https://www.youtube.com/watch?v=oCelMyMtRCk
  regarding the viruses and their microscopic function.
- A short discussion based on adaptations would facilitate the students to understand the educational supplements and extend their new knowledge.

II. Handcrafting

Some hand-work activities (drawing, creating through handcrafting, etc.) could take place within the context of this learning sequence. In this way students with mild intellectual disabilities would improve their skills in social and practical domain, too, as they usually demonstrate high interest and motivation on hand working activities.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: "Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities**"**

Knowledge	
1. Identifies the structure of a virus.	**Question 1.1:** What is a virus? A) A microscopic plant. B) A microscopic infectious agent. C) A small animal. **Question 1.2:** Why cannot we see a virus? A) Because a virus is very small. B). Because a virus is always hidden. C) Because a virus moves very fast. **Question 1.3:** How can we see a virus? We can see a virus through: A) glasses. B) a magnifier. C) a microscope.
2. Recognizes the most risk factors of a virus and defines relevant concepts.	**Question 2.1:** Which of the following is an infectious disease? A) Asthma. B) Cancer. C) COVID-19. **Question 2.2:** When a virus causes a disease, this virus is called: A) pathogenic. B) infection. C) host. **Question 2.3:** A virus cannot be transmitted A) through air. B) through physical contact. C) through a healthy person. **Question 2.4:** When a virus has infected too many people around the world, it is called: A) an epidemic. B) a pandemic. C) nothing like that.
3. Identifies the importance of vaccination to track the progress of a pandemic.	**Question 4.1**: How can you protect yourself from being infected by a virus? A) being vaccinated. B) visit the doctor. C) you cannot protect yourself whatever you do. **Question 4.2**: How do vaccines work? A) They strengthen body's defence/immune system. B) They cause other diseases. C) They last forever.
4. Characterizes the association between the precautionary measures and the infection and applies new knowledge in decision making.	**Question 5.1**: What are the precautionary measures? A) A doctor diagnosis for a disease. B) Some acts that help prevention from diseases. C) The symptoms of a disease. **Question 5.2:** How can you make decisions to prevent the spread of an infection? A) Social distancing. B) By the law. C) There is nothing you can do. **Question 5.3**: An example of social distancing is A) a pharmacological intervention. B) a party in a crowded place. C) hand washing.
SKILLS	

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1. Can propose concrete actions towards promoting public health.	**Question 1.1:** Which individual actions can be taken to help advancing public health during a pandemic outbreak? A) Acquire scientific and health literacy. B) Rely yourself on the others. C) Visit the doctor. **Question 1.2**: Which individual actions can be taken to help advancing social behaviour during a pandemic outbreak? A) place yourself in quarantine. B) describe the precautionary measures. C) train yourself in decision making skills.
2. Can communicate the adoption of choices by others (e.g., family, peers, friends).	**Question 2.1:** I feel able to discuss and communicate the adoption of actions that help achieving public health by others (family, peers, friends). 1) definitely true ... 5) definitively false. **Question 2.2:** I will try to discuss and communicate the adoption of actions that help achieving public health by others (family, peers, friends). 1) definitely true ... 5) definitively false.
3. Is able to demonstrate values and to adopt individual attitudes that lead to public health.	**Question 3.1:** I feel able to adopt individual attitudes that lead to public health during a pandemic outbreak. 1) definitely false… 5) definitely true. **Question 3.2:** I feel able to identify social behaviour actions that lead to public health during a pandemic outbreak. 1) definitely false… 5) definitely true.
4. Selects appropriate scientific data and information to describe the progress of public health during a pandemic outbreak.	**Question 4.1:** I feel able to identify scientific sources to describe the progress of public health during a pandemic outbreak. 1) strongly disagree… 5) strongly agree. **Question 4.2:** I know the main precautionary measures to contribute to public health promotion. 1) strongly disagree… 5) strongly agree. **Question 4.3:** I feel able to describe a thinking process regarding a social behaviour problem during a pandemic outbreak. 1) strongly disagree… 5) strongly agree.
5. Can identify the community challenges in relation to pandemic outbreak, connect them with social behaviour and find the relevant resources to address them.	**Question 5.1:** I feel able to identify the main community challenges during a pandemic outbreak in relation to public health. 1) definitely false… 5) definitely true. **Question 5.2:** I can understand how the community challenges are related to public health. 1) definitely false... 5) definitely true. **Question 5.3:** I feel capable of proposing actions that address public health. 1) definitely true... 5) definitively false.
Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that is important to contribute to the public health goals.	**Question 1.1:** My participation and actions will increase the chances of public health promotion during a pandemic outbreak. 1) strongly disagree… 5) strongly agree. **Question 1.2:** I am willing to adopting actions that contribute to the public health promotion during a pandemic outbreak (e.g., wear a mask, use distance communication, acquire awareness regarding vaccination, etc.). 1) Extremely unlikely... 5) Extremely likely. **Question 1.3:** My family and friends think that I should adopt actions that contribute to public health promotion. 1) Extremely unlikely... 5) Extremely likely.
2. Believes that working on public health promotion can lead to positive outcomes at the community level.	**Question 2.1:** To contribute to public health promotion will lead to positive outcomes at my community. 1) strongly disagree… 5) strongly agree. **Question 2.2:** My community thinks that public health promotion will bring positive outcomes 1) Extremely unlikely... 5) Extremely likely.
3. Believes that it is crucial to identify obstacles and problems faced by communities regarding public health.	**Question 3.1:** The identification of obstacles and problems that my community faces is crucial for solving them. 1) strongly disagree… 5) strongly agree. **Question 3.2:** It is possible to identify obstacles and problems that my community faces regarding public health 1) strongly disagree… 5) strongly agree.

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	Question 3.3: It is common knowledge that it is necessary to identify obstacles and problems that the community faces for solving them. 1) strongly disagree… 5) strongly agree.
4. Believes that efforts must be employed to achieve public health.	**Question 4.1:** It is important to employ efforts to achieve public health. 1) strongly disagree… 5) strongly agree. **Question 4.2:** It is possible to employ efforts to achieve public health. 1) strongly disagree… 5) strongly agree. **Question 4.3:** It is common knowledge that it is necessary to employ efforts to achieve public health. 1) strongly disagree… 5) strongly agree.
5. Has intention to perform social behaviour in his/her lifestyle during a pandemic outbreak.	**Question 5.1:** I will try to contribute to prevention of a pandemic outbreak. 1) Extremely unlikely... 5) Extremely likely. **Question 5.2:** I plan to incorporate social distancing in my day-to-day life during a pandemic outbreak. 1) Strongly disagree... 5) Strongly agree. **Question 5.3:** I plan to be vaccinated during a pandemic outbreak. 1) Strongly disagree... 5) Strongly agree. **Question 5.4:** I plan to influence my family and friends to be vaccinated during a pandemic outbreak. 1) Strongly disagree... 5) Strongly agree. **Question 5.5:** I will try to walk or bike instead of taking public transport during a pandemic outbreak. 1) Strongly disagree... 5) Strongly agree. **Question 5.6:** Among the following statements, choose the one that best describes what you currently think. 1) I do not promote social behaviour in my day-to-day life, and I also have no intention of doing so. 2) I do not promote social behaviour in my day-to-day life, but I have been thinking about the possibility of starting to do so. 3) I never or rarely promote social behaviour in my day-to-day life, but soon I will start doing it on a regular basis. 4) I do promote social behaviour in my day-to-day life regularly, but I have only begun to do so in the last 6 months. 5) I do promote social behaviour in my day-to-day life regularly I have been doing so for longer than 6 months.
6. Is committed to communicate and address the challenges of the community in relation to public health.	**Question 6.1:** I intend to discuss and communicate the challenges of the community in relation to public health. 1) Extremely unlikely... 5) Extremely likely. **Question 6.2:** It is expected from me that I discuss and communicate the challenges of the community in relation to public health. 1) Strongly disagree... 5) Strongly agree.
7. Attitude toward public health.	**Question 7.1:** For me to achieve public health is harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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9. Specifications for an educational scenario on the topic "Function of vaccines, vaccination hesitancy and misinformation".

Main partner responsible

University of Ioannina, Ioannina, Greece

Overview

This educational scenario focuses on vaccination and particularly on the topics of the mechanism by which vaccines work, the types of vaccines, herd immunity, the eradication of infectious diseases and the misinformation about vaccines. Students are initially shown some facts concerning vaccination and its importance aiming at their more effective engagement in the learning process. Students' initial conceptions are detected with a questionnaire and they express, then, their expectations from the learning sequence. For the following two hours students are given the necessary conceptual background regarding microorganism biology and immune response mechanisms so that a meaningful conceptualization of vaccination is feasible. For this reason, students make use of a great variety of digital educational resources with emphasis on the visualization of the phenomena examined. Afterwards, students are familiarized with the mechanism with which vaccines function and the different types of vaccines used. They are assigned to match pathogen cases to the more appropriate vaccine types. For the next hours, students are concerned with the importance of vaccination for public health through the phenomenon of herd immunity. Students actively handle simulations by testing parameters that affect the achievement of herd immunity (disease transmissibility, vaccination coverage and vaccine efficacy) and find the critical vaccination coverage point for herd immunity for authentic disease cases. They also study the mechanism with which the application of mass vaccination programs on children can lead to the eradication of a disease, and the case of smallpox eradication is mentioned, as well as the reemergence of measles due to reduction in vaccination coverage. Students compare the harshness and the frequency of severe adverse affects of the vaccine with those that are caused by the disease itself and argue whether the vaccine adverse effects are a sufficient reason not to vaccinate. Afterwards, students are trained to recognize and discern medical misinformation texts from scientific texts. Students work in small groups to conduct a mini project. Each group can choose to take over either the making of a short informative guide regarding how one could detect misinformation texts about vaccines, or to prepare the launching of a short informative campaign for the general public, concerning vaccination necessity. The groups present the prepared material to the class and a self-reflective discussion concerning the learning sequence takes place.

Scientific content and its relevance to public health education

- Education regarding vaccination, which is one of the most determinative practices for the preservation of public health, throughout the entire history of medicine.
- Detailed education concerning herd immunity, and consequently about the notion that vaccination is not just concerned with the individual health condition of the vaccinated but is also concerned with the public health of the whole community.
- Illustration of a characteristic case when personal health-related decisions (vaccination) have health outcomes with a collective benefit for the community, and reversely, cases where the community health condition (herd immunity) had health outcomes towards the protection of the individual health condition of unvaccinated population (public health literacy).
- Presentation of vaccination as a practice of solidarity and protection towards people who cannot get vaccinated due to health issues and often belong to groups of high danger, through the achievement of herd immunity.
- Highlight of the need for international cooperation in terms of public health promotion, which can bring astonishing results, such us the total eradication of smallpox.
- Confrontation of a modern threat to public health (vaccine hesitancy) which is usually due to incomplete information or misinformation.

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- Evaluation of the trustworthy of health information, which is a skill of vital importance for public health as shown by the vast amount of misinformation (infodemic) during the COVID-19 pandemic.

Estimated duration & relevant subjects

14 teaching hours organized in continuous two-hour periods if possible.
Designed for Biology classes (or Science classes in general) of K7-9 grades.

STEM Content

- Education on fundamental issues of life sciences (vaccination, immunity, pathogens) which are necessary for making decisions in everyday life.
- Education on crucial topics of life sciences (vaccination) which are necessary for the informed decision making by citizens (citizenship) in order to promote the collective benefit for the community (public health literacy).
- Highlight of critical STEM literacy, critical health literacy and critical scientific literacy in terms of the critical appraisal of scientific information.
- Illustration of the vital importance scientific and technological progress has for the improvement of living standards, the welfare of humanity and the progress of human civilization (control and eradication of deadly infectious diseases through vaccination).
- Shaping of positive attitudes towards scientific and technological progress.
- Illustration of the convergence between science and technology at the development of different types of vaccines (biomedical technology).
- Use of mathematics (numerical data, probabilities, graphs) in health contexts (health numeracy).
- Introduction to the distinction between science and pseudoscience.
- Production of informative material by students themselves as an attempt to popularize and communicate scientific knowledge to the general public.
- STEM education for the confrontation of a crucial contemporary phenomenon with devastating consequences to public health (vaccine hesitancy).

Content glossary

Adaptive immunity: Adaptive immunity includes all the immune response mechanisms which are extremely specialized against each different kind of pathogen (e.g., different specialization for each kind of virus).

Antibodies: Antibodies are proteins produced in the case of an immune response which have high specialization against the pathogen, onto which they attach to inactivate it.

B lymphocytes: B lymphocytes are a subgroup of cells of the immune system with great variety in structure and function.

Bacterium: Bacteria are a kind of unicellular microorganism which does not have a nucleus.

Communicable/infectious/contagious disease: Communicable diseases are those diseases (which are in turn the harmful unnatural conditions of the human organism) which can be transmitted from one person to another. Communicable diseases are mainly caused by pathogens, such as bacteria, viruses, fungi and protozoa (they can be rarely caused by infectious particles, as in the case of the Creutzfeldt-Jakob disease).Disease transmission can be direct (through human intercourse) or indirect (e.g., through insects or infected objects). Some examples of communicable diseases are influenza, chickenpox, malaria, and the Ebola disease. On the other hand, there are non-communicable diseases, such as diabetes, phenylketonuria and Alzheimer's disease.

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Dendritic cell: Dendritic cells are a kind of immune system cells specialized in antigen presentation (exposure of parts of the pathogen).

DNA/RNA vaccines: These vaccines have viral DNA or RNA parts with the encoded information for some proteins, which are produced in the human body and cause, in turn, the immune response.

Fungus: Fungi are a broad category of unicellular or multicellular microorganisms with great diversity.

Genetic material: Genetic material is the molecule which has encoded all of the genetic information of an organism on it. Cells have DNA as genetic material, whereas viruses may have DNA or RNA.

Herd immunity: Herd immunity is the situation in a population when vaccination coverage is high enough, yet not 100%, to protect the population from the spread of the disease. The vaccinated people act as a barrier protecting the few unvaccinated people.

Immune response: Immune response is the sum of cellular and biochemical processes which take place as a pathogen enters the body and aim at the destruction of the pathogen.

Inactivated vaccines: These vaccines have dead pathogens, and often repeated vaccines doses are needed in order to achieve or maintain immunity.

Infectious disease eradication: When referring to infectious disease eradication we mean the World Health Organization policy to eliminate communicable diseases in some areas or even worldwide through massive vaccination programs.

Infodemic: As infodemic (information pandemic) was the characterization of the huge amount of misinformation and fake news that was spread during the COVID-19 pandemic.

Innate immunity: Innate immunity includes all the immune response mechanisms which take place indiscriminately for every pathogen, without specialization.

Lipid envelope: The lipid envelope is a lipid layer that surrounds the capsid of some viruses, and is particularly common in viruses infecting animal cells.

Live-attenuated vaccines: These vaccines have living, yet weakened pathogens. They usually cause strong immunity but they are often unsuitable for immunosuppressed patients.

Macrophage: Macrophages are a category of big-in-size white blood cells which perform phagocytosis to pathogens having entered the body during an infection.

Memory cells: Memory cells are specialized B and T lymphocytes which activate a rapid immune response when the organism gets infected by the same pathogen for the second time.

Misinformation: Misinformation is the spread of false or inaccurate news, especially when it is done deliberately in order to deceive the receiver of the news.

mRNA: The messenger RNA (mRNA) is the kind of RNA which transfers the genetic information which is encoded in a part of DNA (gene) to ribosomes where proteins are made according to the information transferred by the mRNA.

Pathogen: Pathogens are the microorganisms that can cause diseases to humans. The main pathogen categories are bacteria, viruses, protozoa, fungi and helminthes.

Primary immune response: The immune response is characterized as primary when the immune system encounters a pathogen for the first time.

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Protein capsid: The protein capsid is a protein structure which surrounds the genetic material of viruses and is made of smaller subunits which often form characteristic geometrical shapes.

Protein: Proteins are a category of biological molecules with extreme diversity, which have a structural or functional role and are made of amino acids.

Recombined vaccines: These vaccines have combined parts from a pathogen and from a harmless microorganism, which have been produced in the laboratory.

Secondary immune response: The immune response is characterized as secondary when the immune system encounters a pathogen that has already encountered in the past.

Subunit vaccines: These vaccines do not contain entire pathogens but only some of their proteins which are going to cause the immune response.

T lymphocytes: T lymphocytes are a subgroup of cells of the immune system with great variety in structure and function.

Toxoid vaccines: These vaccines contain inactivated forms of pathogen toxins, which cause the immune response.

Vaccination coverage: The vaccination coverage of a population refers to the percentage of people in the population who are vaccinated.

Vaccine efficacy: In this scenario by the term vaccine efficacy we refer to the percentage of vaccinated that the vaccine protects from an infection by the disease.

Vaccine hesitancy: By the term vaccine hesitancy we mean the hesitations some people might have towards vaccination, without necessarily characterizing them as supporters of antivaccination.

Vaccine: Vaccine is a pharmaceutical product which contains a form of a pathogen (complete, partial, pathogen toxins or pathogen genetic material) in a harmless form which is able to cause immune response but without causing an infection. In this way memory cells are made for this disease.

Virus: Viruses are infectious particles which contain genetic material (DNA or RNA) in a protein structure, but are not characterized by cellular structure. They are parasites of living animal, plant or bacterial cells and reproduce themselves by making use of the cell mechanisms they parasite.

Virus-like-particle vaccines: These vaccines have particles resembling viruses but without their genetic material, so as not to be able to multiply.

Pedagogical glossary

Assessment rubric: An assessment rubric is a strictly organized assessment system with certain assessment criteria, which is used for the precise quantitative assessment of several features of an answer or a project according to certain criteria and corresponding grading scales.

Brainstorming: Brainstorming is an instructional technique, with several variations, that might take place within a small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning: By the term collaborative learning we refer to a sum of learning techniques, during which students cooperate or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participation and their collaboration and communication skills.

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Concept map: Concept maps are a kind of graphic organizers. They include concepts in frames interconnected with arrows. A verb is written above each arrow which determines the kind of the semantic connection, in a way that the two interconnected concepts and the arrow (verb) form a semantically independent sentence.

Critical health literacy: Critical health literacy is an important dimension of health literacy beyond fundamental literacy and comprehension skills in health contexts. It includes quite useful notions and skills for a health literate citizen in modern society. Critical health literacy mainly consists of the critical appraisal of health information, the comprehension of the interconnection between health and society - and the notion of social determinants of health in particular - and the participation in civic actions for the promotion of health.

Critical reading: Critical reading is an instructional technique which consists of the thorough study of an information source (e.g. a text or a diagram). During critical reading, students have to recall, interpret and evaluate information from the source, training the corresponding critical thinking skills.

Digital simulation: With the term educational digital simulations we mean the digital representation of functions, processes and phenomena which have an educational value, but they cannot usually be done in natural conditions at school for practical reasons. Through digital simulations their educative value remains, but the difficulties of their practical application are bypassed.

Graphic organizer: Graphic organizers are a group of various ways of schematic (visual) and diagrammatic representation of the connections among facts, concepts or processes. They can be used as teaching, learning, or assessment tools. Common kinds of graphic organizers are mind maps, concept maps, flow charts and Venn diagrams.

Infographic: An infographic (information graphic) is a kind of multimodal representation of facts and information. It usually forms a broad graphic composition combining short texts, numerical data, graphs, diagrams, sketches, colors, and shapes. The aim of the infographic is to present a big load of information on a topic in a visual way, making it immediately comprehensible.

Inquiry based learning: By the term inquiry-based learning we refer to the engagement of students in active learning processes during which they practice several scientific skills. Students make use of these skills in order to answer scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some other common inquiry skills include models construction and use, carrying out experiments, data collection and organization, variable handling, data driven conclusion-making and communicating over scientific issues.

KWL (Know, Want to learn, Learnt) table: The KWL table is a kind of graphic organizer which has the form of a table with three columns. The student fills in the two first columns at the beginning of the lesson, by noting what they think they already know about the course, and what they expect to learn. After the completion of the lesson, the student fills in the third column according to what they feel they have learnt. It is an activity which practices self-reflective skills.

Project based learning: Project based learning is an instructional approach of active learning having several forms, during which students work in groups on the development of projects, often referring to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Competences/ Learning goals

I. Knowledge (Core Concepts)

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a) Transdisciplinary concepts: Critical health literacy, public health literacy, pseudoscience and misinformation, scientific numeracy.
b) Specific content concepts: Communicable diseases, pathogens, viruses, bacteria, toxins, virus life cycles, immune system, immune response (primary and secondary), adaptive immunity, antibodies, memory cells, vaccines, vaccination, live-attenuated vaccines, inactivated vaccines, recombined microorganism vaccines, DNA vaccines, RNA vaccines, subunit vaccines, virus-like-particle vaccines, toxoid vaccines, herd immunity, vaccination coverage, infectious disease eradication, vaccine hesitancy, antivaccination movement, infodemic.

II. Skills
a) General skills: Critical thinking, reflective thinking, critical reading, decision making, collaboration and communication within small groups, informative material designing skills, presentation skills.
b) Specific skills: Concept mapping, discussion about scientific topics, data-based decision-making on scientific issues, handling of digital scientific simulations, graph interpretation, graph creation, using mathematics within scientific contexts, variable handling in inquiry, hypothesis formulation and testing, data-driven conclusion making, reasoning about scientific topics, critical reading of scientific texts, critical appraisal of scientific information, detection of cases of scientific misinformation, skills concerning with communicating and presenting scientific topics.

III. Attitudes (Affective domain)
a) Attitudes and values: Adoption of a positive attitude towards science, acknowledgment of the value of scientific and technological progress, adoption of a positive attitude towards vaccination, appreciation of the value vaccination has for public health, acknowledgement of vaccination as a humanitarian practice for the common good (solidarity), development of trust towards science, development of a critical attitude towards scientific and health information.
b) Behaviours: Taking vaccination-related decisions driven by scientific evidence, participation in discussions concerning the vaccination necessity, getting vaccinated against infectious diseases, critical appraisal of health information in everyday life.

Classroom organization requirements
During the 1st teaching hour students work independently on computers. From the 2nd to 8th teaching hour students work in pairs, having one computer for each pair. The pairs often cooperate in some activities by two, shaping groups of four (2+2 technique). During the conduct of the projects (9th to 14th teaching hour) students work in small groups, preferably four-member.

Prerequisite knowledge and skills

- The function of pathogens which cause harm to the human body after getting into it, as the cause of infectious diseases (microbial nature of contagious diseases).
- Bacteria and viruses as pathogen categories.
- The protection of ourselves against pathogens thanks to the function of the immune system.
- Vaccination as a precautionary measure against infectious diseases.
- The fact that certain diseases have been eliminated or made very rare thanks to vaccination.
- The conduct of mass vaccination programs for children.
- Examples of diseases for which vaccines exist.
- The existence of disagreements concerning vaccine safety and vaccination necessity.
- The experience of the appearance of the issue of vaccination in the public sphere during the COVID-19 pandemic would be useful.
- Graph interpretation and creation skills.
- Digital skills in terms of handling text processing software and presentation software or graphic composition software.

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School research project

Topics

H. How do vaccines protect me from infectious diseases?
I. What types of vaccines exist and on what occasions is each vaccine type preferable?
J. How does vaccination protect public health?
K. How can I identify a text of medical misinformation?
L. How would I launch an informative campaign in favor of vaccination and against misinformation?

I. Research management, design, and administration
Creation of guide for detecting cases of medical misinformation, designed for the general public.
Design of informative material for a campaign promoting vaccination, designed for the general public.
Detection, commentary and reconstruction of common antivaccination arguments through the use of scientific facts.

II. Data analysis and reporting
Composition of scientific facts, data and arguments concerning the necessity of vaccination, with the aid of the DLOs and the SERs used during the learning sequence.
Detection and reconstruction of common cases of vaccination misinformation found on the Internet.
Design of a guide for the general public, concerning the detection of cases of medical misinformation illustrated by authentic misinformation cases.
Design of a pro-vaccination campaign for the general public, by making use of persuasive scientific arguments and facts, targeting specifically to people who are hesitant toward vaccination.

III. Target audience for recommendations
The rest of the class, maybe teachers and students at the entire school provided that the project is presented at a school event. The parents of the students or even local authorities could also attend the event.
Some of the highest-quality informative material made by the students could be distributed to members of the local community (e.g., health infrastructures, municipal authorities) or be communicated via local media (printed or online press).

IV. Public debates and recommendations
Presentation of the project outcomes within the context of a school event. If the quality of the produced material is high, it can be distributed to the local society via the local media, structures of local government, authorities of educational administration, non formal education organizations, health system structures, etc.

Teacher guidance notes

- There is a great amount of academic literature concerning students' misconceptions concerning microorganisms, infection, immunity and vaccines. These misconceptions are neither few nor uncommon. In summary, it is stated that students often have misconceptions regarding microorganism diversity, size, structure, virulence and, more often, the way they cause diseases. Several students of younger age think that microorganisms just circulate inside the body and that it is enough to cause a disease. Moreover, the function of the immune system is usually unknown to students who have not been taught it yet, and it is generally thought of as a fight or a war against the bad microbes. Vaccines are a common issue of misconceptions, too. Having clear knowledge of the way vaccines function is rare. Indicatively, it is reported that vaccines are often thought to be just a type of therapeutic drug instead of a precautionary mechanism which has to precede the infection. Furthermore, it is considered that vaccines put good microbes into the body which fight against the bad microbes. These misconceptions are common even among senior high school students.

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- There have been several suggestions for a more effective microorganism education. Since microorganisms are not directly perceived through our senses, the common denominator of a lot of these suggestions is to turn them from abstract concepts to concrete examples. One way to achieve this is the utilization of various modes for microbe visualizations (e.g., illustrations, videos, microscope images, models etc.).
- Vaccination is a highly controversial socioscientific issue which causes intense conflicts in the public sphere. Some students will probably come from a background with skeptical or negative attitudes toward vaccination. They are probably going to feel awkward or even defensive during the lesson. In such cases, it is considered that the most appropriate way to persuade somebody having an opposite opinion is not the provision with facts and the explicit invalidation of their opinion. Instead, students must be given the place to express their opinion and to feel that their opinion is heard and is respected even though the teacher does not agree with them. By constructing on these opinions within a respectful discussion environment, this gives much more chances to reconsider their views in the future.
- This learning sequence heavily aims at the development of attitudes and behaviours (affective domain). Students are often emotionally attached to their attitudes and, therefore, the change of attitudes takes place gradually during a long period of time, usually much more than the duration of a learning sequence. The achievement of affective domain objectives cannot be estimated immediately.
- During this learning sequence it must be taken into consideration that some students might have difficulties concerning graphs, digital skills and fluency in English.

Assessment activities

The assessment activities act complementarily to one another and aim at the close monitoring of the students' learning procedure. Some activities aim at formative and some others at summative assessment, some assess students in a quantitative and some others in a qualitative way, some aim at conceptual understandings, some at critical thinking skills, some at collaboration and communication skills and some others at affective domain assessment. They all contribute to having a multi-perspective view for each student. The teacher can omit or undermine some of the assessment activities if they think so. Some of the learning activities happen as the lesson takes place without special activities done or special assessment material designed (e.g., observation of students' participation or performance at question-and-answering).

- Initial assessment of students' initial conceptions and misconceptions via filling in a short questionnaire at the beginning of the learning sequence.
  Diagnostic quantitative assessment aiming at conceptual understanding.
- Formative assessment of students' worksheets during the entire learning sequence.
  Formative qualitative assessment aiming at conceptual understanding and inquiry skills.
- Formative student assessment through their participation in question-and-answering techniques and in class discussions during the entire learning sequence.
  Formative qualitative assessment aiming at conceptual understanding, inquiry and communication skills.
- Formative student assessment through their performance in the short quizzes and the concept maps in the 3rd and 4th teaching hours.
  Formative qualitative and qualitative assessment aiming at conceptual understanding.
- Formative student assessment of their participation, collaboration and individual and group work through observation.
  Formative qualitative assessment aiming at collaboration and communication skills.
- Summative descriptive and quantitative student groups assessment based on the quality of the material produced from the projects and on their presentation, with the aid of specially designed assessment rubrics.
  Summative qualitative and quantitative assessment aiming at conceptual understanding, higher thinking, critical thinking and collaboration skills.

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- Formative student assessment of their participation in the discussion about the presentations of the project outcomes.
  Formative qualitative assessment aiming at communication skills and self-reflection.
- Individual summative assessment of the achievement of cognitive learning objectives via filling in a questionnaire.
  Summative quantitative assessment aiming at conceptual understanding.
- Summative quantitative assessment of students' self-referred beliefs, attitudes and behaviours through a questionnaire with Likert-scale questions at the end of the learning sequence.
  Summative quantitative assessment aiming at affective domain features.
- Summative quantitative and qualitative assessment of the learning procedure by the students in terms of likeability, interest, difficulty, self-fulfillment, collaboration and time management.
  Summative quantitative and qualitative assessment aiming at self-reflection.

Teacher professional development actions

Teacher professional development on:

- The instructional methodology of project-based learning and in collaborative learning principles and techniques.
- The design and implementation of inquiry-based learning, with special reference to the specific scientific skills which are trained through inquiry-based learning.
- The educational integration and utilization of digital educational resources.
- The use of graphic organizers, such as the KWL tables and concept maps, in instruction.
- Teaching of the critical reading of scientific and pseudoscientific texts.
- The importance of critical appraisal of scientific information for a 21st century citizen (critical STEM literacy).
- Common misconceptions regarding microorganisms, immunity and vaccination as stated in scientific literature and ways of coping with them.
- Specific principles and suggestions for teaching microorganism and vaccination issues as documented in relevant literature.

Digital Learning Objects (DLOs)

C. DLOs created specifically for the needs of the PAFSE project

I. *'Table of the learning procedure about vaccines'*
KWL table (Know, Want to learn, Learnt). It is given to students at the phase of the externalisation of students' ideas. At this phase only the first two columns of the table appear, which students fill in, and their answers are saved. At the phase of final assessment, the initial table of each student appears, having the first two columns locked, and only the third column is free to be completed.

II. *'The mechanisms of adaptive immunity during immune response'*
Dynamic visualization of the key stages of adaptive immunity during bacterial and viral infections regarding the cases of primary and secondary immune responses. Short quizzes with feedback are included at the end of each part of the DLO. The comparison of antibodies production curves during primary and secondary immune response also appear.

III. *'Concept map concerning immune response'*
Semi-structured concept map concerning the main points of immune response.

IV. *'The way different types of vaccines work'*
Dynamic visualization of the mechanism of vaccine function and of the differences various vaccine types have. The mechanism with which each vaccine type causes immune response is illustrated and explained.

V. *'Concept map about vaccine types and function'*
Semi-structured concept map concerning the main points of vaccine function and types.

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VI. *'Parameters affecting herd immunity'*
Simulation of the herd immunity mechanism. Students watch the spread of a disease within a specific population combined with an SIR graph. Students can modify the vaccination coverage percentage, the vaccine efficacy, the disease transmissibility and the initial percentage of immune people. The option of choosing real variable values for authentic diseases and vaccines is given.

VII. *'Adverse effects of vaccines'*
Visualization of the frequency and the degree of severe adverse effects, of hospitalizations, of chronic health problems and deaths caused by diseases on vaccinated people, by diseases on unvaccinated people and by vaccines against the diseases themselves.

VIII. *'Information and misinformation about vaccination'*
Environment of critical reading of text of scientific and pseudoscientific context, in which students examine text features, record them on the texts and put them in these two categories.

D. DLOs which have been retrieved from online resources

IX. *'Global map of vaccine coverage against measles'*
http://gamapserver.who.int/gho/interactive_charts/immunization/mcv/atlas.html
Interactive global map by the World Health Organization concerning the evolution of vaccine coverage against measles from 1980 up to 2018.

X. *'Various types of viruses'*
https://www.biointeractive.org/classroom-resources/virus-explorer
Digital learning object by the educational repository hhmi BioInteractive which allows the student to explore and compare the external morphology, the internal anatomy and the life cycles of several different viruses.

XI. *'The mechanism of herd immunity'*
https://graphics.reuters.com/HEALTH-CORONAVIRUS/HERD%20IMMUNITY%20(EXPLAINER)/gjnvwayydvw/
Dynamic simulation of herd immunity in a specific population in which there is provided the capability of controlling the vaccination coverage, disease transmissibility and vaccination efficacy variables.

XII. *'Achievement of herd immunity over time'*
http://rocs.hu-berlin.de/D3/herd/
Dynamic simulation of herd immunity in the case of mass vaccination programs in children during many generations. The modification of the vaccination coverage and disease transmissibility is available.

XIII. *'The phases of vaccine development'*
https://www.edumedia-sciences.com/docs/vaccine/#virus
Visualization about the process and the criteria of the development and the validation of a vaccine. Students can watch the several stages of testing two different candidate vaccines (vaccines X and Y) and are in charge of deciding whether the vaccine is appropriate to pass each testing phase to the next one, and finally to its validation. The DLO is located under the subtitle 'How are vaccines made'.

Supplementary Educational Resources (SERs)

C. SERs created specifically for the needs of the PAFSE project

I. Questionnaire with about 30 closed-ended questions concerning topics on microorganism biology, the function of the immune system and the vaccination process, about which misconceptions are common.

D. SERs which have been retrieved from online resources

II. https://www.cdc.gov/globalhealth/socialmedia/cards/images/2-3million_fb_ig.jpg

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Infographic by the Center for Disease Control and Prevention highlighting the importance of vaccination by using numerical data.

III. https://polioeradication.org/polio-today/polio-now/
Interactive map by the Global Polio Eradication Initiative showing the geographical distribution of polio cases over the last year.

IV. https://www.cdc.gov/globalhealth/socialmedia/cards/images/pnuemonia_fb_ig.jpg
Infographic by the Center for Disease Control and Prevention highlighting the importance of children vaccination against pneumoniococcus by using numerical data.

V. https://www.youtube.com/watch?v=_rjGpF6-WSg
Educational YouTube video by the educational channel Stile, presenting the main characteristics and function of the most important kinds of pathogens (bacteria, viruses, fungi).

VI. https://www.nationalgeographic.org/media/infectious-agents/
Educational infographic by National Geographic concisely presenting the main kinds of pathogens.

VII. https://learn.genetics.utah.edu/content/cells/scale/
Dynamic visualization by the educational repository Learn Genetics, which depicts the relevant size of several cells and biological structures with emphasis on microorganisms (bacteria, viruses, protozoa, yeast cells).

VIII. https://www.youtube.com/watch?v=4hdLTHc7HjQ
YouTube video by the channel Microbiome showing a compilation of bacteria captured under an optical microscope where the diversity of bacterial morphology, their ways of moving and reproduction are shown.

IX. https://www.youtube.com/watch?v=BlPlgGbb2IU
YouTube video showing the phagocytosis of bacteria by a macrophage as captured with an optical microscope.

X. https://www.youtube.com/watch?v=-muIoWofsCE
Educational YouTube video by the channel Oxford VaccineGroup regarding the way vaccines work.

XI. https://www.youtube.com/watch?v=mvA9gs5gxNY
Informative YouTube by the channel Vox concerning the vaccine production against COVID-19, with emphasis on mRNA vaccines.

XII. https://www.youtube.com/watch?v=XJFoOCmJsdg
Educational YouTube visualization video presenting the mechanism behind herd immunity.

XIII. https://www.weforum.org/agenda/2020/03/a-visual-history-of-pandemics
Infographic illustrating the deadliest pandemics in the history of humanity.

XIV. https://books.google.com/ngrams
A Google service which shows graphically the frequency with which selected words or phrases appear in texts from 1800 up to 2019.

XV. https://fred.publichealth.pitt.edu/measles
Simulation showing the emergence of measles outbreaks in USA cities in the case where vaccination coverage would fail.

XVI. https://www.youtube.com/watch?v=zBkVCpbNnkU
Educational YouTube video by the channel Kurzgesagt about the degree of danger vaccine adverse effects have.

Teacher-learning activities

1st teaching hour – Is it important to learn about vaccination?

Teaching phase according to the inquiry & project based instructional model: Engagement – Externalization of students' initial conceptions

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- Initially, students get oriented about the content of the learning sequence in which they are going to be engaged, which is about vaccination and vaccines. For this to be achieved, proper educational resources are suggested to be utilized and discussed in the classroom with meaningful questions addressed to students.
- Prior to exposure to these resources, students answer a questionnaire of about 30 close-ended questions (SER I), which aims at the detection of students' misconceptions and learning gaps concerning topics on microorganism biology, the function of the immune system and vaccination. It is made clear that this process is not any kind of examination or grading, but it will help with the development of a more effective teaching process and that the submission is totally anonymous.
- Then, several educational resources are used to spark students' interest on the topics to be addressed in the learning sequence. Some digital educational resources suggested are the following ones, presented in the suggested order of use:
    i. The infographic (SER II) showing numerical data about the number of lives being saved every year thanks to vaccinations. Students are triggered to guess how many children lives are saved thanks to vaccinations every year and then see how close their estimation was to reality.
    ii. The interactive map (SER III) presenting the polio cases recorded during the previous year. The very restricted geographical area where polio still remains endemic is mentioned. This restriction has been achieved exclusively thanks to the administration of global mass vaccination programs over the last decades.
    iii. The infographic (SER IV) highlighting the importance of vaccination against pneumoniococcus with the aid of numerical data. Students might have heard of the pneumoniococcus vaccine, but have undermined its importance for the general population.
    iv. The interactive map (DLO IX) showing the progress of vaccinations against measles worldwide. The map can provoke discussions concerning the unequal geographical distribution of vaccinations which helps mostly countries of the 'Western World', or the conduct of mass vaccination programs against measles over the last decades. This can be associated to the lack of examples of measles cases in the children's environment, in contrast to the experiences their parents and grandparents had during their childhood. It is also mentioned that vaccination rates have locally decreased in some cases over the last years due to antivaccination actions leading to measles outbreaks in countries where they were not expected to happen.
- Students use DLO I to fill in the first two columns of a KWL table (Know, Want to learn, Learnt) individually, according to their self-reported learning background and their expectations from the learning process.

2nd teaching hour – Variety, structure and life cycle of microorganisms
Teaching phase according to the inquiry & project based instructional model: Completion and reconstruction of students' initial conceptions through inquiry

- During the second teaching hour students handle educational resources (e.g., videos, visualizations and digital learning objects) in order to complete their knowledge and fix their misconceptions about crucial topics of microorganism biology. The activities focus on the topics which are pieces of prerequisite knowledge for the meaningful understanding of the vaccine mechanism. More particularly, emphasis is given on the diversity, the size, the morphology and the life cycle of bacteria and viruses.
- Students watch in pairs the educational video SER V and note down the pathogen categories mentioned in the video (bacteria, viruses, fungi), their basic structural features, and the ways bacteria and viruses cause harm to the human body. Infographic SER VI can be used complementary to the video, providing further explanations. Disease examples caused by each category of pathogens are also mentioned.
- Afterwards, students handle the visualization SER VII to compare the scale of several microorganisms (bacterium, various viruses, yeast) to one another and to human cells. In this way a more realistic approach to the notion of scale of microorganisms is attempted and the reasons why viruses are endocytic parasites and are not visible with the optical microscope are explained.

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- Then, a short reference on bacteria takes place. The teacher briefly explains the main features of bacterial structure and morphology. Students watch video SER VIII which shows real pictures of bacteria captured under an optical microscope. They have to draw and identify different kinds of bacterial forms, to describe their types of movement and the process of bacterial reproduction.
- Students, now, focus on virus biology with the aid of DLO X. The teacher explains the viral structure (protein capsid, lipid envelope), the kinds of viral genetic material, and the various life cycles of viruses depending on the kind of genetic material they have. All these are prerequisite knowledge for the meaningful understanding of vaccine function. Then, students freely select three viruses from DLO X and compare them to one another concerning their morphology and anatomy, their hosts, their genetic material and their life cycles.

3rd teaching hour – The elements of adaptive immune response

Teaching phase according to the inquiry & project based instructional model: Completion and reconstruction of students' initial conceptions

- During the third teaching hour students are introduced to the fundamental mechanisms of immune response, on which the function of vaccination is based. The lesson does not aim to deliver a complete overview of the immune system or the immune response, but to present a general picture of the features and the processes which are prerequisite for the meaningful conceptualization of vaccination -which will be introduced later on- adapted to the age and the prerequisite knowledge of the students. For this reason, a lot of details are omitted, and emphasis is given on adaptive immunity and the differences between primary and secondary immune response.
- Students interact with DLO II to explore in pairs the main stages of immune reaction in the cases of a bacterial and a viral infection. They select the bacterial infection option, and they watch the visualization (in DLO II) of the stages of immune response and mainly the stages of phagocytosis by macrophages, the antigen presentation by dendritic cells, the activation of B and T lymphocytes, the antibodies production and the development of memory cells. The video SER IX is incorporated in DLO II, and it shows the phagocytosis of bacteria by a macrophage as recorded with an optical microscope. Students answer the tasks of their worksheets, and then answer to 4-5 short close-ended questions with feedback as a form of recapitulation.
- Afterwards, students study the immune response in the case of a viral infection in the same DLO. The main stages which are studied are the function of T-cytotoxic cells, the phagocytosis by macrophages, the antigen presentation, the antibody production and the development of memory cells. In order not to confuse the students with terminology overload it is suggested to avoid any explicit reference or distinction between humolar and cell-mediated immunity. They answer the tasks on their worksheets, compare the cases of bacterial and viral infection and answer 4-5 short close-ended questions with feedback.
- Then, students choose the option of a bacterial or viral re-infection by the same pathogen for a second time (secondary immune response). They watch the immune response procedure, and explain the differences it has when compared to the response after the first exposure to the pathogen (primary immune response). They observe the graphs and schematic representations of primary and secondary antibody production and recognize which one represents the primary and which the secondary immune response. They observe and interpret differences in the duration of the response, the speed of the appearance of the response, the antigen quantity and the antigen specialization. Then they attempt to explain why children get more often sick than adults do.
- Finally, students work in pairs to fill in a semi-constructed concept map concerning the immune response mechanisms as a recapitulation and an intermediate assessment of what they have learnt. Feedback is provided both for correct and incorrect answers.

4th teaching hour – Types and function of vaccines

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Teaching phase according to the inquiry & project based instructional model: Completion and reconstruction of students' initial conceptions - *Application of knowledge and skills gained through inquiry*

- During this phase, students study the mechanism behind vaccine function and the different types of vaccines. The educational video SER X is shown to introduce students to vaccine function and to connect it to their already existing knowledge about immune response. The fundamental principle of vaccination is explained, which is that the pathogens are introduced to the human body in a harmless form which causes immune response and memory cell production without causing infection and disease. Students work in groups of four on certain critical thinking tasks such as the sketching of antibody concentration graphs for a vaccinated and an unvaccinated person, the argumentation whether vaccination is meaningful to be done as a therapeutic intervention after the person has already been infected by the pathogen, and whether it is necessary to have the entire microorganism introduced to the body in vaccination. The groups discuss their answers in the classroom.
- Afterwards, students are engaged again in groups of four, in some short problem-solving activities, with the aid of DLO IV. DLO IV presents in a visual mode the ways in which the main vaccine types function. Students are able to select which category they would like to study, and they watch a dynamic visualisation of the entire process of vaccine function from the time it gets introduced to the body until the immune response is triggered. Each category presents the part of the microorganism used, the mechanism in which the vaccine causes immune response, examples of vaccines from each type, and the main advantages and disadvantages of each type. The vaccine types presented are:
  - i. Live-attenuated pathogen vaccines.
  - ii. Inactivated pathogen vaccines.
  - iii. Recombined microorganism vaccines / viral vector vaccines.
  - iv. DNA vaccines.
  - v. RNA vaccines.
  - vi. Protein subunit vaccines.
  - vii. Virus-like protein (VLP) vaccines
  - viii. Toxoid vaccines.
- Students study the vaccine types and are assigned to choose which of them would propose for some hypothetical pathogens, explaining their rationale. There are probably more than appropriate choices for each pathogen. Some indicative pathogen cases are the following ones:
  - i. A highly infectious bacterium which produces harmful protein toxins.
  - ii. A bacterium causing a very severe disease, and for that reason the development of the strongest immune response possible is preferable.
  - iii. A vaccine against a very dangerous bacterium, which is especially targeted at people with a weakened immune system, like the cases of patients under immunosuppression (e.g. AIDS patients or patients with autoimmune diseases).
  - iv. A highly infectious and dangerous bacterium with characteristic protein structures on its surface.
  - v. A highly infectious and dangerous bacterium with well-studied genome and with characteristic protein structures on its surface, which are impossible to get isolated in the laboratory.
  - vi. A very dangerous DNA virus with well-studied structure and genome.
  - vii. A very dangerous RNA virus with well-studied structure and genome.
  - viii. A mildly infectious virus but with very high transmissibility, and therefore it would be crucial to get strong immunity quickly, to prevent the spread of the disease.
  - ix. A novel very dangerous virus which can be easily handled in the laboratory.
  - x. A virus which mutates at a very high rate.
  - xi. A very contagious and dangerous virus, which is a variant of an already existing virus with very low infectivity.
  - xii. A mild virus during a vast epidemic outbreak, during which it is preferable to develop strong immunity as quick as possible (without repetitive vaccine doses).

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- The groups of students present their choices to the rest of the class and they argue about them. Alternative decisions for the same pathogen cases are emphasized during the discussion and the main points and differences of different vaccine types are highlighted. At the closure of this hour the informative video SER XI concerning the COVID-19 vaccine types is shown.
- Students work in groups to fill in a semi-constructed concept map (DLO V) about the vaccine types, as a form or recapitulation and assessment. Feedback is provided for both correct and incorrect answers.

5th teaching hour – How different parameters affect the achievement of herd immunity
Teaching phase according to the inquiry & project based instructional model: Application of knowledge and skills gained through inquiry

- During the fifth teaching hour students are concerned with the notion of herd immunity and the way in which vaccination promotes public health. The formulation of some questions by the teacher to the classroom is suggested as an engagement activity. These questions could be whether it is meaningful for one to get vaccinated if one does not belong to the population immediately in danger by the disease, and whether could someone be protected through vaccination, who cannot be vaccinated because their health conditions (e.g., prone to allergic reactions). The teacher poses these questions to the classroom and a class discussion takes place.
- The notion of herd immunity might get approached through the discussion and students' answers. By posing meaningful questions to the class, the teacher highlights the herd immunity mechanism and explains it with the aid of SER XII.
- Students are involved in structured inquiry activities in order to study the factors (independent variables) which affect the achievement of herd immunity. A brainstorming activity is delivered to the classroom on the possible factors which could affect the herd immunity achievement. The expressed ideas are organized, grouped and completed. The independent variables that are to be tested are the disease transmissibility or infectivity, the percentage of vaccination coverage, the vaccine efficacy and the degree of pre-existing immunity (from past infections). Other variables which might have been expressed (e.g., citizens' social behavior, application of hygiene rules, spatial or geographical distribution of vaccination coverage etc.) although being completely important as well, are not going to be tested during this inquiry process.
- At first, DLO XI is used in which students can modify the variables of vaccination coverage, vaccine efficacy and disease transmissibility (through the R_0 index). They are given two R_0 values (one for a mildly infectious and one for a highly infectious disease) and 100% vaccine efficacy provided they are assigned to find the exact vaccination coverage value for the achievement of herd immunity. They repeat the process for both R_0 values, but now for 85% vaccine efficacy. They record the results, compare them in pairs and draw conclusions about the effect each one of these variables has on herd immunity.
- Students use DLO VI which offers them much more capabilities concerning parameter modification. As an initial activity they gradually change the vaccination coverage percentage and note the percentage of the infected for each case in a table. They repeat the process twice, one for a mildly contagious and one for a highly contagious disease. Then, they make the two graphs regarding the percentage of infected as a function of vaccination coverage percentage, in the same axis system. They observe and comment on the shape of the curve, they locate the area of sharp slope which stands for the achievement of herd immunity, and compare the two curves.
- Afterwards, students select authentic values of infectivity and vaccination efficacy based on data of real cases of diseases and vaccines, like COVID-19, seasonal flu, H1N1 influenza, measles, polio, mumps, chickenpox etc. Students have to determine the critical percentage of vaccination coverage for the achievement of herd immunity in each case.
- Then, students are assigned to test themselves the way the initial immunity percentage (because of previous infection) in the population affects herd immunity achievement and the determination of the

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critical vaccination point for this achievement. After the inquiry, students discuss their findings in the classroom.

6th teaching hour – Herd immunity over time & the role of mass vaccinations of children
Teaching phase according to the inquiry & project based instructional model: Application of knowledge and skills gained through inquiry

- During this phase, students move further on their inquiry processes. They are concerned with the herd immunity phenomenon and connect it to the eradication and re-emergence of infectious diseases.
- During the previous inquiry process students examined how vaccines function on a stable population at a given point of time. What could happen, however, if vaccination takes place for a long period of time in a population where the disease already exists? Could vaccination eliminate the disease? Students handle DLO XII to answer to these questions. DLO XII allows for the monitoring of a vaccination program of a population over generations, as new people are born, and old ones die. Students are given three R_0 values (approximately, since no precise scale is provided), which represent the cases of mild, moderate, and high disease transmissibility. Students have to alter the percentage of children vaccinated in order to determine the critical point which leads to the eradication of the disease from the population. Students record and interpret the results of the inquiry in pairs.
- Afterwards, students discuss in the classroom their conclusions and estimate how realistic the total elimination of communicable diseases would be. They focus on the smallpox case. It is a disease which although they do not have direct experience with, it has led to many epidemics and the second deadliest pandemic in the history of humanity, which killed about 90% of Native Americans (infographic SER XIII). However, the intensification of a worldwide mass vaccination program from 1967 by the World Health Organization lead to record of the last natural case of smallpox in 1977 and the disease was officially declared as eradicated in 1980. At this point a simple search for the word ‘smallpox’ in SER XIV shows that even references to the disease belongs to the past. The World Health Organization is launching successful programs for the worldwide eradication of polio and malaria and diseases such as measles, mumps and rubella could be eradicated in the near future.
- Students now focus on the case of measles, which often leads to outbreaks in spite of the big-scale mass vaccination programs, due to its very high infectivity. The necessary vaccination percentage for herd immunity towards it has been found during the fifth teaching hour and it is about 95%. Students use DLO IX to detect and characterize the situation of the vaccination against measles in their country. Then, they find countries where vaccination percentages have rapidly decreased below 80% since 2015 and make speculations about the consequences this may have. They use SER XV showing the incidence of measles cases in USA cities with a 95% and 80% vaccination coverage among children, and they compare the data to their speculations. They draw conclusions and a class discussion follows where students argue for the importance of the maintenance of high vaccination rates even for diseases that do not to pose a direct threat to public health.

7th teaching hour – Adverse effects of vaccination and the anti-vaccination movement
Teaching phase according to the inquiry & project based instructional model: Application of knowledge and skills gained through inquiry

- During the seventh teaching hour students are concerned with arguments and hesitations referring to vaccine adverse effects which are often posed against vaccination. An initial class discussion takes place about students’ opinions and estimations on the existence, the kind, the harshness, and the frequency of vaccine adverse effects and whether this is a sufficient reason not to get vaccinated. When estimating their frequency students are urged to make an average numerical estimation as a critical point which they would pose as a limit for reconsidering vaccination.
- The video SER XVI is shown in class and the points which draw students’ attention are discussed. This video is introductory to the issue of worries concerning vaccine adverse effects and whether they are

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important enough in order not to be vaccinated. A class discussion about the video content takes place and the issue of the significance of vaccines adverse effects is raised.

- Afterwards, students handle the DLO VIII in order to study how extensive the serious adverse effects of vaccines really are. They select authentic cases of diseases and vaccines (e.g., COVID-19, H1N1 influenza, measles, mumps, rubella, polio, pneumoniococcus, hepatitis B, diphtheria etc.). They observe the frequency and the kind of severe adverse effects, hospitalisations, chronic health problems and deaths by the disease on the unvaccinated, by the disease on the vaccinated and by the vaccine itself. Students work in groups of four to compare and discuss the results for 3-5 diseases and finally argue for the necessity of vaccination.
- Students are shortly engaged with DLO XIII which highlights the successive stages of the development and validation of a vaccine. After the general process is outlined they select ‘vaccine X’ or ‘vaccine Y’ and are responsible to decide whether the vaccine passes the successive stages of testing and the ultimate validation stage. Each team, then, announces their decision and supports it with arguments. It is possible for the teams to have come to different conclusions because they have evaluated the importance of the adverse effects and the vaccine efficacy differently.
- Then, students are asked whether they think antivaccination movements are a recent phenomenon. After expressing their estimations, they use SER XIV to find the appearance frequency of the word ‘antivaccination’ in texts from 1800 to 2019. They have to locate temporally the rise of antivaccination movements, and they will possibly be able to find the modern antivaccination movement from about 1990 till today, a big antivaccination movement around the beginning of the 20th century and a small rise around the 1980’s. Students are provided further explanations about the history of antivaccination, and particularly that there have been reactions against vaccinations since the first vaccinations took place, later on with a huge public clash in the USA around the beginnings of the 20th century which was brought to courts concerning smallpox vaccines and a rise of antivaccination on the 70s and 80s concerning the DTP vaccine. The modern antivaccination movement originated at the end of the ‘90s by the dubious connection of the MMR vaccine to autism, which has been repeatedly refuted since then. Students search the terms ‘antivaccination, MMR vaccine’ in SER XIV and observe the combined rise of these terms in public debates of the 21st century.

8th teaching hour – Misinformation about vaccination

Teaching phase according to the inquiry & project based instructional model: Application of knowledge and skills gained through inquiry

- During the eighth teaching hour students are trained to recognize and discern health texts including scientific content from the ones including pseudoscientific content. The critical appraisal of health information is a key critical health literacy skill, which has been highlighted by the vast amounts of pseudoscientific misinformation that was spread during the COVID-19 pandemic (infodemic).
- Students work in pairs with the DLO VII to train their critical reading skills on scientific and pseudoscientific texts. They get a translated and linguistically adapted excerpt from a scientific paper, and they have to find linguistic and text features which characterize a scientific text (e.g. proper use of scientific terminology, avoidance of logical gaps, use of logical arguments, avoidance of affective use of language, explicit references to trustworthy scientific sources, high quality of language used, avoidance of extreme expressions etc.). Students record the points they identify and characterize the text as scientific or pseudoscientific (misinformation) reasoning about their conclusion. The DLO can provide hints concerning what to look for in the texts, for students who find it difficult to cope with the task. After the groups complete the critical reading of the text, they discuss their findings in class.
- Afterwards, students examine a health text from the news and a misinformative pseudoscientific text concerning vaccinations by using the same criteria. They compare their findings from the three texts to one another and evaluate the trustworthiness of each test. After finishing, they discuss their findings in the class.

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- Students form groups of four and are assigned with the critical evaluation of short text extracts concerning vaccination, provided by DLO VII. The texts are about 8-10 short extracts derived from scientific papers, scientific journalist texts, informative health organisation texts and misinformative texts. Students have to identify the origin of each text and evaluate how trustworthy it seems to be, supporting their evaluation by making references or comments on each text. At the end of the lesson a class discussion concerning the given texts takes place.

9th-10th teaching hours – Developing informative material for a pro-vaccination and an anti-misinformation campaign (School project)

Teaching phase according to the inquiry & project based instructional model: Initiation and conduct of the project

- Students work in small groups (possibly four-member groups) who undertake the conduct of a mini project. Each group can choose the project they are going to undertake between two alternatives.
- As the first project alternative, students take up the role of health journalists and the task assigned is to develop a short informative guide on how to recognize medical misinformation and fake news. Students are assigned the development of a 3-to-5-pages guide which is going to summarize the main points a reader should pay attention to, which might indicate the text they are reading is misinformative. They have also to incorporate and comment on excerpts of authentic misinformation texts about vaccination found on the Internet, selected so as to highlight the criteria presented in the guidelines. At the second part of the guide, students have to find and mention 2-3 common misinformation issues regarding vaccination and to refute them with arguments. The reasoning regarding each misinformation issue has to be analyzed in about one paragraph. Students must keep in mind that their guide is targeted to the general public, who are not familiar with specialized medical knowledge. The information needed in order to make the material is retrieved from the previous lessons, and more specifically from the class discussions, the worksheets, the DLOs, the SERs and possibly the discussions with experts or educational visits done. Some complementary literature may be provided.
- As the second project alternative, students take up the role of health communicators from the Ministry of Health and are assigned to develop an informative health campaign for the general public concerning the benefits and the importance of vaccination. Students are assigned to make an A5 poster or an eight-slide presentation, which are going to promote vaccination and its benefits to public health. The poster or presentation must be designed for the general public and explain with arguments for which reasons vaccination is a necessity and in particular for those who are hesitant. It must explain through facts and arguments the reasons why vaccination is a prerequisite for the promotion of public health. Students are urged to utilize and incorporate material for the SERs and DLOs they used during the learning sequence and possibly the discussions with experts or educational visits done. Moreover, they can include the reconstruction of common worries or arguments against vaccination. Some complementary literature may be provided.

11th-14th teaching hours – Presentation of the project outcomes (School project)

Teaching phase according to the inquiry & project based instructional model: Completion of the project (project presentation) - Final assessment and self-reflection

- The student groups complete their projects and then each group, in turn, present their outcomes to the class. The projects' presentation is organized in two parts, each one each project alternative. After each presentation cycle a class discussion follows about the content and the features of each project outcome presented and emphasis is given on complementary alternative approaches and the central notions presented. A fruitful discussion takes place concerning ways in which the produced material can get even better and how successful it would be regarding the aim it serves. Possible contradictions, misconceptions, repetitions and biases will possibly emerge during these presentations. The teacher and the rest of the classroom point out the benefits and the 'strong points' of each presentation and some suggestions that are made regarding what improvements each team could make in order to advance

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their material. Each team is free to agree with the suggestions and accept them or disagree and think of a middle solution. The groups have to note down the suggestions for the ‘weak points’ of their material.
- The teacher is going to assess the students’ project material and presentations both quantitatively and descriptively, according to specially developed assessment rubrics as part of the summative assessment of the learning sequence. The two cycles of presentations are estimated to take place during the 11^{th} and 12^{th} teaching hours.
- During the 13^{th} teaching hour each team returns to their project and take the comments they gathered during the presentation (both the positive and the negative) into consideration. The task they have during this hour is to make the changes they think in order to advance their project outcome, preferably according to the given guidelines. A part of the 14^{th} teaching hour could also be given to the students in order to finish their work. They mention in a list what changes they have made and give their final versions of the material to the teacher in order to assess them. No classroom presentation of the final version of the material is planned in order to save time and avoid repetition. However, it is strongly suggested to have the final versions presented by the students during a school event in the presence of the rest of the students, the teachers and the parents. If some of the material is of high-quality it could be distributed to local health or municipal structures or be communicated to the local media.
- The 14th teaching hour mainly aims at the final assessment of the learning sequence and the students’ self-reflection on their learning course. Each student looks again at the KWL table they had made at the beginning of the learning sequence, and fills in the third column of the table, noting down the new things that they have learnt during the learning sequence. They make a self-reflective retrospective of their personal learning route and evaluate whether their initial expectations have been fulfilled. They express their impressions to the classroom in a relevant discussion.
- In the end, students fill in a short quiz with about questions concerning core concepts of the learning sequence, in order to assess the degree cognitive learning objectives and skills have been achieved and a short questionnaire assessing self-referred beliefs, attitudes and behaviours.

Supplementary learning activities

I. Discussion with experts

Some discussions with experts could take place as optional educational activities, which act complementary to the educational activities previously described. They can have the form of a short presentation, a free discussion, an interview or a combination of those and they could take place in the physical presence of the expert or via teleconference. The expert might be a person whose scientific specialization or whose profession closely relates to issues that having been discussed in the classroom during the learning sequence. The students’ discussion with the expert has some additive STEM educational value which is summarized with the following points:

- The experts have an advanced scientific or professional expertise so they have deeper content knowledge and are more suitable to give students a deeper understanding of the scientific contents and answer students’ advanced questions.
- Students can see how the content of the learning sequence can be reflected to real world professional specializations. In this way they connect what they learn to authentic contexts and can learn further information about the real work of STEM professionals.
- Students have the opportunity to discuss with STEM professionals, which would otherwise be probably inaccessible to them. They can learn about the real work of scientists and about the real way new scientific knowledge is produced (Nature of Scientific Inquiry).
- Experts could act as role models for some students and trigger them to follow STEM related careers in the future.
- Experts could give students some more specific guidelines or answer advanced students’ questions concerning their research project.

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It is suggested to have the discussions done after the general activities have been completed and before or at the beginning of the school project (more specifically around the 8^{th} or the 9^{th} teaching hour). In this way students will have a good background in order to discuss and meaningfully understand the topics discussed with the experts and can ask them questions that will help them in decision-making concerning the conduct of the school project. Of course, if the teacher thinks that the discussions are better to take place at a different time they, are free to do so.
Some scientific and professional specializations that could be cases of experts are listed below with some indicative topics for discussion:

1. Doctors or medical professionals specialized in infectious diseases – They could discuss with students about the importance of vaccination and mass vaccination programs, the function of vaccines, the eradication of infectious diseases, their experience about people's attitudes towards vaccination, the debunking of anti-vaccination arguments and the re-emergence of past disease due to vaccine hesitancy.
2. Pediatricians – They could discuss with students about the necessity for mass vaccination programs for children, the re-emergence of certain diseases like measles, the attitudes of parents towards children vaccinations, the safety of vaccines and the misinformation about the MMR vaccine.
3. Pharmacists or biomedical experts – They could discuss with students about the different types of vaccines and their function, novel types of vaccines, the chemical constitution of a vaccine, the stages of vaccine development, testing and approval, state-of-the-art news concerning vaccine research, what COVID-19 has changed to vaccine research and development and the potential for a career in biomedical research.
4. Immunologists – They could discuss with students about the components and function of the human immune system, the way vaccines 'cheat' the human immune system, differences in immune response from different vaccine types, possible immunological complications due to vaccination (e.g., allergies, vaccination in immunosuppressed people) and what the future in vaccine development is.
5. Health or science journalists – They could discuss with students about the process of health and science journalism, the issue of the trustworthiness of sources, how fake news or misinformation can be detected and the sources a citizen should trust for information on science or health topics.
6. Health communicators or specialists in health outreach – They could discuss with students about health communication during COVID-19, the vast circulation of fake news and misinformation, their views towards the effective persuasion of vaccine hesitant people and the features that an effective health communication campaign should have.
7. Academics or university professors with relevant expertise.
8. Members of the PAFSE consortium with relevant expertise.

<u>II. Educational visits</u>
Some educational visits could take place within the context of this learning sequence. In this way the school's educational activities will be complemented with educational activities from other organizations or with visits to authentic places where research or work on relevant topics is being done. It would be preferable to make these visits after the students have examined the relevant issues in the learning sequence so that they will be able to meaningfully conceptualize what they examine during the educational visit. A short discussion before and after the educational visit is also necessary in order to determine and summarize the context of the visit and link it to the learning sequence in school.
Some suggested places for educational visits are listed below:

1. Medical museum – During this visit, students could probably come across items concerning historical cases of infectious diseases and their severity and how they have been eradicated over the decades thanks to vaccination.
2. Biomedical research laboratory – During this visit, students could see the actual work of biomedical scientists in drug development and testing, the apparatuses and techniques they use, and can discuss

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with them about their profession, the future of biomedical research and potential STEM careers in this domain.

3. Microbiology laboratory – During this visit, students could see different microbe specimens, cultivations, and microscope images, see common laboratory techniques in a microbiology laboratory, the ways and importance of disinfection and guidelines for the handling of biological material, and can discuss about STEM careers in this domain.
4. Mass vaccination center – During this visit, students could get informed about the importance of mass vaccination programs, maybe with emphasis on COVID-19 vaccination or children vaccination, get informed about the historic evolution of vaccination in the country, the difficulty of the implementation of vaccination programs, common myths concerning vaccines, the practical process of vaccination and the precautions taken guarantying the vaccines' safety.
5. Institution for health awareness, promotion or education – During this visit, students could take part in educational activities concerning the importance of vaccination, herd immunity and the threat of misinformation. They could also see authentic material of pro-vaccination campaigns.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
Scenario topic: "Function of vaccines, vaccination hesitancy and misinformation**"**

Knowledge	
1. States main features of the function of pathogens	**Question 1.1:** Viruses … A) might have RNA as genetic material B) are larger than bacteria C) are responsible for more severe diseases than the bacterial diseases **Question 1.2:** Which category of microorganisms has to infect other cells in order to reproduce? A) Viruses B) Bacteria C) Fungi

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2. Describes the main mechanisms of adaptive immunity during an immune response	**Question 2.1:** Antibodies … A) are attached to microbes and inactivate them B) are produced by T lymphocytes C) have little specialization to each pathogen **Question 2.2:** During the secondary immune response … A) the immune response is faster than during the primary immune response B) a smaller quantity of antibodies is produced than in the case of primary immune response C) the symptoms of the disease are often more severe than during the primary immune response **Question 2.3:** Memory cells … A) fasten the rate of the immune response B) include B cells but not T C) appear after the organism gets infected by a pathogen for a second time **Question 2.4:** Which of the following is NOT true about the secondary immune response? A) The immune response is much faster, more specialised and more effective than in the case of an infection and no symptoms of the disease usually appear B) There is a steadily high number of antibodies in the human body which counterattack the microbes in the case of a future infection C) Memory cells have been produced which circulate around the human body, remembering of these specific pathogens and inactivating them as soon as they enter the body for a second time
3. Explains the function of vaccines	**Question 3.1:** Which of the following is likely to be included in a vaccine? A) microbe parts B) antibodies C) memory cells **Question 3.2:** Vaccines … A) cause immune response without causing the disease B) cause both immune response and the disease C) cause the disease without causing immune response **Question 3.3:** Vaccines … A) are done to a healthy person in order to avoid getting sick B) kill the microbes in the body of vaccinated people C) are done to people who are already sick by a disease in order to get cured **Question 3.4:** A vaccine is usually designed so as to cause … A) a primary immune response B) a secondary immune response C) a tertiary immune response **Question 3.5:** A vaccinated person … A) has memory cells against the disease B) produced a smaller amount of antibodies in the case of an infection C) cannot get infected by the disease **Question 3.6:** During vaccination microbes are put in the body, which might… A) be the ones causing the disease but after some special treatment B) have the same infectivity as the ones causing the disease C) combat or antagonize with the ones causing the disease

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4. Compares and contrasts different types of vaccines	**Question 4.1:** Which of the following vaccine types does not include any part of the microbe? A) Toxoid vaccines B) Recombinant vaccines C) DNA vaccines **Question 4.2:** Which of the following vaccine types is often inappropriate for people with weakened immune system (e.g. immunosuppressed people) A) live-attenuated vaccines B) inactivated vaccines C) recombinant vaccines **Question 4.3:** During a vaccination with an RNA vaccine, a part of viral RNA is introduced in the organism which causes … A) the formation of a single viral protein B) the whole virus, but without capability of reproduction C) the whole virus, but with limited capability of reproduction **Question 4.4:** Which of the following is introduced to the body during a vaccination with virus-like particles? A) The viral proteins, but not the viral genetic material B) The viral proteins and the viral genetic material C) The viral genetic material but not the viral proteins
5. Explains the necessity of vaccination for the promotion of public health	**Question 5.1** If the vaccination coverage is decreased in a population, then … A) it is probable for an epidemic outbreak a disease to get caused, which was believed to be dangerous anymore B) it is probable of an epidemic of a new disease to break out C) there is a danger or a past disease to reappear but not in the near future **Question 5.2:** Vaccination can lead to … A) the local, and sometimes the global, eradication of certain diseases B) the local, but not the global, eradication of certain diseases C) the maintenance of disease cases an low levels, but not to the complete eradication of diseases
6. Describes the notion of herd immunity	**Question 6.1:** In order to have a disease eradicated in a population it is necessary A) a large enough percentage of the population to get vaccinated, which relies to the pathogen infectiousness B) to have about 95% of the population vaccinated C) to have the whole population vaccinated **Question 6.2:** Vaccination … A) protects unvaccinated people if the vaccination coverage is high B) protects only vaccinated people C) protects vaccinated people and people who got infected and recovered
Skills	
1. Argues for the necessity of vaccination	**Question 1.1:** In which of the following cases is it necessary to have larger vaccination coverage achieved? A) In the case of a highly infectious disease B) In the case of a mildly infectious disease C) There is no difference between the two cases **Question 1.2:** Why is vaccination necessary even for the unvaccinated? A) The vaccinated act as a barrier preventing the transmission of the disease to the unvaccinated B) The unvaccinated catch the disease and complete the immunity of the vaccinated, due to their naturally acquired immunity C) The unvaccinated get sick less severely because the microbe has been weakened because of the vaccination

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2. Disproves common arguments against vaccination	**Question 2.1:** Mass vaccination programs for children for diseases like the rubella and the measles … A) protect against the re-emergence against of these diseases B) are not necessary for developed countries anymore C) are useful but solely for the protection of people of bad health condition **Question 2.2:** The most important function of vaccines is usually … A) the prevention of the spread of diseases B) the prevention death by the disease but not getting sick C) the eradication of diseases
3. Designs research plans for hypotheses testing	**Question 3.1:** I want to learn how often the adverse effects of a vaccine are. Which of the following research designs would be preferable in order to get the most useful results? A) To monitor a small sample of vaccinated people, observe how many people had adverse effects and how severe they were, and organise them into categories (e.g. gender, age) B) To monitor a large sample of people and observe the overall number of people who had adverse effects and the kind of these adverse effects C) To compare the frequency of the adverse effect in a large sample of vaccinated people with the frequency of the appearance of the same adverse effects in people who got sick. The comparison is going to be done separately for each age group and gender **Question 3.2:** In order to test the effectiveness of vaccination against COVID-19 it would be preferable to compare … A) data from unvaccinated and vaccinated populations which are as similar to one another as possible (e.g. in terms of gender, age, health condition) B) data from unvaccinated and vaccinated populations for which I can obtain a big load of data, even if the populations are quite dissimilar C) Data from unvaccinated and vaccinated populations for other diseases (e.g. measles, influenza, polio) because they are more easily available and have been studied to much greater extent
4. Gathers and handles mathematical data	**Question 4.1:** I am able to gather and organize numerical data (e.g., put them in appropriate tables) with ease. 1) I strongly disagree … 5) I strongly agree **Question 4.2:** If I am given organized numerical data regarding a research question (e.g., how often deaths are in vaccinated and unvaccinated people), I am able come to a conclusion quite surely. 1) I strongly disagree … 5) I strongly agree

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5. Evaluates the trustworthiness of health texts	**Question 5.1:** In which of the following websites is it expected to find highly trustworthy health texts? A) In the World Health Organization website B) In a news website C) In social networks **Question 5.2:** 'Deadly vaccine': See what happened to a child who got vaccinated against COVID-19!' This title probably come from a text originating from … A) a misinformation text B) a medical academic journal C) a valid news website **Question 5.3:** I read about severe adverse effects of an influenza vaccine according to 'research carried out by an Italian university'. In this case … A) the text is probably untrustworthy because no exact data about the origin of the research are given B) the text is quite trustworthy because it relies on a scientific research done by a university C) the text is probably untrustworthy because it refers just to one research instead of several ones **Question 5.4:** Which of the following can help indicate that a health text I read in a website is not trustworthy? A) Extravagant claims and spelling mistakes B) Content concerning medical mistakes and common references to other texts C) Origin of the text form official accounts by health organisations in social **Question 5.5:** Which of the following is usually absent from a misinformatory text? A) A logical flow of arguments B) Emotionally charged words C) A catching title
6. Produces informative material concerning the necessity of vaccination	**Question 6.1:** I am able to explain the necessity of vaccination by making use of arguments. 1) With great difficulty … 5) With great convenience **Question 6.2:** I am able to rebut common antivaccination arguments. 1) With great difficulty … 5) With great convenience **Question 6.3:** I am able to make informative material for the promotion of. 1) With great difficulty … 5) With great convenience **Question 6.4:** I am able to express what I have learnt in a comprehensible language for the general public. 1) With great difficulty … 5) With great convenience
7. Handles digital simulations	**Question 7.1:** I am able to handle digital simulations. 1) With great difficulty … 5) With great convenience
Beliefs, Attitudes and Behaviours	
1. Adopts a positive attitude towards vaccination	**Question 1.1:** The disadvantages of vaccination outweigh its advantages nowadays. 1) I strongly disagree … 5) I strongly agree **Question 1.2:** Vaccination is a medical practice which is not secure or tested enough. 1) I strongly disagree … 5) I strongly agree **Question 1.3:** Vaccination has been one of the milestones which changed the history of humanity. 1) I strongly disagree … 5) I strongly agree

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2. Adopts a positive attitude towards scientific and technological progress	**Question 2.1:** The development of vaccines is a specimen of scientific and technological progress. 1) I strongly disagree … 5) I strongly agree **Question 2.2:** Vaccines contribute to the improvement of quality of life. 1) I strongly disagree … 5) I strongly agree
3. Recoginses vaccination as a practice which promotes the good of the community	**Question 3.1:** Vaccination is a beneficial practice for the promotion of public health. 1) I strongly disagree … 5) I strongly agree **Question 3.2:** Vaccination is a necessary practice for the assurance of public health. 1) I strongly disagree … 5) I strongly agree **Question 3.3:** Even unvaccinated citizens can be protected thanks to vaccination. 1) I strongly disagree … 5) I strongly agree **Question 3.4:** Vaccination is the main way of combating deadly infectious diseases. 1) I strongly disagree … 5) I strongly agree **Question 3.5:** Mass vaccinations of children were necessary until many diseases were vanished (e.g., tetanus, polio, tuberculosis) but it is now meaningless in developed countries. 1) I strongly disagree … 5) I strongly agree **Question 3.6:** The global decrease of cases of several infectious diseases (e.g., measles, tuberculosis, polio) has been achieved thanks to vaccination. 1) I strongly disagree … 5) I strongly agree **Question 3.7:** Vaccination is an act of solidarity. 1) I strongly disagree … 5) I strongly agree
4. Gets aware about the consequences of antivaccination	**Question 4.1:** The antivaccination movement does not pose a serious threat to public health for the near future. 1) I strongly disagree … 5) I strongly agree **Question 4.2:** The antivaccination movement is a recent phenomenon. 1) I strongly disagree … 5) I strongly agree **Question 4.3:** The antivaccination movement has little presence in my country. 1) I strongly disagree … 5) I strongly agree **Question 4.4:** The antivaccination movement does not rely on scientific facts. 1) I strongly disagree … 5) I strongly agree
5. Trusts scientists' opinions when dealing with scientific topics	**Question 5.1:** I believe that the scientific medical community is the most suitable source of information regarding news and recommendations about health issues. 1) I strongly disagree … 5) I strongly agree **Question 5.2:** I make daily medical decisions depending on scientists' recommendations. 1) I strongly disagree … 5) I strongly agree.
6. Evaluates the scientific information they come upon in everyday life	**Question 6.1:** When I come across a medical or scientific article or text I get concerned about its trustworthiness. 1) I strongly disagree … 5) I strongly agree **Question 6.2:** Scientific misinformation texts were quite common during the COVID-19 pandemic. 1) I strongly disagree … 5) I strongly agree **Question 6.3:** Medical misinformation text concerning antivaccination do not pose a realistic threat to public health. 1) I strongly disagree … 5) I strongly agree **Question 6.4:** I closely check the trustworthiness of a medical text, or I crosscheck it with other sources before I perceive its content as true. 1) I strongly disagree … 5) I strongly agree

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7. Is willing to get vaccinated against communicable diseases	**Question 7.1:** I would be willing to be vaccinated against a communicable disease under the urgent conditions of an epidemic. 1) I strongly disagree … 5) I strongly agree **Question 7.2:** I would be willing to be vaccinated against a communicable disease without the existence of an epidemic or having strong recommendations by the doctors to do so (e.g. seasonal influenza vaccine 1) I strongly disagree … 5) I strongly agree **Question 7.3:** I would have my children vaccinated with all the prescribed vaccines for children. 1) I strongly disagree … 5) I strongly agree **Question 7.4:** I would discuss about the benefits of vaccination with people who are vaccine hesitant. 1) I strongly disagree … 5) I strongly agree **Question 7.5:** I am opposite to the conduction of mandatory vaccinations, even under urgent health conditions. 1) I strongly disagree … 5) I strongly agree

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10. Specifications for an educational scenario on the topic of " Sustainable Mobility"

Main partner responsible:

Portuguese Road Safety Association – PRP

Context

There has been a crescent interest in the environmental crisis in the last decades, and the concept of "sustainability" has become the keystone and the reason for the development of environmental education, increasing the relevance in changing individual behavior. Not only has "sustainability" gained attention, mobility has also become a very important issue for people. The goal should conciliate both concepts, delivering mobility with minimal effect on human health and the environment.

The development of transportation and with it mobility in the last century became an essential factor in the globalisation of modern civilization. Today we are more mobile than we have ever been, the success of a particular society is also reflected in its mobility. The more mobile it is, the more a society is economically developed and prosperous. Although the development of mobility has also had its dark side. Humans in the 20th century changed the world's ecosystem more than ever, and the consequences are global. Virtually all economic and other activities have had an impact on the environment and nature, though mobility has been particularly significant since it is embedded in practically all human activities. Today transport produces around a third of emissions which cause an increase in the greenhouse effect.

One of the major challenges of the 21st century is thus how to make global transport systems sustainable. The development of technology is an important element of this transition, though we believe that education on the importance of sustainable mobility is no less an important element, since it bolsters demand for the development of sustainable (unfortunately sometimes still referred to as alternative) forms of transport. We are aware that only long-term and systematic education about the benefits of sustainable mobility compared to conventional transportation can lead to a shift in people's mindset that will cause a shift in behaviour, understanding and actions. This scenario hopes to supports the efforts to shift the pattern of mobility towards greater sustainability.

Stating the SDGs of the United Nations (UN, 2015), "Rethinking Environment "and thus an ecological transformation of society presupposes Education for Sustainable Development (ESD) at schools. Schools focus mainly on traditional road safety education, rarely approaching the field of mobility and related concerns. It is of utmost importance to have a more comprehensive mobility education – with a look at human-environment interactions and one's behavior.

Children and young people are the most affected by the negative impacts associated with traffic. Lack of active mobility choices and a high rate of traffic accidents result in an unsafe road environment for school children. If we want children to continue to live well in a society where traffic plays a vital role, it is of prime importance that adults, in particular those in direct contact with children, are aware of their prominent mobility behavior.

Sustainable mobility in schools aims to promote the health of students through their movement, reduce the presence of cars in front of schools, and promote sociality and autonomy. Promoting more sustainable mobility patterns for young people, trying to focus on the importance of designing and reorganizing daily routes from home to school. The main objective is to improve air quality and reduce pollution, reducing health risks for citizens, especially the youngest, who are among the most at risk.

Therefore, this scenario wants not only to contribute to how an educational concept for schools in sustainable mobility needs to be designed to initiate and change students' ways of thinking and acting but

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also to show that pedagogical activities need to be oriented toward sustainable mobility as a tool to guarantee a better future for younger generations.

Scientific content and its relevance to public health education

One of the biggest environmental challenges we face today is mobility. Transportation still accounts for 24% of direct CO_2 emissions from fuel burning, according to the International Energy Agency (IEA). Road vehicles account for almost three quarters of CO_2 emissions and those from aviation and maritime transport continue to increase. The way we travel impacts economic sustainability, the social cohesion of cities and, of course, air quality. Sustainable mobility advocates a form of locomotion that does not harm the environment through polluting emissions and meets the needs of citizens while taking care of the city's spaces. Sustainable mobility contributes mainly to six of the 17 United Nations Sustainable Development Goals: SDG 8, 9, 11, 12 and 13. In this context, this learning scenario contributes to the reflection, awareness and alteration of behaviours and attitudes in order to promote sustainable and safe mobility of road users.

Subject: Physical-Chemical Classes and Citizenship and Development Classes.
Grade: 7th grade (+/- 12-13 years old students) - 8th year (13-14 years-old students)
Title of educational scenario: Sustainable Mobility.

Estimated duration
5 sessions of 40-45 minutes (lesson 1 – lesson 5)
6 sessions of 40-45 minutes for supplementary learning activities and school project (lesson 6 – lesson 11)

Classroom organization requirements
From session 1 to session 5, students work essentially in groups, in pairs and individually, with the teacher's coordination.

It's required, a typical classroom with tables, chairs for students and equipped with:

- tablets/laptops with internet access for students to do research, explore teaching resources and carry out activities;
- a support table to place material;
- a laptop, video projector and speakers, Wi-Fi internet access to view and explore teaching resources (powerpoint presentations, videos, animations, activities);
- whiteboard or flipchart and respective markers of different colors and erasers, to register key ideas, collect opinions and discuss ideas; ask questions, write down information from students in the face of challenges.

To carry out the research project, about 6 classes are needed. Students work in groups of 4 or 5 elements. It is necessary to have a computer/tablet with internet access to answer the questionnaire on mobility patterns and data processing, as well as to create infographics/posters about school mobility patterns and suggestions for measures to be taken.

Content glossary

Accessibility. The accessibility of an activity for a person is the ease with which the person can get to places where that activity (e.g. education, work, leisure) takes place. The term accessibility therefore refers to the ability to reach activities and not movement itself using different modes of transport.

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Air pollution. The presence of contaminant or pollutant substances in the air at a concentration that interferes with human health or welfare or produces other harmful environmental effects.

Alternative energy. Energy that does not come from fossil fuels.

Bicycle. A road vehicle which has two or more wheels and generally propelled by the muscular energy of the persons on that vehicle, in particular by means of a pedal system, lever or handle (e.g. bicycles, tricycles, quadricycles and invalid carriages).

Bike Sharing. Service for sharing a fleet of bicycles through a rental or loan system for a certain period.

Car. Vehicle with a propulsion engine, equipped with at least four wheels, with a tare weight greater than 550 kg, whose maximum speed is, by design, greater than 25 km/hour, and which is intended, due to its function, to travel on public roads, without being subject to rails.

Carbon dioxide. Gas naturally produced by animals during respiration and through decay of biomass and used by plants during photosynthesis. Although it only constitutes 0.04 percent of the atmosphere, it is one of the most important greenhouse gases. The combustion of fossil fuels is increasing carbon dioxide concentrations in the atmosphere, which is believed to be contributing to global warming.

Carbon footprint. Measures CO2 emissions associated with fossil fuel use.

Carpooling. An initiative in which two or more people share a private car to make the same or part of a similar route, including the sharing of fuel and toll costs, allowing to save money, improve the environment and even meet people.

Carsharing. Model for making vehicles available for public use, allowing the same vehicle to be used by different customers throughout the day, thus avoiding the expenses associated with the acquisition and maintenance of vehicles. Pickup and delivery of vehicles are carried out at different locations (preferably strategically located).

Climate change. A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Coal. The natural, rocklike, brown to black derivative of forest-type plant material, usually accumulated in peat beds and progressively compressed and indurated until it is finally altered in to graphite-like material.

Cube corner retroreflection. This technology returns light more efficiently than glass beads. With this technology, each cube corner has three carefully angled reflective surfaces. Incoming light bounces off all three surfaces and returns to its source.

Cycle track. Independent road or part of a road designated for use by cyclists and sign-posted as such. A cycle track is separated from other roads or other parts of the same road by structural means.

Decibel. A logarithmic scale used to denote the intensity, or pressure level, of a sound relative to the threshold of human hearing. A step of 10 dB is a 10-fold increase in intensity or sound energy and actually sounds a little more than twice as loud.

Diffuse reflection. The reflection of light from a surface such that an incident ray is reflected at many angles, rather than at just one angle.

Driver. A person who controls a vehicle or animal on a public road.

Ecological Footprint. The impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated.

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More simply, it is the amount of the environment necessary to produce the goods and services necessary to support a particular lifestyle.

Energy. Measure of a System's ability to interact, it is present in all phenomena that occur in nature, it can be transferred or converted from one form to another, but it is never created or destroyed.

Energy efficiency. Refers to actions to save fuels by better building design, the modification of production processes, better selection of road vehicles and transport policies, the adoption of district heating schemes in conjunction with electrical power generation, and the use of domestic insulation and double glazing in homes.

Energy Footprint. It is an indicator that allows us to assess the amount of energy we use in all our daily activities.

Energy recovery. A form of resource recovery in which the organic fraction of waste is converted to some form of usable energy. Recovery may be achieved through the combustion of processed or raw refuse to produce steam through the pyrolysis of refuse to produce oil or gas; and through the anaerobic digestion of organic wastes to produce methane gas.

Energy saving. Avoiding wasting energy.

Environmental Citizenship. The exercise of good practices and public, individual and collective participation in environmental and sustainable development issues, through the design and development of information and communication strategies, as well as education and training, using the channels and means considered most appropriate, taking into account the requirements of the information society and lifelong learning.

Environmental Ethics. Ability to reflect on the value we attribute or should attribute to the environment and on the values that guide or should guide our relations with the environment.

Environmental health. Aspects of human health and disease that are determined by factors in the environment. It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect health. Environmental health includes both the direct pathological effects of chemicals, radiation and some biological agents, and the effects (often indirect) on health and well-being of the broad physical, psychological, social and aesthetic environment, which includes housing, urban development, land use and transport.

Environmental impact. Impacts on human beings, ecosystems and man-made capital resulting from changes in environmental quality related, since it is nearly impossible to produce, transport, or consume energy without significant environmental impact. The environmental problems directly related to energy production and consumption include air pollution, climate change, water pollution, thermal pollution, and solid waste disposal.

Environmental noise. Unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity such as those defined in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control.

Environmental risk. Likelihood, or probability, of injury, disease, or death resulting from exposure to a potential environmental hazard.

Equality. The right for all human beings to be equal in dignity, to be treated with respect and consideration and to participate on an equal basis with others in any area of economic, social, political, cultural or civil life. All human beings are equal before the law and have the right to equal protection and benefit of the law.

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Equity. Being fair and impartial, ensuring that everyone has access to the resources, opportunities, power and responsibility they need to reach their full, healthy potential – acknowledging that different people have different needs.

E-scooter. (Synonym: Standing Electric Scooter) A stand-up or seated scooter that can be propelled by the electric motor itself, irrespective of the user kicking.

Ethics. Moral principles by which an individual governs his personal or professional conduct.

Excessive Speed. Speed that, taking into account the characteristics and condition of the road and the vehicle, the load carried, the weather or environmental conditions, the intensity of traffic and any other relevant circumstances, does not allow, in safety conditions, to carry out the maneuvers whose need to anticipate and, in particular, stop the vehicle in the clear and visible space in front of it.

Fossil fuel. Any of a class of hydrocarbon-containing materials of biological origin occurring within Earth's crust that can be used as a source of energy.

Glass-bead retroreflection. An incoming light beam bends as it passes through a glass bead, reflects off a mirrored surface behind the bead, then the light bends again as it passes back through the bead and returns to the light source.

Global Warming. Increase in Earth's temperature caused by the increase in greenhouse gas emissions that has been occurring since the mid-19th century.

Greenhouse effect. Warming of the atmosphere due to the reduction in outgoing solar radiation resulting from concentrations of gases such as carbon dioxide.

Greenhouse gas. Gas that contributes to the natural greenhouse effect. The Kyoto Protocol covers a basket of six greenhouse gases (GHGs) produced by human activities: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Annex I Parties' emissions of these gases taken together are to be measured in terms of carbon dioxide equivalents on the basis of the gases' global warming potential. An important natural GHG that is not covered by the protocol is water vapour.

Hazard. Any potential source of harm, injury or adverse health effect to a person, or damage to something; an object, process or condition that may expose a person to risk of harm or injury. Driving-related hazards include practices (e.g. speeding, following too close, not wearing seatbelt, overloading vehicle, insufficient driver training), conditions (fatigue, slippery roads), objects (loose wheel nut), substances (carbon monoxide, alcohol), materials (gravel surface) and energy (from your vehicle, or an oncoming vehicle).

Human health. The avoidance of disease and injury and the promotion of normalcy through efficient use of the environment, a properly functioning society, and an inner sense of wellbeing.

Intergenerational Responsibility. Ability of each generation to care for the cultural and natural heritage received from previous generations and keep it for future generations.

Law of reflection. If a ray of light could be observed approaching and reflecting off of a flat mirror, then the behavior of the light as it reflects would follow a predictable *law.*

Lifestyle. A way of living based on identifiable patterns of behaviour which are determined by the interplay between an individual's personal characteristics, social interactions, and socio-economic and environmental living conditions.

Micromobility. Personal transportation using devices and vehicles weighing up to 350 kg and whose power supply, if any, is gradually reduced and cut off at a given speed limit which is no higher than 45 km/h.

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Mitigation (climate change). Human intervention aimed at reducing sources or increasing sinks of greenhouse gases.

Mobility. Ability to reach a place, which is enhanced by accessibility, which is the ease by which a place can be reached.

Moped. Vehicle equipped with two or three wheels, with a maximum speed, on a level and by construction, not exceeding 45 km/h, and whose engine has a cylinder capacity not exceeding 50 cm^3 or whose maximum power does not exceed 4 kW.

Mortality. The death rate; the ratio of the number of deaths per year to a given population.

Multimodal transport. Integration of various modes of transport such as walking, cycling, private car, public transport and railway into transport planning. It seeks to promote complementarity and interconnection among these modes to ensure a seamless flow of people and goods from one place to another.

Noise. Consists of all unwanted sound; sound that is loud, unpleasant or unexpected.

Noise level. Physical quantity of sound measured, usually expressed in decibels.

Noise pollution. Harmful or unwanted sounds in the environment, which in specific locals, can be measured and averaged over a period of time.

Non-renewable energy sources. Sources that are found in nature in limited quantities and whose reserves are depleted, as their formation process is very slow when compared to their rate of consumption by human beings.

Ozone. Triatomic form of oxygen (O3), is a gaseous atmospheric constituent. In the troposphere - at ground level - it is created both naturally and by photochemical reactions involving gases resulting from human activities (photochemical smog).

Ozone hole. A sharp seasonal decrease in stratospheric ozone concentration that occurs over Antarctica in the spring. First detected in the late 1970s, the ozone hole continues to appear as a result of complex chemical reaction in the atmosphere that involves CFCs.

Passenger. A person carried by a vehicle on a public road and who is not a driver.

Passive safety. Any device that automatically provides protection for the occupant of a vehicle, such as safety-belts, motorcycle helmets, child restraints, padded dashboard, bumpers, laminated windshield, head restraints, collapsible steering columns and air bags.

Pedestrian. Person who transits on public roads and in places subject to road legislation on foot. Pedestrians are also, all persons who drive bicycles or two-wheeled mopeds by hand without a car towed, or cars for children or the physically handicapped.

Pedestrian Lane. Public road or transit lane specially designed for pedestrian traffic on foot.

Pollution prevention. The use of materials, processes, or practices to reduce, minimise, or eliminate the creation of pollutants or wastes. It includes practices that reduce the use of toxic or hazardous materials, energy, water, and/or other resources.

Prevention. Action taken to reduce known risks.

Prevention principle. This principle allows action to be taken to protect the environment at an early stage. It is now not only a question of repairing damages after they have occurred, but to prevent those damages

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occurring at all. This principle is not as far-reaching as the precautionary principle. It means in short terms: it is better to prevent than repair.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Public space. The entire space-time area, in principle outside the buildings and with free access and use.

Public transport. Systems of transport consisting of services and routes that are used for travel by the general public as passengers as opposed to an individual. These group travel systems are also referred to as mass transit and high-capacity transit services in some countries.

Quality of life. The general well-being of a person or society, based on a range of criteria such as health and happiness, rather than only wealth.

Renewable Energy Sources. Energy sources such as the sun, wind, water, biomass, tides, geysers and fumaroles that are continually renewed in nature, not being possible establish a time limit for their use, and are therefore considered inexhaustible.

Retroreflection. When a surface returns a large portion of directed light beam back to its source.

Retroreflective materials. Appear brightest to observers nearest the light source (such as a motorist). The object’s brightness depends on the intensity of the light striking the object and the materials the object is made of.

Risk Factors. Characteristics, situations, behaviors that can trigger the occurrence of an accident and/or potentiate its consequences. Among the main risk factors are excessive or inappropriate speed, driving under the influence of alcohol, cell phone use while driving, fatigue, distraction and the ingestion of medication and drugs.

Road. Line of communication (travelled way) open to public traffic, primarily for the use of road motor vehicles, using a stabilized base other than rails or air strips. Included are paved roads and other roads with a stabilized base.

Road accident. A break in the balance of the road system. When the demands of the road environment, in a given place, are greater than the user's response capabilities.

Road environment. Set of elements and external conditions that surround road users and influence them.

Road motor vehicle. A road vehicle fitted with an engine whence it derives its sole means of propulsion, which is normally used for carrying persons or goods or for drawing, on the road, vehicles used for the carriage of persons or goods.

Road safety. Any measure, technique or design intended to reduce the risk of harm posed by moving vehicles along a constructed land route.

Road space. Infrastructures that involve the road context – type of road and configuration, guides, walks, signage, surrounding constructions and location.

Road traffic. Circulation of motor vehicles and people on the road network.

Road user behaviour. Actions exhibited by people who travel on the road that either increase or reduce the risk of a road traffic collision occurring.

Roadway. Part of the public road especially intended for the circulation of vehicles.

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School Mobility Plans. A planning tool that aims to achieve a more sustainable management of travel by the entire school community (students, parents, staff and teachers), through the implementation of practical solutions aimed at: changing travel habits, reducing dependence on the car in favor of pedestrians, bicycles or public transport; improve safety and quality of life at school access; and sensitize the school community to more sustainable mobility.

Shared mobility. Shared use of a vehicle, motorcycle, scooter, bicycle, or other travel mode. Shared mobility provides users with short-term access to one of these modes of travel as they are needed.

Sidewalk. Part of the public road reserved for the circulation of pedestrians and which flanks the carriageway.

Social cost. The full cost including external cost imposed on society by a given activity.

Specular reflection. Reflection off of smooth surfaces such as mirrors or a calm body of water leads to a type of reflection.

Street. Includes a central aisle dedicated to longitudinal circulation (vehicles, bicycles), as well as sidewalks or side spaces, most often represented by shoulders.

Stress. A stimulus or succession of stimuli of such magnitude as to tend to disrupt the homeostasis of the organism.

Sustainability. Meeting the needs of the present without compromising the ability to meet future needs.

Sustainable Development Goals (SDGs). Also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The 17 SDGs are integrated—that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability

Sustainable Mobility. A set of processes and actions aimed at the movement of people and goods, with a reasonable economic cost and at the same time minimizing the negative effects on the environment and on the quality of life of people, with a view to the principle of meeting current needs without compromising future generations.

Transport mode. The way in which passengers and/or goods can be transported.

Urban noise. Noise emitted from various sources in an urban environment.

Vehicle. (motor vehicle) Any power-driven vehicle which is normally used for carrying persons or goods by road or for drawing on the road, vehicles used for the carriage of persons or goods. This term embraces trolley buses, that is to say, vehicles connected to an electric conductor and not rail borne. It does not cover vehicles, such as agricultural tractors, which are only incidentally used for carrying persons or goods by road or for drawing, on the road, vehicles used for the carriage of persons or goods.

Vulnerable Road Users. (VRU) are defined in the European Union Intelligent Transport Systems Directive as "non-motorised road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation".

Waste. Any substance or object that the holder discards or intends or is obliged to discard, namely those identified in the European Waste List.

Well-being. Well-being is a positive state experienced by individuals and societies. Similar to health, it is a resource for daily life and is determined by social, economic and environmental conditions.

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Sources: European Commission, European Environment Agency, General Direction of Education, Institute of Mobility and Transport, National Road Safety Authority, Portuguese Road Safety Association, The Urban Mobility Observatory.

Pedagogical glossary

Active Learning. A teaching and learning approach that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.".

Brainstorming. An instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative Learning. An umbrella term that covers many different methods in which students work together to solve a problem, complete a task, or create a product. Collaborative learning is founded in the concept that learning and knowledge building is social and requires active engagement from students.

Critical Thinking. The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

Cross Debate Technique. In this modality, each of the groups must defend a certain thesis, generally contrary to the other groups. The advantage of this technique is that participants need to hear opposing opinions, make them reflect on them and learn to compete in the field of ideas.

Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Engagement. How a student does or does not feel toward learning and his or her learning environment.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Inclusive Teaching. A mode of teaching that intentionally designs course content and curricula to engage with students of diverse backgrounds, abilities, and lived experiences. The ultimate goal of inclusive teaching is to create a learning environment where all students feel valued and supported to succeed.

Information. Facts, ideas, concepts and data that have been recorded, analysed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

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Knowledge - a familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

Lifelong learning. A broad concept where education that is flexible, diverse and available at different times and places is pursued throughout life. It takes place at all levels—formal, non-formal and informal—utilizing various modalities such as distance learning and conventional learning.

Pedagogical Techniques. Essential resources that the teacher uses to enhance the pedagogical relationship between the students and the teacher in order to ensure learning. Different forms of application to achieve the objectives of a class.

Project based learning. An instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Quiz. A form of student assessment, usually with fewer, less difficult questions than a test, and with less difficulty.

Research. The systematic process that looks to discover, interpret, and revise facts to produce a greater understanding of behaviors, events, and theories. It creates practical applications through theory and law. Research can also be used to describe information collected about a subject, most often associated with the scientific method.

Skill. The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

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Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, literacy, citizenship

Knowledge
Science concepts:
- Energy Sustainability.
- Fossil and renewable energy.
- Air pollution and noise.
- Climate change.

Social concepts and global concerns:
- Sustainable Mobility.
- Environmental protection and social and economic dimension.
- Climate change: the impact of the transport sector.
- Eco-mobility.
- Shared mobility.
- Integrated mobility.
- Active mobility.
- Public Health.
- Quality of life.
- Road Safety.
- Urban and Environmental Health.
- Lifestyles.
- Road risk.

Knowledge - outcome assessment:
1. Recognizes and characterizes patterns of Sustainable Mobility.
2. Identifies the principles of Sustainable Mobility and explains their relationship with the SDGs.
3. Recognizes the advantages and disadvantages of fossil and renewable energy and proposes general action to reduce air pollution and fight climate change.
4. Identifies the most important consequences of motorized transport in the environment, quality of life and road safety.
5. Identifies the best national and international practices that promote Sustainable Mobility.
6. Identifies relevant action to address challenges related with Sustainable Mobility at the community and societal level.
7. Recognizes relevant road risks for vulnerable road users and identifies appropriate actions to prevent or mitigate them.

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Skills (abilities/competences)
General: Critical thinking, curiosity; data analysis and interpretation, risk assessment, public speaking and active debate/participation; social responsibility; respect and solidarity with others; problem-based learning; scientific and technical knowledge; teamwork; collaboration; argumentation; self-awareness, citizenship.

Specific:
- Finding, analyzing, and interpreting scientific data, texts, dynamic graphical representations and videos to map the principles of Sustainable Mobility.
- Understanding the relevance of scientific evidence to explain phenomena related to environment, mobility, health and illness and produce argumentation.
- Obtaining, assessing, and communicating evidence concerning the impact of transport choices on environment, health, quality of life and road safety.
- Assessing risks and behaviours in traffic as well as patterns of sustainable mobility.
- Analyzing the impact of different transportation options in terms of air pollution and ecological footprint.
- Understanding appropriate strategies to reduce personal and community risk and getting access to the relevant resources.

Skills – outcome assessment:
1. Selects appropriate concepts, principles, and evidence to characterize Sustainable Mobility.
2. Can anticipate the consequences of different transport choices and users' behaviour in terms of Sustainable Mobility.
3. Can adopt sustainable mobility patterns to achieve a healthier and safer lifestyle (e.g., chooses a sustainable and safe transportation mode instead of an unsustainable and unsafe one).
4. Rejects unsafe traffic behaviours in the interactions with his/her peers.
5. Can propose concrete action towards adopting sustainable mobility patterns in his/her/others routine.
6. Feels able to influence the adoption of sustainable mobility patterns and safe traffic options by others (e.g., family, peers, friends).
7. Can identify the problems and challenges of the community in relation to Sustainable Mobility. connects them with SDGs and finds the relevant resources to address them.

Affective/Attitudes Behaviour (*beliefs)*
- Adopting safe behaviours in traffic as a pedestrian, cyclist, motorcyclist, moped rider, and/or as a passenger (car/bus).
- Adopting attitudes towards sustainable mobility.
- Adopting attitudes supporting health, sustainable development, urban and environmental health.
- Recognizes risks in traffic and adopts attitudes towards minimizing or mitigating them.
- Engaging public speaking and debating of measures to reduce risky behaviour in traffic, with a particular focus on public policy concerned with road safety and Sustainable Mobility.

Attitudes and behaviour - outcome assessment:
1. Believes that Sustainable Mobility is a fundamental component of health and quality of life.
2. Believes that is important to contribute to a more sustainable mobility
3. Believes that individual choices influence Sustainable Mobility and Sustainable Mobility influences health and quality of life.
4. Believes that is important to adopt sustainable mobility patterns to prevent climate change, to be healthy and safe.
5. Reproves patterns of risky, unhealthy and unsafe behaviour, as a vulnerable road user.

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6. Adopts eco-friendly mobility patterns and believes that it contributes to healthier and safer lifestyles (e.g., Integrated mobility through transport offer; security; schedules; duration; traffic fluidity; cost; walking route).
7. Is committed to communicate and address the challenges of the community in relation to the determinants of Sustainable, Secure and Healthy Mobility, and to contribute to the SDGs.

Learning goals and outcomes

- Uses online tools to plot tables, graphs, and maps, using updated data.
- Describes the concept of sustainable mobility and recognizes its importance.
- Analyzes the consequences of motorised transport options, in environmental terms, energy dependency, economy, health, efficiency of the transport system, quality of life of cities and road safety.
- Uses evidence to build argumentation that sustainable mobility requires the combination of changes in environmental, economic and social policies and humans' behaviour.
- Recognizes the need to use environmentally friendly technologies in mobility systems.
- Identifies solutions that promote sustainable mobility based on national and international best practices.
- Identifies road risk situations.
- Adopts appropriate and safe behaviours in traffic as a pedestrian, cyclist, driver of personal transportation vehicles, and public transport passenger.
- Recognizes that road citizenship is based on risk perception and respect for all road users.

Assessment methods

- ✓ Outcome assessment
    - Quantitative – questionnaire.
    - Qualitative - students project.

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content

- Energy unit: joule (J) and calorie (cal).
- Fossil energy.
- Renewable energy: kW; MW.
- Environmental pollution and noise.
- Greenhouse gas emissions: carbon dioxide, sulphur dioxide, carbon monoxide, nitrogen oxides, lead.
- Noise scale - decibels (Db) and hertz frequency (Hz).
- Optical phenomenon – Retroreflection.
- Safe and appropriate measures/ behaviours for vulnerable road users.

Non-STEM content

- Quality of life - well-being.
- Active and soft modes of transportation (trends).
- Vulnerability of pedestrians and 2-wheel users.

Digital Learning Objects

- New

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

- **New Digital Learning Object 1**: Greenhouse Effects (digital interactive quiz).
- **New Digital Learning Object 2**: Road risk, dangers and main behaviours to adopt while users of smooth travel modes (interactive booklet).
- **New Digital Learning Object 3**: Optical phenomenon – Retroreflection - Simulator “Be seen” - Simulator that allows estimating the visibility distances of pedestrians with and without the use of retroreflective material.
- **New Digital Learning Object 4**: Quality of Life & Road Safety (digital interactive quiz).

Available resources (link) :
Sustainable Mobility Scenario - Google Drive

From other sources/high quality platforms:

- Environmental protection and social and economic dimension:
  - Digital Learning Object 5: indices - Air Quality Index | State of the Environment (apambiente.pt) and/or the APP - QUALAR
  - Digital Learning Object 6: Ecological footprint calculator

- EcoMobility:
  - Digital Learning Object 7: Citymapper - The Ultimate Transport App and/or App Moovit

Digital Educational Resources

- New:
  - New Digital Educational Resource 1: Principles and pillars of sustainable mobility (animation)
  - New Digital Educational Resource 2: School Mobility Patterns (self-declared questionnaire: webpage or pdf file).
  - New Digital Educational Resource 3: Digital Sheet with advantages and disadvantages of modes of transport and their impact on individual quality of life and public health.
  - New Digital Educational Resource 4: PowerPoint presentation/infographic with concepts related to road risk for vulnerable road users in situations of poor luminosity and at night.

From other sources/high quality platforms:

- Sustainable Mobility
  - Digital Educational Resource 5: What is Sustainable Mobility? - Video
  - Digital Educational Resource 6: Benefits of Sustainable Mobility - Infographic

- Energy Sustainability:
  - Digital Educational Resource 7: All solutions are needed: Fossil and renewable energy - Video
  - Digital Educational Resource 8: Natural resources – Video

- Environmental protection and social and economic dimension:
  - Digital Educational Resource 9: Noise pollution — European Environment Agency (europa.eu)
  - Digital Educational Resource 10: Noise Levels - Infographic
  - Digital Educational Resource 11: Air pollution: how it affects our health - Infographic

- EcoMobility:
  - Digital Educational Resource 12: Education for Sustainable Development Goals - UNESCO
  - Digital Educational Resource 13: Sustainable Transport, Sustainable Development - ONU
  - Digital Educational Resource 14: We have the power to move the world – best practices
  - Digital Educational Resource 15: How safe is walking and cycling in Europe

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

- Quality of Life and Road Safety:
  - Digital Educational Resource 16: Light Reflection
  - Digital Educational Resource 17: Reflective Material – 3M - Video
  - Digital Educational Resource 18: Crash Test Personal Transportation Vehicle/Truck
  - Digital Educational Resource 19: Crash Test Personal Transportation Vehicles/Pedestrian

Teaching -learning activities

Principal target:
Physics and Chemistry classes (12-14 years old students); Citizenship and Development classes (students 12-15 years old)
4-6 sessions/classes of 40-45 minutes
Chemistry, Physics and Sciences teachers integrate other colleagues in the enactment of the scenario (e.g., ICT, visual education, science and english teachers), as it aims to be interdisciplinary.

Lesson 1: Sustainable mobility

- **Concept and principles of sustainable mobility.**

Students will be organized in groups of 4/5 people with the aim to answer the following questions:

- “What does sustainability mean?
- “What is sustainable mobility? Can you identify the underlining principles?"

Through a *brainstorming e*ach student gives their inputs while the group organizes the main ideas to present them to the class. In parallel, the teacher writes on the board, the main ideas of each group, distributing them in order to answer each question.

What does sustainability mean?
"Sustainability means meeting the needs of the present without compromising the ability to meet future needs."

➢ **Explore the animation – New Digital Educational Resource 1:** Principles and pillars of sustainable mobility

Using this animation that addresses the issue of sustainable mobility at various levels (health, environmental, economic) the teacher raises awareness on the need to choose sustainable modes of transportation. Students are guided through the benefits and disadvantages of different modes of transportation and think about the possibility of combining different ones in their routines.
As a way of cementing knowledge and defining the most complete concept of sustainable mobility and its principles, the following multimedia resource is presented to the students:

➢ **Watch the video - Digital Educational Resource 5:** What is Sustainable Mobility?

Definition of Sustainable Mobility: a set of processes and actions aimed at the movement of people and goods, with a reasonable economic cost and at the same time minimizing the negative effects on the environment and on the quality of life of people, with a view to the principle of meeting current needs without compromising future generations.

Principles of Sustainable Mobility: energy, economy, environment and quality of life.

- **Energy sustainability**

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Energy resources: fossil and renewable energy sources - advantages and disadvantages.

- **Debate:** The class will be divided into 2 groups, the "fossil energy advocates" and the "renewable energies defenders", the teacher being the moderator and responsible of previously identified and differentiated the sources. With this debate students position themselves in the defense of advantages and disadvantages of the selected resources.

Example of debate topics:

- ✓ Renewable energy (advantages - a fuel supply that never runs out; zero carbon emissions; cleaner air and water; a cheaper form of electricity...);
- ✓ Fossil energy (disadvantages - Contribute to climate change, fossil fuels are the main driver of global warming; fossil fuels are non-renewable sources of energy; unsustainable, we are using too many fossil fuels too quickly; accident-prone.

At the end of this session, after analyzing the results of the debate, it should be concluded that environmental pollution has a direct impact on the health and quality of life of the populations.

<u>Lesson 2: Environmental protection and social and economic dimension</u>

Environmental pollution and noise and their impact on health.
Understanding the impact of noise on health by exploring an infographic of noise levels of daily activities, from low audibility to pain limit.

- **Infographic – <u>Digital Educational Resource 10: Noise Level Scale</u>**

(Decibel scale - since low audibility - zero db; 120 dB - corresponds to the pain threshold and 200 dB corresponds to a nuclear explosion. And the minimum level to which a sound, with a frequency of 3000 Hz, can be heard).

Explanation and identification of sound levels (dB) and frequency - (Hz) - Students are asked to give examples of daily activities that can correspond to the noise levels presented in the infographic, from birds singing, to cars passing and plane landing.

- **Students are invited to search some examples of diseases that they think are related to noise and air pollution.**

Impact on health: it addresses the issue related to the health impact of different types of pollution - environmental and noise - the following infographics are analyzed and discussed:

- **Digital Educational Resource 11: <u>Air pollution: how it affects our health</u>**

Air pollution is a major cause of premature death and disease and is the single largest environmental health risk in Europe. Latest estimates by the European Environment Agency (EEA) show that fine particulate matter (PM2.5) continues to cause the most substantial health impacts.

- **Digital Educational Resource 9: <u>Noise pollution — European Environment Agency (europa.eu)</u>**

Noise pollution is a growing environmental concern. Noise disturbs sleep and makes it harder to learn in school. It can also cause or aggravate many health problems. The most important source of environmental noise in Europe is road traffic.

- ✓ **Air quality:**

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Through an exploration method, the teacher presents and explains the impact of air quality in health, using the Portuguese Environment Agency website with analysis of air quality.

- **Digital Learning Object 6:** **indices - Air Quality Index | State of the Environment (apambiente.pt)** and/or the **APP - QUALAR** that maps the air quality in Portugal and in certain locations in Europe with alerts of *weak* or *bad* air quality.

Students get that air quality is not the same every day and it's different from place to place, from city to city and country to country. By exploring the website or app, students capture those different variables affect air quality: weather, gas emissions, location, fires, etc.

✓ **Greenhouse Gas Emissions:**

Students are introduced to the concepts of "burning fuel", "greenhouse gas emissions" and their impacts, as well as the meaning of "Road to Zero" and "carbon-neutral".
Students are asked to formulate and contribute with keywords to better understand each of the previous concepts in order to recognize the connection between greenhouse gas emissions and the transport sector impact.

- **Burning fossil** fuels releases carbon dioxide/greenhouse gases into the atmosphere.
- **Greenhouse gases** absorb energy from the Earth, trapping it in the atmosphere. This causes the temperature to rise, which drives climate change.
- **Road to Zero**: Cars are the greatest contributor of greenhouse gases released by transport. If cars have zero emissions, then there will be a lower proportion of greenhouses gases in the atmosphere. This means that less energy is trapped, and the temperature increases less.
- **Carbon-neutral**: When a process does not increase the overall amount of carbon dioxide in the atmosphere because it takes in as much carbon dioxide as it releases.
- **Fossil fuel** powered road transport is the most significant source of transport related air pollution. Each vehicle releases pollutants from a set of sources.

In order to strengthen knowledge about greenhouse gas emissions and related concepts, students are challenged to individually respond to an **interactive digital quiz – Greenhouse effects. – New Digital Learning Object 1**

✓ **Ecological Print – our individual role:**

Small group (4/5 students): Discussion around the questions:
- "Do you think your lifestyle follows the sustainable principles?"
- "How can you tell if your lifestyle is sustainable?"
- "How can we compare lifestyles?"

Students must measure/compare everything, leading them to the concept of "Ecological Footprint" as a unit to measure and compare different lifestyles. Our ecological footprint allows us to calculate how much pressure our lifestyle is putting on the planet.

- **Digital Learning Object 7: The ecological footprint calculator:** website (www.footprintnetwork.org) must be use first as a demonstration and then as a tool that helps each student/group to be aware that individual behaviour has an impact on the planet, especially the choice of mode of transport.

In order to engage students in the agenda of sustainability, they are challenged to make a commitment to reduce their ecological footprint by indicating how willing they are to modify their habits – (e.g., eating

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fewer animal products, adopting more environmentally friendly travel habits, saving on water consumption...)

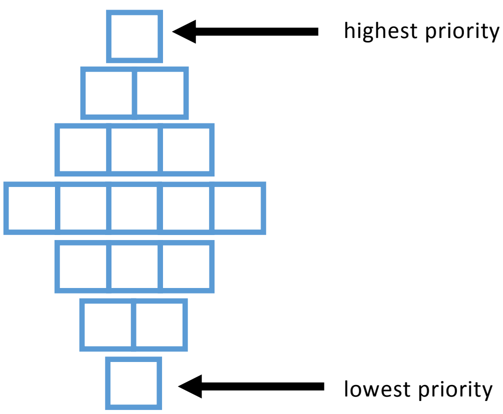
<u>Lesson 3: EcoMobility</u>

Sustainable Development and SDGs.
Students are asked if they know what is Sustainable Development and how many are the Sustainable Development Goals defined in the Global Agenda launched by the United Nations.

Sustainable development means that we need to reach this vision without preventing future generations from also being able to meet their needs.
The agenda includes 17 Sustainable Development Goals (SDGs) which aim to transform the world in areas that are critical for both people and the planet.

- Activity: After identifying all 17 SDGs, students are asked to choose the most important **- Digital Educational Resource 12-** Education for Sustainable Development Goals - UNESCO

The 17 SDG cards are projected by the teacher and each student has to place a diamond shaping the numbers for each objective to represent how would they prioritize the goals. Goals on the same row have equal priority.



- **Debate/Conclusion: Was it easy to decide which goals were the most important? If not, why?**

Many of these issues are interconnected, which means we can't address them on their own. For example, if we don't address poverty and provide everyone on the planet with a sustainable way to produce food, then we won't be able to protect ecosystems on land and below water, and we will fail to curb climate change.

SDGs and Sustainable Transport/Mobility.

Students are asked to map the contribution of Sustainable Mobility to the SDGs.
Sustainable Mobility contributes mainly to six of the 17 United Nations Sustainable Development Goals:

- ✓ SDG 8 - Decent work and economic growth
- ✓ SDG 9 - Industry, innovation and infrastructure
- ✓ SDG 11 - Sustainable cities and communities
- ✓ SDG 12 - Responsible consumption and production
- ✓ SDG 13 - Climate action

- ✓ **Combating climate change: impact of the transport sector:**

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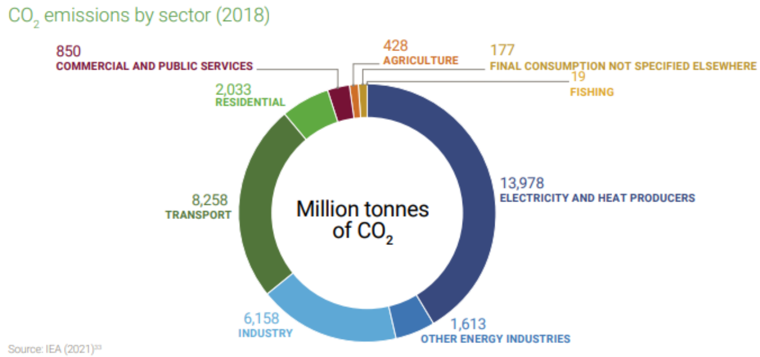

Based on the Sustainable Transport - Sustainable Development - UN report - **Digital Educational Resource 13**, students divided into groups of 5/6, must research the weight of the transport sector in the world's total energy consumption and in the emission of greenhouse gases and address the main ideas.
The transport sector remains a significant contributor to GHG emissions and climate change, while at the same time being vulnerable to climate-related extreme weather and disasters, albeit with different levels of risk and exposure across modes and geographical localities. The ways in which transport systems evolve and adapt are central to reach sustainable transportation networks, which is critical to reduce the probability of climate change events.

National and international best practices in sustainable mobility.

To address the best national and international practices of sustainable mobility, it is proposed to groups of 5/6 students to choose one of the cities and present the best practices implemented by them to the class based on the following pdf document: We have the power to move the world – best practices – **Digital Educational Resource 14.**

Rethinking how we move around our shared landscapes is central to the effort to combat emissions. From offering free public transport during rush hour and tax discounts to electric cars, to building green corridors through public cycling systems, introducing bus rapid transit systems, and expanding pedestrian only zones, decisive action is already making a difference.

✓ **EcoMobility**

Students are organized in groups to discuss the advantages of using more environmentally friendly modes of transport that contribute to healthier and safer lifestyles.
Each group is responsible for presenting to the class each type of mobility pattern: public transport, shared mobility, integrated mobility and active mobility.

- Main advantages of the use of public transport (Means of economic transport; Less occupation of urban space; Facilitation of mobility within cities; Greater equity in access to mobility; Contribution to conservation and greater experience of cities).
- Shared mobility (Bikesharing; Carsharing; Scooter sharing, Carpooling).
- Integrated mobility - mobility using the combination of different types of travel (walking, public transport, individual transport...).
- Active mobility - healthy mobility with the use of physical exertion.

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Travel planning on public transport – the importance of integrated mobility: each group chooses a starting point and a point of arrival planning the best way of travel using the applications : **Digital Learning Object 8 App Moovit and/or Citymapper - The Ultimate Transport App**, taking into account:

- Transport offer.
- Security.
- Schedules.
- Duration.
- Traffic fluidity.
- Cost.
- Walking route.

Students are asked to discuss how they can incorporate some of the actions and practices identified (related to sustainable mobility patterns) in their home to school journey and the impact those changes can produce. Students also discuss the challenges faced with these changes. Students understand that everyone is part of the solution and they can contribute to that. To better understand the mobility patterns of the school community, the teacher presents to the students the mobility patterns questionnaire – **New Digital Educational Resource 2** that they have to answer and that will be applied to the school community project by Lesson 6. This lesson is aligned with the School Research Project, and students can start getting insights and preparing to it. The discussion between students and moderated by the teacher should be registered by students, as this information will be useful for the School Research Project.

Lesson 4: Quality of life and road safety

Quality of life and road safety.

Advantages and disadvantages of modes of transportation and their impact on individual quality of life and public health: in pairs, students must identify and mark on a **New Digital Educational Resource 3,** a digital sheet, the advantages and disadvantages of active modes of transport and motor vehicles at an individual and collective level:

Active modes:
- ✓ Individual advantages: more physical exercise, contributes to physical well-being, reduces obesity; contributes to the better functioning of the respiratory system…
- ✓ Advantages at the collective level: contributes to the public health of all; influences the behaviour of others towards the practice of physical exercise, contributes to the reduction of air and noise pollution.

Motor vehicles:
- ✓ Disadvantages at the individual level (e.g., sedentary lifestyle; increases the likelihood of developing diseases; obesity, deafness, is exposed to polluting gases).
- ✓ Disadvantages at the collective level (e.g., increase in environmental and noise pollution).

Road risks and behaviours to adopt as vulnerable users.

Individually, students are asked to identify the elements that form the road environment and clarify the concepts associated with.

Road environment and its composition: infrastructure, traffic signs, weather conditions, legislation, enforcement, road users (pedestrian, driver and passenger) and vehicles (cars, heavy vehicles – passengers and goods, 2-wheel vehicles (bicycles, mopeds, motorcycles…) and the definition of vulnerable users.

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Through an infographic - How safe is walking and cycling in Europe - **Digital Educational Resource 15** students will have a brief overview of road accidents at European level referring to vulnerable users.

Key questions to students:
1. What are the main road risks that cyclists face in traffic?
2. What are the main risks that pedestrians face in traffic?
3. What are the main risks for drivers of soft modes?

Students are divided into 3 groups: cyclist, pedestrians and drivers of personal transportation vehicles, and invited to explore the **Flipbook/booklet about vulnerable road users - New Digital Learning Object 2**, to identify the risks and dangers associated to each of the groups.
After searching the learning object each group must create an infographic using Canva with the desirable behaviours to adopt as pedestrian, cyclist or driver of personal transportation vehicle. The final result is then presented to the class.

Lesson 5 Quality of life and road safety

- How important is visibility distance in road safety?
- When driving at night and in conditions of poor visibility, is it even more important or not to ensure the visibility distance?
- Is the severity of road accidents related to force of collision– speed at the time of the accident?
- What is run over speed?

Students are introduced to the concepts of visibility distances; severity of accidents, the force of collision, and risk of get run over through a **New Digital Educational Resource 4,** a ***PowerPoint* presentation and/or complementary infographics**.

Retroreflective material: how it works and the importance of visibility - See and be seen at night and in low-light conditions.

How it works:
- ✓ Optical phenomenon of light reflection:
  - diffuse reflection and specular/regular reflection.
  - laws of light reflection.
- ✓ Retroreflective technology:
  - Microbead technology.
  - Microprism technology.

Viewing and analyzing the **video about Light Reflection Phenomena Digital Educational Resource 16** about the optical phenomenon of light reflection and its laws.

The importance of visibility:
- Advantages of retroreflective material.
- Visibility distances.
- Different applicability of the retroreflective material - clothing, accessories and vehicles.

Use of the new **simulator Be Seen – New Digital Learning Object 3 -** Identification of visibility distances of vulnerable road users with and without retroreflective material, especially in reduced visibility conditions or at night.

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Students should individually explore each of the following scenarios in order to understand how far away is the vulnerable user seen under the headlight lights:

- If he/she wears dark clothing, only 25 meters.
- If he/she wears light clothing, this distance doubles - 50 meters.
- If he/she uses retroreflective material, the distance is 6 times greater – 150 meters.

In order to consolidate the concepts and the knowledge about the importance of wearing reflective material, its shown the **Reflective Material film – 3M - Video - Digital Educational Resource 17** that clearly demonstrates the difference between walking/riding with and without retroreflective material with evidence of the distances to which vulnerable road user is seen.

In order to assess and consolidate knowledge and attitudes regarding the issue of quality of life and road safety, students are invited to individually answer a digital and interactive quiz – quality of life and road safety – New Learning Object.

Lesson 6-forward:
After analyzing and identifying the challenges regarding mobility patterns in their home to school journey, students are challenged to apply the mobility patterns questionnaire to their school community and family. Students collect data and build a poster/infographic with the results. This is the School Project described down, in autonomous section.

Supplementary learning resources and educational activities

During lesson 3 and 6 (or in the sessions devoted to the development of the research project) is desirable to organize:

1. Presentation Session of the Ecological Footprint Commitments signed in the Session 2 to parents and school community.
2. Meetings (teleconference) with road safety experts, policy makers, public health authorities, officers of the municipality working on road safety, data scientists, researchers of PAFSE consortium, among others.

School Research Project

Topics
- Sustainable mobility.
- Energy sustainability.
- Social and economic dimension.
- Environmental protection.
- Quality of life and road safety.

Challenge: Build a poster/infographic about your school community mobility patterns and its impacts on environment, health and road safety

Goal: Analyze the results of the mobility patterns questionnaire and build a poster/infographic about school community mobility patterns and the impacts on various aspects: environmental, health and road safety.
Development process:
The project is based on guided research about Sustainable Mobility and the data obtained through the mobility patterns questionnaire.

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To address this challenge, students can draw their first thoughts from the lessons discussed in the classroom in this scenario and the supplementary educational activities. In a second approach students are asked to share their points of view with each other, and ask others about their own experiences and investigation process, sharing ideas. This will help them to think again about their initial thoughts and the path taken so far, possibly generating new perspectives that may enhance their final project. For example, this may be accomplished through a debate between groups of students about the five main topics. Each group is responsible for one of the topics and should write down their strengths and weaknesses and then present them for debate. One of the students will be the moderator of the debate.
After understanding the importance of adopting sustainable modes of transportation, students collect reliable data and real-life cases to propose measures. Students will advocate for actions that promote a more sustainable and safer mobility in their route from home to school. To address the mobility patterns indicators, students and school community are asked to fill a questionnaire and answer a set of questions, such as:

1. What is the distance between your school and your home?
2. Usually, what is your way of moving between home-school-home? (walking, cycling, car with parents, public transport, other...)
3. How long does it take approximately to get to school, by type of transport?
4. If you're going to school by car, you'll point out the top three reasons. (list a number of possible reasons, such as distance, habit, bad weather, risks of walking in traffic, other hazards, other reasons...)
5. When you use the car to go to school, do you always wear your seatbelt? Or do you put it half way? Do you always put your seatbelt on when you travel in the back seat of the car? Do you only put your seatbelt on when you travel in the front seat?
6. If you travel by bike to school, mark the main reasons. (list a set of personal and collective reasons, such as: it is good for health, it is more economical, faster, less polluting, other reasons)
7. If you travel by bike to school, do you always put on your helmet, or do you never wear it or depends on how far you go?
8. During your usual school journey, what dangers do you encounter most often in traffic? (mark the dangers and situations, such as: narrow rides, cars parked on sidewalks, lack of crosswalks, lots of traffic, speeding; absence of signals, others ...)
9. How do you rate your journey to school? (tick the option on a scale: very safe, safe, unsafe and very unsafe)
10. What measures would make it easier for you to get to school, on foot or by bike? (mark those you consider more and less important, such as: pedestrian walks, more walkways, pedestrian areas, lanes for cyclists, spaces to park bicycles at school, less traffic, others...)

During the learning process:

- Students will be able to incorporate evidence in their poster/infographic coming from reputable data sources to support their ideas and show media literacy.
- Students will be able to analyze quantitative evidence on the importance of a sustainable and safer mobility and their progress, to support their recommendations of strategies.

Teaching-learning process milestones:

1. Students will be able to incorporate evidence in their poster/infographic coming from reputable data sources to support their ideas and show media literacy.
2. Students will be able to identify and communicate evidence-based policy measures that promote sustainable and safer mobility and produce positive outcomes in the school and community settings.
3. Students will be able to suggest and advocate for action by different stakeholders, though data and scientific evidence.

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Teaching-learning process for school project (summary):

1. Collection of evidence (data, information, reports, case studies).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Identify effective presentation formats.
4. Produce the posters/infographics.
5. Present the poster/infographic in open schooling event and debate the need to change to a more sustainable and safer mobility and its impacts on the community.

Organization of the open schooling event:

1. Each project output (poster/infographic) is presented by the students to the community and debate the need to change to a more sustainable and safer mobility and its environmental, health and road safety impacts on the community.
2. Students will communicate policy measures using science-based argumentation. Students appeal to the action of all in health and safety of the community, providing great understanding that health, environmental and road safety literacy and promotion are a responsibility of all.

Students, families, school community and relevant local stakeholders attend the event and understand how important is to change behaviour related to mobility patterns. They also get high-level understanding on strategies that minimize disease, environmental hazards and road safety impacts - and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community level).

Data Analysis and Reporting

Poster or infographic with the most important findings of possible measures implemented at the school to help improving sustainable mobility patterns based on science-driven data research.

Target Audience for Recommendations

School community and local stakeholders: students, parents, municipalities, healthcare providers, local enterprises.

Public Debate and Recommendations (based on research results)

Public presentation of the results by students in a community setting and dissemination of evidence-based recommendations via social, community and conventional media.

Main partner responsible:

Portuguese Road Safety Association – PRP

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: Sustainable Mobility

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Knowledge	
1. Recognizes and characterizes patterns of Sustainable Mobility.	**Question 1.1:** What is Sustainable Mobility? A) a set of processes and actions aimed at the movement of people and goods, with a reasonable economic cost and at the same time minimizing the negative effects on the environment and on the quality of life of people, with a view to the principle of meeting current needs without compromising futuregenerations. B) a development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. C) a long-term shift in temperatures and weather patterns that may be natural, such as through variations in the solar cycle. **Question 1.2:** Which one of these is a Sustainable Mobility pattern? A) use the bicycle to go to school daily; B) for short travels the car is always the best option; C) public transport isn't a good alternative for everyday car travels.
2. Identifies the principles of Sustainable Mobility and explains their relationship with the SDGs.	**Question 2.1:** What are the principles of Sustainable Mobility? A) politics, education, industry and optimism; B) technology, physics, justice and freedom; C) energy, economy, environment and quality of life. **Question 2.2:** How many SDGs are related to Sustainable Mobility? A) all 17 of them; B) 10; C) 5.
3. Recognizes the advantages and disadvantages of fossil and renewable energy and proposes general action to reduce air pollution and fight climate change.	**Question 3.1:** Which of these are renewable energy resources? A) oil, coal and wind; B) solar, water and biomass; C) nuclear, natural gas and geothermic. **Question 3.2:** What kind of mobility pollution has the most impact on health? A) visual pollution; B) air and noise pollution; C) none. **Question 3.3:** Which activity is the largest contributor of greenhouse gases? A) deforestation; B) industry; C) transportation.
4. Identifies the most important consequences of motorized transport in the environment, quality of life and road safety.	**Question 4.1**: What is NOT a consequence of motorized transport in the environment? A) greenhouse gas emissions; B) noise pollution; C) clear air. **Question 4.2**: What are the consequences of motorized transport on quality of life and road safety? A) less urban space specially for vulnerable road users; B) improved health and time saving; C) safer roads.
5. Identifies the best national and international practices that promote Sustainable Mobility.	**Question 5.1**: Which cities made a C40 commitment to have healthier and safer streets? A) London, Oslo, Milan, Copenhagen and Paris; B) Medellín, Jakarta, Auckland, Seoul and Vancouver; C) all of the above. **Question 5.2:** What kind of Sustainable Mobility policies did these cities implement? A) revamped its entire bus network, changing fossil fuel vehicles for electric ones and redesigning the system to provide a more streamlined service with higher frequencies; B) reclaiming space for people as a vital way to fight against climate change; C) all of the above.

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6. Identifies relevant action to address challenges related with Sustainable Mobility at the community and societal level.	**Question 6.1**: Select the action that DOES NOT address a challenge of Sustainable Mobility at a community level: A) give back the city to the people; B) expand bicycle infrastructure with new and wider bicycle tracks and more bicycle parking; C) promote the use of individual fossil fueled vehicles.
7.Recognizes relevant road risks for vulnerable road users and identifies appropriate actions to prevent or mitigate them.	**Question 7.1:** Who is a vulnerable road user? A) Pedestrians, especially children and seniors; B) Pedestrians, 2 wheelers and bus drivers; C) All road users. **Question 7.2:** What are the main road risks that vulnerable road users face in traffic? A) Drivers that don't give way to pedestrians and don't respect crosswalks; B) Distraction and Speeding of the car and motorcycle drivers; C) Poor visibility at night and low-light conditions; D) All of the above. **Question 7.3:** Select the appropriate actions to prevent or mitigate road risk: A) Better road safety education at school; B) More road safety campaigns; C) All of the above.
SKILLS	
1. Selects appropriate concepts, principles and evidence to characterize Sustainable Mobility.	**Question 1.1:** Which data sources may we use to proper understand what Sustainable Mobility is? A) International Institutions such as ETSC, EEA, ONU; B) Social media publications from unreliable sources; C) Data retrieved by google searches. **Question 1.2** To find scientific information about Sustainable Mobility I should consult the following sources. A) researchers, scientific publications and national and international experts' institutions. B) friends, journalists, social media; C) google, radio, newspapers.
2. Can anticipate the consequences of different transport choices and user's behaviour in terms of Sustainable Mobility.	**Question 2.1:** Which individual actions can be taken to help promote a more sustainable mobility? A) use an integrated mobility option; B) choose the car no matter the distance; C) don't look for the better transport options for your travels. **Question 2.2**: Which individual behaviours affect negatively the goal of a more sustainable mobility? A) prefer to walk rather them use individual transportation in small travels; B) favor trains and boats over plane trips; C) buy a new car that runs on diesel.
3. Can adopt sustainable mobility patterns to achieve a healthier and safer lifestyle.	**Question 3.1:** I feel able to adopt sustainable mobility patterns that help me achieve a healthier and safer lifestyle. 1) definitely true... 5) definitively false. **Question 3.2:** I will try to change my mobility patterns in order to help me achieve a healthier and safer lifestyle 1) definitely true... 5) definitively false.
4. Rejects unsafe traffic behaviours in the interactions with her/his/they peers.	**Question 4.1:** Please identify which of the following is an unsafe traffic behaviour: A) riding an e-scooter without helmet and give a ride to a friend; B) driving under the influence; C) all of the above. **Question 4.2:** What can you do to prevent unsafe traffic behaviors of your friends: A) when being a car passenger answer their phone calls if he/she/they is driving; B) be sure that everyone has their seatbelt on before you start the journey;

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	C) all of the above.
5. Can propose concrete actions towards adopting sustainable mobility patterns and safe traffic options by others.	**Question 5.1:** Please identify which individual protection gear is recommended when cycling? A) helmet and gloves; B) knee and elbow protection; C) all of the above. **Question 5.2:** As a pedestrian, which of the following behaviours are not safe? A) crossing the road on the crosswalk; B) use earphones while walking on the street; C) look left-right-left before crossing the road;
6. Feels able to influence the adoption of sustainable mobility patterns and safe traffic options by others.	**Question 6.1:** I feel able to influence others (family, friends, colleagues) to adopt individual attitudes in their day-to-day life that lead to more sustainable mobility (e.g., Preferring walking rather than driving by car, choosing public transport over driving a car). 1) definitely false… 5) definitely true. **Question 6.2:** I feel able to influence others (family, friends, colleagues) to adopt individual attitudes in their day-to-day life that lead to safer and healthier mobility (e.g.: wearing a seatbelt, driving at low speeds). 1) definitely false… 5) definitely true.
7. Can identify the problems and challenges of the community in relation to Sustainable Mobility, connects them with SDGs and find the relevant resources to address them.	**Question 7.1:** I feel able to identify the main problems my community faces in relation to Sustainable Mobility. 1) definitely false… 5) definitely true. **Question 7.2:** I can understand how the Sustainable Mobility challenges my community faces are related to the SDGs. 1) definitely false... 5) definitely true. **Question 7.3:** I feel capable of proposing actions that address the SDGs related to Sustainable Mobility in my community. 1) definitely true... 5) definitively false.
Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that Sustainable Mobility is a fundamental component of health and quality of life.	**Question 1.1:** Sustainable Mobility is a fundamental component of health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 1.2:** Sustainable mobility patterns will promote a better health and quality of life. 1) strongly disagree… 5) strongly agree.
2. Believes that is important to contribute to a more sustainable mobility.	**Question 2.1:** My actions will increase the chances of success of a more Sustainable Mobility. 1) strongly disagree… 5) strongly agree. **Question 2.2** I am physically and financially capable of adopting actions that contribute to a more Sustainable Mobility (e.g., use the car less times, prefer walking and cycling for short distances, use the public transports on a daily basis) 1) Extremely unlikely... 5) Extremely likely. **Question 2.3** My family and friends think that I should adopt actions that contribute to a Sustainable Mobility. 1) Extremely unlikely... 5) Extremely likely

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3. Believes that individual choices influence Sustainable Mobility and Sustainable Mobility influences health and quality of life.	**Question 3.1** Sustainable Mobility influences citizens' health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.2** Using the car for every single need to travel influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.3** Preferring integrated mobility options influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.4** Choosing public transport over individual motorized transport influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.5** Favoring shared mobility (bikesharing, carpooling, carsharing) influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.6** Active mobility (walking, cycling) influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.7** Access to different types of transportation modes influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree. **Question 3.8** Changing oil fueled vehicles to electric vehicles influences Sustainable Mobility, health and quality of life. 1) strongly disagree… 5) strongly agree.
4. Believes that it is important to adopt sustainable mobility patterns to prevent climate change and to be healthy and safe.	**Question 4.1** Youths should adopt sustainable mobility patterns to fight climate change and be healthy and safe in older ages. 1) strongly disagree… 5) strongly agree. **Question 4.2** The adoption of sustainable mobility patterns will contribute to fight climate change and to have a healthier and safer lifestyle. 1) strongly disagree… 5) strongly agree.
5. Reproves patterns of risky, unhealthy and unsafe behaviours, as a vulnerable road user.	**Question 5.1** The adoption of sustainable mobility patterns will ruin my image. 1) strongly disagree… 5) strongly agree. **Question 5.2** For me the adoption of sustainable mobility patterns in the next three months, would be: 1) Bad... 5) Good. **Question 5.3** For me to adopt more sustainable mobility patterns, in the next three months, would be: 1) useless... 5) useful. **Question 5.4** I don't accept patterns of risk, unhealthy and unsafe behavior in my mobility patterns. 1) definitely true... 5) definitively false. **Question 5.5** The people in my life whose opinions I value (family, friends) 1) will use ... 5) will not adopt sustainable mobility patterns in the next three months.

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6. Adopts eco-friendly mobility patterns and believes that it contributes to healthier and safer lifestyles.	**Question 6.1** I believe that the adoption of eco-friendly mobility patterns influences people security, health and quality of life: 1) strongly disagree… 5) strongly agree. **Question 6.2** I will make an effort to adopt eco-friendly mobility patterns to in the next three months. 1) strongly disagree… 5) strongly agree. **Question 6.3** I plan to use more public transports in the next three months. 1) strongly disagree… 5) strongly agree. **Question 6.4** I plan to use active mobility (walking, cycling…) in the next three months. 1) strongly disagree… 5) strongly agree. **Question 6.5** I plan to use more shared mobility (carsharing, bikesharing, carpooling) in the next three months 1) strongly disagree… 5) strongly agree. **Question 6.6** I plan to use integrated mobility options in the next three months. 1) strongly disagree… 5) strongly agree. **Question 6.7** I plan to avoid car travels over more sustainable options in the next three months. 1) strongly disagree… 5) strongly agree. **Question 6.8** Among the following statements, choose the one that best describes what you currently think. 1) I do not have eco-friendly mobility patterns, and I also have no intention of doing so. 2) I do not have eco-friendly mobility patterns but I have been thinking about the possibility of starting to do so. 3) I never or rarely have eco-friendly mobility patterns, but soon I will start doing it on a regular basis. 4) I adopt eco-friendly mobility patterns regularly. 5) For more than six months I have always or almost always followed eco-friendly mobility patterns. 6) For several years now, I have adopted eco-friendly mobility patterns, and I will continue to do so.
7. Is committed to communicate and address the problems and challenges of the community in relation to the determinants of sustainable, secure and healthy mobility and to contribute to the SDGs.	**Question 7.1** I intend to identify the problems of the community in relation to the determinants of sustainable, secure and healthy mobility in the next three months. 1) Extremely unlikely... 5) Extremely likely. **Question 7.2** I intend to address the challenges of the community in relation to the determinants of sustainable, secure and healthy mobility in the next three months. 1) Extremely unlikely... 5) Extremely likely. **Question 7.3** Among the following statements, choose the one that best describes what you currently think. 1) I am not contributing to sustainable mobility patterns in my community, and I also have no intention of doing so. 2) I am not contributing to sustainable mobility patterns in my community, but I have been thinking about the possibility of starting to do so. 3) I am never or rarely have been contributing to sustainable mobility patterns in my community, but soon I will start doing it on a regular basis. 4) I am contributing to sustainable mobility patterns in my community regularly. 5) For more than six months I have always or almost always been contributing to sustainable mobility patterns in my community. 6) For several years now, I have been contributing to sustainable mobility patterns in my community, and I will continue to do so.
8. Attitude towards Sustainable Mobility.	**Question 8.1** For me to adopt patterns of sustainable mobility is harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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11. Specifications for an educational scenario on the topic of " Road traffic crashes – a public health issue"

Main partner responsible: Portuguese Road Safety Association – PRP

Context

Road traffic crashes cause approximately 1.3 million deaths and 20 to 50 million non-fatal injuries worldwide every year. More than half of all road traffic deaths and injuries involve vulnerable road users, such as pedestrians, cyclists, motorcyclists, and their passengers. Young people are particularly vulnerable in the world roads – road traffic injuries are the leading cause of death for children and young adults aged 5-29 (WHO, 2018). The scenario supports 7th to 9th grade teachers in exploring road traffic crashes as a public health challenge. It is expected that the learning experience leads the young students to understand that road traffic crashes are major public health threats, the influencing variables and how to move to less risky patterns of behaviour in the road, and reach high-level comprehension on how STEM (Science, Technology, Engineering, Mathematics) may contribute to address these issues, contribute to evidence-based personal decision-making, and public policy. The scenario aims to address the Sustainable Development Goals (SDGs), not only by contributing to the quality of education (SDG 4), but also by improving road safety and making the cities safer, especially for vulnerable road users (SDGs 3 and 11, targets 3.6, 11.2, 3.D). The scenario empowers students to adopt safe behaviours in traffic by creating awareness on risky behaviours, social influences, and modifiable risk factors, supports their participation in civic society initiatives and in the design of local responses for the issue, while providing significant interactions with the community (researchers, public health specialists, municipalities, policy makers, enterprises).

Scientific content and its relevance to public health education

To European Commission defined the goal to move to close to zero deaths on the EU roads by 2050 ("Vision Zero") and to halve the number of serious injuries by 2030 from a 2020 baseline. To reach these goals, the European Commission based its road safety policy framework for the decade 2021 to 2030 on the Safe System approach, whose core elements are ensuring safe vehicles, safe infrastructure, safe road use (speed, sober driving, wearing safety belts and helmets) and better post-crash care. The EC also stated that the mindset of "Vision Zero" needs to take hold both among policy makers and in the society (European Commission, 2020). The traffic safety and mobility education play an important role in strengthening and/or changing attitudes and intrinsic motivations towards risk awareness, personal safety and the safety of other road users in order to contribute towards a safety-minded culture. It is considered an essential part of an integrated approach to traffic safety, as education provides the possibility for people to learn how to participate in traffic safely. The aim of traffic safety and mobility education is to positively influence behaviour patterns that result in safer traffic. The transfer of knowledge and gaining an understanding of traffic rules and situations are the basis of traffic safety and mobility education (ETSC, 2020).

The scenario aims to contribute towards a safety-minded culture in traffic. Its content endorses teachers to play a key role in developing knowledge and skills for incorporating road safety as a central topic in their classes and in teaching public health science using high-level methods, high-quality learning objects, and updated evidence. It also challenges them to have a contribution for the community road safety by engaging families in educational activities and reaching the local community with inquiry-based projects and open schooling events leaded by students. The scenario also contributes to increase the interest in STEM (Science, Technology, Engineering, Mathematics) by providing an opportunity to develop a real-world research project in which students will develop and apply knowledge and skills learned in classes. During the scenario, students will design, plan, and carry out a research project that involves concepts as population,

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sample, sampling, or percentages – learn in Mathematics classes. The project also involves data collection, data manipulation, data analysis and communicating/discussing results based in scientific evidence.

Subject: Mathematics and Citizenship classes
Grade: 7th to 9th grade (12-15 years old students)
Title of educational scenario: Road traffic crashes – a public health issue
Estimated duration
5 sessions of 40-45 minutes (lesson 1 - lesson 5)
10 sessions of 40-45 minutes for supplementary learning activities and school project (lesson 6 - lesson 15)

Classroom organization requirements

From lesson 1 to lesson 5 students work alone and/or in groups. Classroom with computers with internet access is needed.
From lesson 6 to lesson 15 students work in groups to plan and develop the school project. The use of computer is required.

Prerequisite knowledge and skills

Knowledge: population, sample, sampling, probabilities, percentages, frequency tables, graphs.
Skills: using a web browser, using spread sheets

Content glossary

Blood alcohol concentration (BAC). Amount of alcohol present in the bloodstream, usually denoted in grams per decilitre (g/L). A legal BAC limit refers to the maximum amount of alcohol allowed in the bloodstream that is legally acceptable for a driver on the road. In some countries, the law stipulates an equivalent quantity of alcohol in the air breathed out, in order to facilitate detection of drink-driving.

Braking distance. Distance taken to stop once the brakes are applied.

Collaboration. A recognized relationship among different sectors or groups, which have been formed to take action on an issue in a way that is more effective or sustainable than might be achieved by the public health sector acting alone.

Community participation. Procedures whereby members of a community participate directly in decision-making about developments that affect the community. It covers a spectrum of activities ranging from passive involvement in community life to intensive action-oriented participation in community development (including political initiatives and strategies).

Countermeasure. An activity or initiative to prevent, neutralize, or correct a specific problem.

Distracted driving. Any activity that could divert a person's attention away from the primary task of driving. Includes activities such as texting or talking on a cell phone while driving.

Driving under the influence (DUI) of alcohol, drugs, or a combination of alcohol and drugs. Operating a vehicle while the alcohol and/or drug concentration in the blood or breath, as determined by chemical or other tests, equals or exceeds the level established by law.

Data. Information collected through research. It can include written information, numbers, sounds and pictures, and can be collected through surveys, interviews, direct observation, focus groups or documents.

Data analysis. Process of transforming raw data into usable information, often presented in the form of a report, article or presentation in order to add value to the statistical output.

Dataset. A collection of data, usually presented in a table where each column represents a particular variable and each row a particular case.

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Disability-Adjusted Life-Years (DALYs). A time-based measure that combines years of life lost due to premature mortality (YLLs) and years of life lost due to time lived in states of less than full health, or years of healthy life lost due to disability (YLDs). One DALY represents the loss of the equivalent of one year of full health.

Enforcement. Actions taken to ensure compliance with legislation; traffic enforcement is usually done by the police.

Evidence. Information such as analyzed data, published research findings, results of evaluations, prior experience, expert opinions, any or all of which may be used to reach conclusions on which decisions are based.

Excessive speed. Driving at a speed higher than the maximum allowed.

Fact-checking. the process of checking that all the facts in a piece of writing, a news article, a speech, etc. are correct.

Fatigued driving. Is a reduction in driving or riding ability as a result of prolonged driving or being tired while driving. It should be noted that prolonged driving/ riding activity is not solely responsible for fatigue. Other factors such as the elapsed time since the person last slept, the time of the day or night, as well as the human circadian rhythm may be involved.

Helmet. A protective device worn on the head to prevent injuries in the event of a crash.

Inappropriate speed. Driving at too high a speed given the traffic situation, infrastructure, weather conditions, and/or other special circumstances

Incidence. The number of cases of disease that have their onset during a prescribed period of time. It is often expressed as a rate. Incidence is a measure of morbidity or other events that occur within a specified period of time.

Mortality. A measure of number of deaths in a given population, location or other grouping of interest.

Mortality rate. A measure of number of deaths in a given population, location or other grouping of interest, scaled to the size of that population, per unit of time (e.g. 9.5 deaths per million population in 2020).

Passive safety/safety equipment. Any device that automatically provides protection for the occupant of a vehicle, such as safety-belts, motorcycle helmets, child restraints, padded dashboard, bumpers, laminated windshield, head restraints, collapsible steering columns and air bags.

Post-crash response. Sequence of time-sensitive actions, beginning with activation of the emergency care system, and continuing with care at the scene, care during transport, and facility-based emergency care.

Population. In research, the population is the entire set of individuals that are of interest to the researcher.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Quality-Adjusted Life-Years (QALYs). A measure of the state of health of a person or group in which the benefits, in terms of length of life, are adjusted to reflect the quality of life. One quality-adjusted life year (QALY) is equal to 1 year of life in perfect health. QALYs are calculated by estimating the years of life remaining for a patient following a particular treatment or intervention and weighting each year with a quality-of-life score (on a 0 to 1 scale).

Reaction distance. Distance travelled between the presentation of a sensory stimulus and the subsequent behavioural response; the distance travelled from the moment a driver observes a stimulus (e.g. sees a

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pedestrian or a changing traffic light) until the moment they have decided on their response (but have not yet initiated that response).

Reaction time. The elapsed time between the presentation of a sensory stimulus and the subsequent behavioural response; the time from the moment a driver observes a stimulus (e.g. sees a pedestrian or a changing traffic light) until the moment they have decided on their response (but have not yet initiated that response).

Research. Activities designed to develop or contribute to knowledge, e.g., theories, principles, relationships, or the information on which these are based. Research may be conducted simply by observation and inference, or by the use of experiment, in which the researcher alters or manipulates conditions in order to observe and study the consequences of doing so.

Risk. The possibility of an unwanted event; usually the possibility will be quantified as a probability and the event will be described in terms of its consequences, resulting in this definition of risk: Risk= Probability x Consequence.

Risky behaviours in traffic. Acts that increase the risk of a road traffic crash and/or the severity of its consequences in the road users. The main risky behaviours in traffic are speeding, driving under the influence of alcohol/drugs, fatigue, distraction, and no using protective devices/systems (helmet, set belt).

Risk factor. A factor that affects the probability of accident occurrence or the severity of the consequences of an accident.

Road infrastructure. Road facilities and equipment, including the network, parking spaces, stopping places, draining system, bridges and footpaths. Roadside furniture: functional objects by the side.

Road safety. Approaches, strategies and measures used to prevent people from being killed or seriously injured in road traffic collisions.

Road safety indicators. Measures that enable to assess and monitor a road traffic system (country, region, …). Includes statistics from road traffic crashes, safety of vehicles and infrastructure, post-crash response, or road users' behaviours.

Road traffic crash. A collision involving at least one vehicle in motion on a public or private road that results in at least one person being injured or killed.

Road traffic fatality. A death occurring within 30 days of a road traffic crash.

Road traffic injuries. Fatal or non-fatal injuries incurred as a result of a road traffic crash.

Road user. A person using any part of the road system as a non-motorized or motorized transport user.

Roadside observation survey. Study aiming to estimate indicators (percentages, means, …) that "measure" the road users' behaviours in a given population (city, country, …). Examples of indicators: percentage of car drivers using the mobile phone while driving, mean speed of vehicles by road type.

Sample. A subset of the population that is actually used in research. One common method for selecting a sample is called probability sampling. In probability sampling, each person in the group or community has an equal chance (probability) of being chosen.

Seatbelt. Vehicle occupant restraint, worn to protect an occupant from injury, ejection or forward movement in the event of a crash or sudden deceleration.

Speed limit. The highest speed permitted by legislation; speed limits are often signposted.

Speed. The distance covered per unit of time; speed is often measured in kilometres per hour.

Speeding. Violations of the speed limit.

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Stopping distance. Distance travelled between the time when someone decides to stop a vehicle moving, and the time when the vehicle completely stops. The total stopping distance is the sum of the perception-reaction distance and the braking distance.

Sustainable Development Goals (SDGs). Also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The 17 SDGs are integrated—that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic, and environmental sustainability.

Visual field (field of view). The size of the area a person can see measured horizontally and vertically.

Vulnerable road users. Road users most at risk in traffic, such as pedestrians, cyclists and public transport passengers. Children, older people and disabled people may also be included in this category.

Pedagogical glossary

Active Learning. A teaching and learning approach that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work".

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative Learning. An umbrella term that covers many different methods in which students work together to solve a problem, complete a task, or create a product. Collaborative learning is founded in the concept that learning and knowledge building is social and requires active engagement from students.

Critical Thinking. The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

Engagement. How a student does or does not feel toward learning and his or her learning environment.

Inclusive Teaching. A mode of teaching that intentionally designs course content and curricula to engage with students of diverse backgrounds, abilities, and lived experiences. The ultimate goal of inclusive teaching is to create a learning environment where all students feel valued and supported to succeed.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

Knowledge. A familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

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Lifelong learning. A broad concept where education that is flexible, diverse and available at different times and places is pursued throughout life. It takes place at all levels—formal, non-formal and informal—utilizing various modalities such as distance learning and conventional learning.

Pedagogical Techniques. Essential resources that the teacher uses to enhance the pedagogical relationship between the students and the teacher in order to ensure learning. Different forms of application to achieve the objectives of a class.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Skill. The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

The 5E Model (engage; explore; explain; elaborate; evaluate). developed in 1987 by the Biological Sciences Curriculum Study, promotes collaborative, active learning in which students work together to solve problems and investigate new concepts by asking questions, observing, analyzing, and drawing conclusions.

Work Group. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

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Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, literacy, citizenship

Knowledge

Science concepts:

- Disease burden measures: Mortality, Mortality rate, Quality-Adjusted Life-Years (QALYs) and Disability-Adjusted Life-Years (DALYs).
- Road safety indicators:
  - road crash statistics (number of crashes, deaths, injuries, rates).
  - roadside observations (observed behaviours).
- Research and scientific method.
- Roadside observation survey.
- Population, sample, and dataset.

Social concepts and global concerns:

- Public health.
- Major public health causes of death and disability.
- Road safety.
- Risk factors in traffic: speeding, driving under the influence of alcohol/drugs, fatigue, distraction, protective devices/systems (helmet, set belt).
- Sustainable Development Goal (SDG).

Knowledge - outcome assessment:

- Recognizes road traffic accidents as a leading cause of death and disability. Defines SDG 3 and target 3.6.
- Identifies disease burden indicators in the context of road safety (road safety indicators).
- Identifies the main risky behaviours in traffic and explains their relationship with risk of crashing and injury.
- Knows the steps of the scientific method applied to a roadside observation survey.
- Defines population, sample, and dataset.

Skills (abilities/competences)

General: critical thinking; curiosity; problem-based learning; teamwork; collaboration; argumentation; self-awareness; citizenship; public speaking and active debate/ participation.

Specific:

- Understanding the relevance of scientific evidence to explain road safety phenomena.
- Searching, analysing, and interpreting scientific data to understand and characterize road safety deaths and injuries worldwide, in the continent, in the country, at and at the region/city/local level.
- Identifying reliable sources of information, the difference between facts and opinions, and how to find fake claims (fact checking techniques).
- Collecting and organizing data and choosing appropriate instruments to present the results (e.g., tables, graphs, infographics).
- Calculating and understanding road safety indicators at the population level, by gender, by age group, and by road user.
- Planning and executing a data-driven science project and communicating the results.
- Mapping patterns of risky behaviour, the dynamics between risk factors, protective behaviour and outcomes, in terms of road traffic injuries.
- Understanding appropriate strategies to reduce personal and community risk of injury from road traffic accidents.

Skills – outcome assessment

- Selects appropriate concepts, data, and evidence to characterize performance on road safety indicators at different levels (international/ national/ country/ community).
- Anticipates the consequences of risky behaviour in traffic.
- Can identify problems and challenges in the community in relation to road safety related issues.
- Can adopt safe behaviours in traffic.
- Is able to carry out a roadside observation survey.

Affective /Attitudes/ Behaviour (*beliefs)*

- Adopting safe behaviours in traffic, as a pedestrian, cyclist, motorcyclist, moped rider, and/or as a passenger (car/bus).
- Adopting attitudes towards minimizing risks in traffic.
- Being aware of risks in traffic and contribute to community awareness on those risks.
- Engaging public speaking and debate of measures to remove sources of risk and reduce patterns of risky behaviour in traffic, with a particular focus on public policy.

Affective, Attitudes and behaviour - outcome assessment

- Believes that safe behaviour in traffic reduces the risk of road crashes and the severity of its consequences.
- Reproves patterns of risky behaviour in traffic.
- Adopts safe behaviours in traffic, as a pedestrian, cyclist, motorcyclist, moped rider, and/or as a passenger (car/bus).
- Is committed to communicate and address the problems and challenges of the community in relation to road safety.

Learning goals and outcomes

- Understands why road traffic crashes are a major public health concern.
- Identifies the most important patterns of risky behaviour in traffic (e.g.: speeding, driving under the influence of alcohol/drugs).
- Understands the relationship between risky behaviour and increasing risk of road traffic crashes and the severity of its consequences.
- Extracts statistical information online relative to road safety indicators (e.g., deaths, disability-adjusted life years).

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- Plans and executes a roadside observation survey to characterize indicators at the community level based on roadside observations.
- Calculates road safety indicators based on crash statistics and roadside observations.
- Builds a report, presentation, or infographic to communicate the findings.
- Uses evidence to propose actions that improve road safety.

Assessment methods

✓ Outcome assessment
  - Quantitative – questionnaire in paper.
  - Qualitative – students project.

✓ Process assessment – *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Assessment of the scenario's impact – questionnaire based on knowledge, skills, attitudes, and behaviour. The questionnaire is answered before and after the scenario by students involved in the scenario and by a control group (students not involved in the scenario).

<u>Content (relevant to learning goals & research topics)</u>

STEM content

- Road traffic crashes as a major issue in public health.
- Measures of disease burden: mortality, mortality rate, quality-Adjusted Life-Years (QALYs), Disability-Adjusted Life-Years (DALYs).
- Risk factors and patterns of risky behaviour in traffic.
- Road safety indicators (road crash statistics, and roadside observations).
- Probabilities and statistics:
  - percentages, rates, frequency tables, graphs.
  - population and sample.
  - data collection, data, and dataset.

Non-STEM content

- Quality and trustfulness of information sources, facts, opinions, fact-checking techniques.
- Global trends (e.g., agenda for sustainable development) and road traffic accidents.

Digital Learning Objects (DLO) & Digital Educational Resources (DER)

<u>New</u> (*developed by the project team*):

- **DER_1 –** definitions of "public health" and "public health problem". Includes the main public health issues in 2019 and weblinks to updated data on the main causes of death worldwide, distribution by country.
- **DER_2 –** definitions and examples of disease burden measures: mortality, mortality rate, Quality-Adjusted Life-Years (QALYs) and Disability-Adjusted Life-Years (DALYs).
- **DLO_1 –** road crash simulators.
- **DLO_2 –** road safety indicators based on roadside observations (to be used in lesson 4 and in the project) – webpage (and/or pdf file) with all the steps (step by step) to collect and calculate the road safety indicators. Includes:

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- Possible indicators for the different road users. *Example – percentage of the cyclists who do not wear the helmet while cycling (number of cyclists without helmet/ number of cyclists observed)*;
- guidelines for the definition of the observation places;
- sample size (sample size calculator - interactive);
- the random process of the observations (interactive);
- tools for data collection – record sheets/online forms;
- how to calculate the indicators;
- how to communicate the results - examples.

Available resources (link) :
Road Traffic Crashes Scenario - Google Drive

From other sources/high-quality selected platforms

- **DER_3 –** Top ten causes of death worldwide (WHO): https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death
- **DER_4** – Cause-specific mortality by country (WHO): https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death
- **DLO_3 –** Death on the Roads (WHO): https://extranet.who.int/roadsafety/death-on-the-roads/
- **DER_5** – Top 10 global causes of disability-adjusted life years (DALYs) in the world: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates
- **DER_6 –** Top 10 global causes of disability-adjusted life years (DALYs) by country, sex and age group: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/global-health-estimates-leading-causes-of-dalys
- **DER_7** – Road traffic mortality (WHO): https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/road-traffic-mortality
- **DLO_4 –** Roads kill (Pulitzer center): https://roadskillmap.com
- **DER_8** – Road safety statistics (European Commission): https://ec.europa.eu/transport/road_safety/specialist/statistics/map-viewer/
- **DER_9 –** Road deaths in the European Union – latest data (ETSC): https://etsc.eu/euroadsafetydata/
- **DER_10 –** Walking and Cycling Data (ETSC): https://etsc.eu/walking-and-cycling-data/

Complementary

- Causes of Death (Our World in Data): https://ourworldindata.org/causes-of-death
- Road safety indicators based on roadside observations – Baseline project: https://www.baseline.vias.be

Teaching -learning activities

Principal target

- Citizenship and Mathematics classes + Science clubs. Other teachers may be involved in the enactment of the scenario (e.g, English, Arts, Informatics) as it aims to be interdisciplinary and innovative.
- 7th to 9th grade (12-15 years old students)

Number of sessions/classes

4-6 sessions/classes of 40-45 minutes; classroom with computers with internet access is needed.

Lesson 1- Concept of public health, main public health problems in the world, road traffic crashes as a major issue.

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The teacher raises the questions "What is public health about?" and "What are the main public health problems we face nowadays?". Students are challenged to work in groups to answer both questions (3-4 students). Each group writes a definition of public health (and/or attributes of public health) and identifies 3 main public health problems. Each group presents their ideas on the board. After debating the students' answers, the teacher presents definitions of public health, the main causes of death worldwide and in the country (**DER_1 and DER_3**): Top ten causes of death worldwide (WHO) - https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death).

Then the groups explore the WHO website "Leading causes of death" (**DER_4**) to find if road injuries are one of the top 10 causes in the country, by age group, and by sex (focus on the age group of the students: 10-14 and 15-19 years old).

After finishing this task, the results are discussed with the class: are road traffic injuries one of the 10 causes of death in our country? In which age groups? In our (students) age group?

Evaluation: informal assessment of the students' contributions.

Lesson 2 - Road safety indicators based on road crash statistics, international and national level

The teacher starts the lesson by recalling road traffic crashes as a major public health issue and connecting it with sustainable development, particularly SDG 3, target 3.6. Students capture differences between countries by exploring World Bank dashboard (World Bank SDGs Dashboard: Track, Monitor and Report Data on Global Goals). Then the teacher organizes debate and promotes a brainstorming around the questions "What are the major consequences of road traffic crashes?" and "How to measure and monitor the problem?". After the discussion, the definitions and examples of disease burden measures (mortality, mortality rate, number of injuries, QALY and DALY) are presented and explained (**DER_2**). The importance of easy accessibility for people with disabilities is discussed. Following the presentation, the teacher presents examples connected with road safety:

- **DLO_3 -** Death on the Roads (WHO): https://extranet.who.int/roadsafety/death-on-the-roads/ (mortality worldwide – overall and by road user; mortality and mortality rates in the country);
- **DER_5 -**Top 10 global causes of disability-adjusted life years (DALYs) in the world: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates (road injuries are one of the 10 global causes of DALYs in 2019);
- **DER_6 -** Top 10 global causes of disability-adjusted life years (DALYs) by country, sex and age group: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/global-health-estimates-leading-causes-of-dalys (show the DALYs in the country. Focus on the DALYs of the age group of the students: 10-14 and 15-19 years).

Students are organized in groups (3-4 students) and are challenged to search online (sources below) the statistics of road crashes in the country to answer the questions: "What is the mortality rate from road traffic accidents in our country (overall, car users, cyclists, motorcyclists, and pedestrians)?", "Is the problem of road traffic crashes in our country getting better or worse?", "How is the performance of our country in comparison with other countries of the world/region?", "What is the distribution of road deaths by road user/transport mode in our country?".

Each group must write the answers to the questions with reference to the statistics that support their answers.

Sources:

- **DLO_3 -** Death on the Roads (WHO): https://extranet.who.int/roadsafety/death-on-the-roads/
- **DER_7 -** Road traffic mortality (WHO): https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/road-traffic-mortality
- **DLO_4 -** Roads kill (Pulitzer center): https://roadskillmap.com

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- **DER_8 -** Road safety statistics (European Commission): https://ec.europa.eu/transport/road_safety/specialist/statistics/map-viewer/
- **DER_9 -** Road deaths in the European Union – latest data (ETSC): https://etsc.eu/euroadsafetydata/
- **DER_10 -** Walking and Cycling Data (ETSC): https://etsc.eu/walking-and-cycling-data/

After the task is completed, one of the students of each group presents the results to the class. The results are discussed in the class.

Evaluation: informal assessment of the students' contributions in the debates. Written assignment produced during the work group.

Lesson 3 - Risk behaviours in traffic

The teacher starts lesson by promoting a brainstorming with the question "Why so many road crashes happen?". After discussion in the class, the teacher concludes that the main cause of road crashes are risky behaviours in traffic. Students are challenged to identify the main risky patterns of behaviour in traffic for the different road users (car drivers, car passengers, pedestrians, cyclists, and motorcyclists/moped riders).

After the discussion in the class, students are challenged to explore the crash simulators (**DLO_1**).

After the exploration of the crash simulators, the students are organized in groups (3-4 students) and are challenged to explain how the velocity, the friction, the distances, and the reaction time are related to the risk of a crash on the road. One of the students of each group presents the results to the class. The results are discussed in the class.

Evaluation: informal assessment of the students' contributions in the debates. Formal assignment – short quiz with questions related to influence of velocity, friction, distances, and the reaction time on the risk of crash on the road.

Lesson 4/5 – roadside observation survey, statistical concepts, tools for data collection

The teacher starts the lesson by recalling the previous lesson (risky behaviours in traffic). A brainstorming is promoted based on the questions "How can we "measure" the risky behaviours in traffic?" and "how to estimate the percentage of people that engage in these behaviours?".

After the discussion, the teacher uses the **DLO_2** (road safety indicators based on roadside observations) to present the students the School Research Project (described below) and explain what a roadside observation survey is:

- the steps of a roadside observation survey.
- definitions and examples of population, sample, sample size, and associated margin of error.
- examples of instruments for data collection: record sheets or online forms (if possible, online forms should be used – e.g.: Google Forms, Microsoft Forms, …).
- build a dataset for the example of the cyclists (use of the helmet) using a spreadsheet (Microsoft excel, Google sheets, or other) and explains the functions needed for calculating the road safety indicators based on roadside observations (percentage of cyclists who do not wear the helmet while cycling);
- discuss the limitations of scientific evidence obtained with the roadside observation survey.

After exploring the examples and definitions, students are organized in groups (4-5 students). Each group must choose a road safety indicator (for pedestrians, cyclists, car drivers, car passengers, motorcyclists/moped riders) and carry out the following tasks:

- *First task*: define a population, a sample, the sample size, and the associated margin of error. Explain how the margin of error is related to the sample size.

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- *Second task*: build a dataset using a spreadsheet (Microsoft excel, Google sheets, or other), enter fictitious data into the dataset, calculate the road safety indicator and the error associated.
- *Third task*: build an app (online form with Microsoft forms, Google forms, or other) for data collection of observed behaviours for the same road safety indicator.

Evaluation: tasks produced by the groups.

Lesson 6 - forward

After these lessons, the students are challenged to build road safety indicators at the community level trough roadside observations (observed behaviours). This is the **School Research Project** described below, in autonomous section. The previous lessons work as the engaging stage for the development of the project.

Supplementary learning resources and educational activities

During lesson 6 or in the sessions devoted to the development of the research project is desirable to organize:

1. **Meetings** (teleconference) with road safety experts, policy makers, public health authorities, officers of the municipality working on road safety, data scientists, researchers of PAFSE consortium, among others.
2. **Visits to research centers** – examples in Lisbon: Portuguese Road Safety Association (PRP), National Laboratory for Civil Engineering (LNEC).
3. **Competition** and reward of best outcome (poster/infographic).

School Research Project

Topics

- Plan, design, and carry out a roadside observation survey.
- Data collection to calculate road safety indicators in the community based on roadside observations (observed behaviours).
- Recommendations to improve road safety in the community.

Challenge

Plan, design and carry out a roadside observation survey to characterize performance on road safety indicators in the scholar community

Research management, design and administration

Goal: calculate road safety indicators through roadside observations (observed behaviours) for risky behaviours as a pedestrian, cyclist, motorcyclists/moped rider, car passengers, and/or car driver. Build a poster/infographic with the main findings, present the results to the community, aware for risky behaviours in traffic, and propose measures to improve road safety in the community.

NOTE: the teacher is free to decide the topics (pedestrian, cyclist, motorcyclists/moped rider, car passengers, and/or car driver), depending on the dynamics of the community (e.g. if the bicycle it is not a common transport mode in the community, the topic "cyclist" should not be included).

Development process:

The project is based on guided research to aware for risky behaviours in traffic. To address this challenge, students are asked to measure risky behaviors in traffic in the community through roadside observations. Students can draw their first ideas from the topics discussed in the classroom in this scenario and the supplementary educational activities, mainly the **DLO_2** (road safety indicators based on roadside

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observations), which includes all the information needed for the different phases of the project development.

During the learning process:

- Students will be able to carry out a roadside observation survey in the community.
- Students will be able to aware for risky behaviours in traffic and to propose policy measures to increase the road safety in the community.

Teaching-learning process milestones:

1. Students will be able to incorporate evidence in their poster/infographic coming from a roadside observation survey to support their ideas and show media literacy.
2. Students will be able to identify and communicate evidence-based policy measures to help promoting road safety in the school and community settings.
3. Students will be able to suggest and advocate for actions by different stakeholders, though scientific-based data and information.

Teaching-learning process for school project (summary):

1. Planning: define the topics to include in the project (pedestrian, cyclist, motorcyclists/moped rider, car passengers, and/or car drivers); build the instruments for data collection with the selected indicators; define the observation places, the sample size, and other details of the data collection process.
2. Data collection: carrying out the roadside observations.
3. Data analysis: organizing the data and calculating the road safety indicators.
4. Produce the posters/infographics with the main findings.
5. Present the poster/infographic in open schooling event.

Organization of the open schooling event:

1. Each project output (poster/infographic) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair).
2. Students will communicate policy measures using science-based argumentation. Students appeal to the action of all in health and safety of the community, providing great understanding that road safety promotion is a responsibility of all.
3. Students, families, school community and relevant local stakeholders attend the event and understand how important is to change behaviours in traffic. They also get high-level understanding on strategies to improve road safety - and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community level).

Data Analysis and Reporting

Poster or infographic with the most important findings of a research project (roadside observation survey) and possible measures to implement in the community to help improving the road safety.

Target Audience for Recommendations

School community and local stakeholders: students, parents, municipalities, healthcare providers, local enterprises.

Public Debate and Recommendations (based on research results)

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Public presentation of the results by students in a community setting and dissemination of evidence-based recommendations via social, community and conventional media.

Parents assessment of the scenario (*research purpose*) - attitudes/beliefs concerned with PAFSE project and scenario enactment:

1. If the scenario is relevant for students learning and for school community.
2. If the scenario positively influenced the behaviours in traffic in family environment.
3. If the scenario was well balanced for the youth and for the adult to help and engage.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: Road traffic crashes – a public health issue

Knowledge	
1. Recognizes road traffic accidents as a leading cause of death and disability. Defines SDG 3 and target 3.6.	**Question 1.1.** According to the World Health Organization, what is the leading cause of death for children and young adults aged 5-29 years worldwide? A) road traffic injuries. B) cancer. C) cardiovascular diseases. **Question 1.2.** How many people died in car accidents each year around the world? A) Approximately 1.3 million people. B) Approximately 3 million people die. C) Approximately 13 thousand people. **Question 1.3**. What is the goal of the Sustainable Develop Goal (SDG) – target 3.6 – defined by the United Nations? A) by 2030, halve the number of global deaths and injuries from road traffic accidents. B) Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks. C) By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.
2. Identifies disease burden indicators in the context of road safety (road safety indicators).	**Question 2.1.** Which of the following indicator should be used to compare the road safety situation between two countries in a given year? A) number of deaths per million people. B) number of accidents. C) number of injured people. **Question 2.2.** In a country with 8,094,807 people, in a given year, 565 people have died in road traffic crashes. What was the mortality rate? A) 69.8 deaths per million people. B) 56.5 deaths per million people. C) 565 deaths per million people. **Question 2.3.** In a roadside observational study, 876 of the 2455 cyclists observed were using the helmet. What was the percentage of cyclists who were using the helmet while cycling? A) 35.7%. B) 87.6%. C) 75.3%.
3. Identifies the main risky behaviours in traffic and explains their relationship with risk of crashing and injury.	**Question 3.1.** Which of the following conditions increases most the risk of a road crash? A) risky behaviour of the road users (drivers, pedestrians). B) unsafe roads. C) unsafe vehicles (cars, motorcycles, bicycles, …). **Question 3.2.** What is the effect of speeding, driving after drinking alcohol, driving when tired, and using the mobile phone while driving, in the reaction time? A) increases the reaction time.

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	B) reduces the reaction time. C) does not affect the reaction time. **Question 3.3.** As a pedestrian, crossing the road when the traffic light is red, crossing the road outside the crosswalk, or using the mobile phone while crossing the road: A) Increases the risk of being run over by a vehicle. B) Decreases the risk of being run over by a vehicle. C) Does not affect the risk of being run over by a vehicle.
4. Knows the steps of the scientific method applied to a roadside observation survey.	**Question 4.1.** Which of the following options shows the steps of the scientific method in a correct order? A) 1º - define the research goal, 2º - collect data, 3º - analyse the data, 4º - draw conclusions. B) 1º - collect data, 2º - analyse the data, 3º - draw conclusions, 4º - define the research goal. C) 1º - define the research goal, 2º - draw conclusions, 3º - collect data, 4º - analyse the data. **Question 4.2.** In a roadside observation survey, the researcher: A) collects data on road users' behaviours. B) collects data on road crashes. C) collects data on road users' opinions. **Question 4.3.** In a roadside observational survey that aims to estimate the percentage of drivers using the mobile phone while driving, the process of data collection must be: A) observe the first driver, record the data, observe the next driver on the road, record the data of second driver, …. B) observe and record the data only of drivers who are using the mobile phone. C) observe the first driver, record the data, observe the next driver who is using the mobile phone, record the data of second driver, ….
5. Defines population, sample, and dataset.	**Question 5.1.** Which of the following sentences is correct in the context of a statistical study? A) a population is the entire group that a researcher wants to study and a sample is a subset of the population from which the data are collected. B) a sample is the entire group that a researcher wants to study and a population is a subset of the sample from which the data are collected. C) none of the above. **Question 5.2.** What is a dataset? A) A collection of data, usually presented in a table where each column represents a particular variable and each row a particular case. B) A collection of data, usually presented in a table where each row represents a particular variable and each column a particular case. C) A collection of data, usually presented in several unrelated tables.
SKILLS	
1. Selects appropriate concepts, data, and evidence to characterize performance on road safety indicators	**Question 1.1.** Which data sources may we use to proper characterize the road safety situation? A) International Institutions such as World Health Organization, European Commission, Word Bank. B) Social media publications from multiple sources. C) Data retrieved by google searches. **Question 1.2.** To find scientific information about road safety I should consult the following sources. A) researchers, scientific publications and national and international experts' institutions. B) friends, journalists, social media. C) google, radio, newspapers.
2. Anticipates the consequences of risky behaviour in traffic.	**Question 2. What level of risk do you perceive in…** 1) low risk... 5) high risk. **2.1.** travel as a car passenger without wearing the seatbelt. **2.2.** as a pedestrian, use the mobile phone while crossing the road. **2.3.** as a pedestrian, cross the road when the pedestrian light is red. **2.4.** as a pedestrian, cross the road outside a crosswalk. **2.5** cycle without a helmet.

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	2.6. not respecting the traffic rules while cycling (e.g., don't stop when the traffic light is red or before the "STOP" sign). **2.7.** use the mobile phone while cycling.
3. Can identify problems and challenges of the community in relation to road safety related issues.	**Question 3.1.** I feel able to identify the main problems my community faces in relation to road safety. 1) definitely false… 5) definitely true. **Question 3.2.** I feel capable of proposing actions that address road safety challenges in my community. 1) definitely true... 5) definitively false.
4. Can adopt safe behaviours in traffic	**Question 4. Choose the option that applies:** 1) definitely true... 5) definitively false. **4.1.** I never use the mobile phone while crossing the road. **4.2.** I never cross the road when the pedestrian light is red. **4.3.** I always use the seat belt while travelling as a passenger in a car. **4.4.** I always use the helmet while cycling. **4.5.** I never use the mobile phone while cycling.
Beliefs, attitudes and behavior	*Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.*
1. Believes that safe behaviour in traffic reduces the risk of road crashes and the severity of its consequences.	**Question 1. Choose the option that applies:** 1) strongly disagree… 5) strongly agree **1.1.** As a pedestrian, using the mobile phone while crossing the road increases the risk of being run over by a vehicle and severe injury. **1.2.** As a pedestrian, crossing the road when the pedestrian light is red increases the risk of being run over by a vehicle and severe injury. **1.3.** As a pedestrian, crossing the road outside a crosswalk increases the risk of being run over by a vehicle and severe injury. **1.4.** Using the seat belt while travelling in a car may save my life in case of a crash. **1.5.** Cycle with a helmet decreases the risk of severe injury in case of a crash. **1.6.** Driving after drinking alcohol increases de risk of a road traffic crash and severe injury. **1.7.** Not respecting the traffic rules while cycling (e.g. don't stop when the traffic light is red or before the "STOP" sign) is dangerous. **1.8.** Driving after drinking alcohol increases de risk of a road traffic crash and severe injury. **1.9.** Speeding on the road with a car or moped/motorcycle is dangerous.
2. Reproves patterns of risky behaviour in traffic.	**Question 2.1.** The adoption of safe behaviours in traffic will ruin my image 1) strongly disagree… 5) strongly agree **Question 2.2.** For me, the adoption of safe behaviours in traffic (e.g.: always use the seat belt, not use the mobile phone while crossing the road, always cross the road in the crosswalk, always wear the helmet while cycling) in the next 3 months, would be: 1) bad... 5) good **Question 2.3.** For me, the adoption of safe behaviours in traffic (e.g.: always use the seat belt, not use the mobile phone while crossing the road, always cross the road in the crosswalk, always wear the helmet while cycling), in the next three months, would be: 1) useless... 5) useful **Question 2.4.** I don't accept patterns of risky behaviours in traffic even when I am with my family and friends. 1) definitely true... 5) definitively false.
3. Adopts safe behaviours in traffic	**Question 3. During the last 30 days, how often have you…?** 1) never… 5) (almost) always **3.1.** travelled as a car passenger without wearing the seatbelt. **3.2.** as a pedestrian, used the mobile phone while crossing the road. **3.3.** as a pedestrian, crossed the road when the pedestrian light was red.

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	3.4. as a pedestrian, crossed the road outside a crosswalk, when there was a crosswalk nearby. **3.5** cycled without a helmet. **3.6.** ignored the traffic rules while cycling (e.g. did not stop when the traffic light was red or before the "STOP" sign). **3.7.** used the mobile phone while cycling.
4. Is committed to communicate and address the problems and challenges of the community in relation to road safety.	**Question 4.1.** I intend to identify the problems of the community in relation to road safety in the next three months. 1) extremely unlikely... 5) extremely likely **Question 4.2.** I intend to address the challenges of the community in relation to road safety in the next three months. 1) extremely unlikely... 5) extremely likely **Question 4.3.** Among the following statements, choose the one that best describes what you currently think. 1) I am not contributing to the road safety of my community, and I also have no intention of doing so. 2) I am not contributing to the road safety of my community, but I have been thinking about the possibility of starting to do so. 3) I am never or rarely have been contributing to the road safety of my community, but soon I will start doing it on a regular basis. 4) I am contributing to the road safety of my community regularly. 5) For more than six months I have always or almost always been contributing to the road safety of my community. 6) For several years now, I have been contributing to the road safety of my community, and I will continue to do so.
5. Attitude towards safe behaviours in traffic	**Question 5.** For me to adopt safe behaviours in traffic is: **5.1**. harmful :_____:_____:_____:_____:_____: beneficial **5.2**. pleasant :_____:_____:_____:_____:_____: unpleasant **5.3**. good :_____:_____:_____:_____:_____: bad **5.4**. worthless :_____:_____:_____:_____:_____: valuable **5.5**. enjoyable :_____:_____:_____:_____:_____: unenjoyable

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12. Specifications for an educational scenario on the topic of " Road traffic crash risk factors"

Main partner responsible: Portuguese Road Safety Association – PRP

Context

Road traffic crashes cause approximately 1.3 million deaths, and 20 to 50 million non-fatal injuries worldwide every year. Injuries caused from these, are the leading cause of death for children and young adults aged 5 to 29 (source: World Health Organization). The scenario supports teachers in exploring with students the factors contributing to outcomes in terms of injury, severity and fatality. The learning activities prepare students to follow a data-driven approach in addressing and mitigating risks, and so contribute to the reduction of burden from road traffic accidents at the community level. The scenario also creates awareness on the Global Goals, namely SDG target 3.6 (halving the number of road deaths by 2030).

Scientific content and its relevance to public health education

To European Commission defined the goal to move to close to zero deaths on the EU roads by 2050 ("Vision Zero") and to halve the number of serious injuries by 2030 from a 2020 baseline. To reach these goals, the European Commission based its road safety policy framework for the decade 2021 to 2030 on the Safe System approach, whose core elements are ensuring safe vehicles, safe infrastructure, safe road use (speed, sober driving, wearing safety belts and helmets) and better post-crash care. The EC also stated that the mindset of "Vision Zero" needs to take hold both among policy makers and in the society (European Commission, 2020). The traffic safety and mobility education play an important role in strengthening and/or changing attitudes and intrinsic motivations towards risk awareness, personal safety and the safety of other road users in order to contribute towards a safety-minded culture. It is considered an essential part of an integrated approach to traffic safety, as education provides the possibility for people to learn how to participate in traffic safely. The aim of traffic safety and mobility education is to positively influence behaviour patterns that result in safer traffic. The transfer of knowledge and gaining an understanding of traffic rules and situations are the basis of traffic safety and mobility education (ETSC, 2020).

The scenario aims to contribute towards a safety-minded culture in traffic. Its content endorses teachers to play a key role in developing knowledge and skills for incorporating road safety as a central topic in their classes and in teaching public health science using high-level methods, high-quality learning objects, and updated evidence. It also challenges them to have a contribution for the community road safety by engaging families in educational activities and reaching the local community with inquiry-based projects and open schooling events leaded by students. The scenario also contributes to increase the interest in STEM (Science, Technology, Engineering, Mathematics) by providing an opportunity to develop a real-world research project in which students will develop and apply knowledge and skills learned in classes. The project also involves data collection, data manipulation, data analysis and communicating/discussing results based in scientific evidence.

Subject: Science classes
Grade: 9th grade (+/- 14-15 years old students)
Title of educational scenario: Road traffic crash risk factors

Estimated duration

6 sessions of 40-45 minutes (lesson 1 – lesson 6)
5-6 sessions of 40-45 minutes for supplementary learning activities and school project (lesson 7 – lesson 12)

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Classroom organization requirements

Students will work alone, in pairs and in groups under the coordination of the teacher.
The classroom should be equipped with:

- Tables
- Internet access
- Computers/tablets/laptops with internet access
- Projector
- Speakers
- Whiteboard or flipchart

Glossary

Content glossary:

Airbags: safety devices installed in vehicles that inflate to protect the driver or passengers in case of a collision.

Blood alcohol concentration (BAC): is the amount of alcohol present in the bloodstream, usually denoted in grams per decilitre (g/dl). A legal BAC limit refers to the maximum amount of alcohol allowed in the bloodstream that is legally acceptable for a driver on the road. In some countries, the law stipulates an equivalent quantity of alcohol in the air breathed out, in order to facilitate detection of drink-driving.

Braking distance: the distance taken to stop once the brakes are applied.

Breathalyser: an instrument that measures the relative quantity of alcohol in the air a person breathes out.

Change in velocity during a collision (ΔV): in crash reconstructions, the change in velocity occurring as a result of an impact – usually at the centre of gravity of the vehicle – is widely used as the measure of the severity of a collision. At substantial speeds, collisions between cars are almost totally inelastic so there is very little rebound. Thus, if a car travelling at 100 km/h strikes a stationary car of the same mass, they will both undergo a change in velocity of 50 km/hr. ΔV is an important measure of the input severity or energy dosage, that relates to the outcome or injury severity. It is therefore a widely used variable in assessing the characteristics of crashes and the benefits of various countermeasures, such as the use of seat-belts and air bags, and changes in speed limits.

Contributing factor: a contributing factor is a logical category into which one or more similar contributing circumstances are classified. For example, the contributing circumstances "condition – under influence of liquor/drug", "violation – over prescribed concentration of alcohol" and "violation – tested for drugs only" are categorised into the contributing factor of "alcohol/drug related".

Countermeasure: An activity or initiative to prevent, neutralize, or correct a specific problem.

CRAAP test: is a test to check the objective reliability of information sources across academic disciplines. CRAAP is an acronym for Currency, Relevance, Authority, Accuracy, and Purpose

Crash: Any accident involving at least one road vehicle in motion on a public road or private road to which the public has right of access, resulting in at least one injured or killed person.

Data-driven: Informed by a systematic review and analysis of quality data sources when making decisions related to planning, target establishment, resource allocation and implementation.

Distracted Driving: Any activity that could divert a person's attention away from the primary task of driving. Includes activities such as texting or talking on a cell phone while driving.

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Distracted/inattentive: where the controller is attributed with the contributing circumstance of "driver – inattention/negligence", "driver distracted – mobile phone" or "violation – driving without due care and attention".

Drink driving: is attributed to the controller of a motor vehicle who had an illegal blood alcohol concentration (BAC) for their licence level, vehicle type or purpose of vehicle use at the time of the crash.

Driving under the influence (DUI) of alcohol, drugs, or a combination of alcohol and drugs: Operating a vehicle while the alcohol and/or drug concentration in the blood or breath, as determined by chemical or other tests, equals or exceeds the level established by the State, or is equivalent to the standard offense, for driving under the influence of alcohol or drugs in the State.

Enforcement: Actions taken to ensure compliance with legislation; traffic enforcement is usually done by the police

Evidence-based: Based on approaches that are proven effective with consistent results when making decisions related to countermeasure strategies and projects.

Excessive speed: driving at a speed higher than the maximum allowed.

Fact-checking: the process of checking that all the facts in a piece of writing, a news article, a speech, etc. are correct.

Fatal injury: According to the Vienna convention, a fatal injury is one that results in death within 30 days of the accident. Most highly motorised countries apply this definition of a traffic accident fatality.

Fatality: Death within 30 days of the road accident; confirmed suicide and natural death are not included.

Fatigue: is a reduction in driving or riding ability as a result of prolonged driving or being tired while driving. It should be noted that prolonged driving/ riding activity is not solely responsible for fatigue. Other factors such as the elapsed time since the person last slept, the time of the day or night, as well as the human circadian rhythm may be involved.

Haddon Matrix: Developed by William Haddon in 1970, the matrix looks at factors related to personal attributes, vector or agent attributes and environmental attributes; before, during and after an injury or death. By utilizing this framework, one can then think about evaluating the relative importance of different factors and design interventions.

Helmet: a protective device worn on the head to prevent injuries in the event of a crash.

Inappropriate speed: driving at too high a speed given the traffic situation, infrastructure, weather conditions, and/or other special circumstances.

Inattention: see without due care and attention.

Mass (of a vehicle): The mass of a body is its weight.

Mean speed of traffic: The mean speed of vehicles passing a measurement point on the road

Passive safety/safety equipment: is any device that automatically provides protection for the occupant of a vehicle, such as safety-belts, motorcycle helmets, child restraints, padded dashboard, bumpers, laminated windshield, head restraints, collapsible steering columns and air bags.

Public health: An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences,

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skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Post-crash response: is a sequence of time-sensitive actions, beginning with activation of the emergency care system, and continuing with care at the scene, care during transport, and facility-based emergency care.

Probability: The long-term frequency of occurrence of an event in repeated trials that have the event as one of the possible outcomes; how likely something is to happen.

Reaction distance: the distance travelled between the presentation of a sensory stimulus and the subsequent behavioural response; the distance travelled from the moment a driver observes a stimulus (e.g. sees a pedestrian or a changing traffic light) until the moment they have decided on their response (but have not yet initiated that response).

Reaction time: the elapsed time between the presentation of a sensory stimulus and the subsequent behavioural response; the time from the moment a driver observes a stimulus (e.g. sees a pedestrian or a changing traffic light) until the moment they have decided on their response (but have not yet initiated that response).

Risk factor: A factor that affects the probability of accident occurrence or the severity of the consequences of an accident.

Road infrastructure: road facilities and equipment, including the network, parking spaces, stopping places, draining system, bridges and footpaths. Roadside furniture: functional objects by the side.

Road safety: are approaches, strategies and measures used to prevent people from being killed or seriously injured in road traffic collisions.

Road safety indicators: Measures that enable to assess and monitor a road traffic system (country, region, …). Includes statistics from road traffic crashes, safety of vehicles and infrastructure, post-crash response, and road users' behaviours.

Road traffic accident: a collision involving at least one vehicle in motion on a public or private road that results in at least one person being injured or killed.

Road traffic crash: a collision or incident that may or may not lead to injury, occurring on a public road and involving at least one moving vehicle.

Road traffic fatality: is a death occurring within 30 days of a road traffic crash.

Road traffic injuries: are fatal or non-fatal injuries incurred as a result of a road traffic crash.

Road user: a person using any part of the road system as a non-motorized or motorized transport user.

Safety performance standards: definitions or specifications for equipment or vehicle performance that provide improved safety. They are produced nationally, regionally, or internationally by a variety of standard-producing organizations.

Seat-belt: vehicle occupant restraint, worn to protect an occupant from injury, ejection or forward movement in the event of a crash or sudden deceleration.

Speed limit: The highest speed permitted by legislation; speed limits are often signposted.

Speed: The distance covered per unit of time; speed is often measured in kilometers per hour.

Speeding: Violations of the speed limit.

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Star rating (vehicle)/ Car assessment programmes: are established at country, regional or global level, to assess safety performance of new cars using a star rating system which ranges from 0 to 5 (5 being the highest level of safety). These programmes are intended to provide consumer information on vehicle safety. Safety ratings are provided for different categories of users, including adult occupant protection, child occupant protection and pedestrian protection.

Stopping distance: the distance travelled between the time when someone decides to stop a vehicle moving, and the time when the vehicle completely stops. The total stopping distance is the sum of the perception-reaction distance and the braking distance.

Sustainable Development Goals (SDGs). Also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The 17 SDGs are integrated—that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability.

Travel speed: The mean speed of a vehicle between points A and B.

Victims: Total of fatalities, seriously injured and slightly injured and injured.

Visual field (field of view): The size of the area a person can see measured horizontally and vertically.

Vulnerable road users: road users most at risk in traffic, such as pedestrians, cyclists and public transport passengers. Children, older people and disabled people may also be included in this category.

Physics Glossary:

Acceleration: The rate at which the velocity of a body change with time, also the rate of change of the rate at which the position of a body changes with time.

Average speed of an object in an interval of time: is the distance travelled by the object divided by the duration of the interval;

Coefficient of kinetic friction: is a dimensionless scalar value which equals the ratio of the force of friction between two bodies and the force pressing them together, either during or at the onset of slipping.

Collision: is any event in which two or more bodies exert forces on each other in a relatively short time.

Deformation: the continuum mechanics transformation of a body from a reference configuration to a current configuration.[1] A configuration is a set containing the positions of all particles of the body.

Forces: Any interaction that, when unopposed, will change the motion of a physical body. A force has both magnitude and direction, making it a vector quantity. The SI unit used to measure force is the newton.

Friction: is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other.

Inertia: The resistance of any physical object to a change in its state of motion or rest, or the tendency of an object to resist any change in its motion.

Instantaneous speed: Instantaneous speed: When the speed of an object is constantly changing, the instantaneous speed is the speed of an object at a particular moment (instant) in time.

Kinetic energy: The energy that a physical body possesses due to its motion, defined as the work needed to accelerate a body of a given mass from rest to its stated velocity. The body continues to maintain this kinetic energy unless its velocity changes.

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Mass: is the quantity of matter in a physical body. It is also a measure of the body's inertia, the resistance to acceleration (change of velocity) when a net force is applied.[1] An object's mass also determines the strength of its gravitational attraction to other bodies.

Motion: is the phenomenon in which an object changes its position with respect to space and time.

Newton's First Law, Inertia law: An object at rest remains at rest unless acted upon by a force. An object in motion remains in motion, and at a constant velocity, unless acted upon by a force

Newton's Second Law, Dynamic law: The acceleration of a body is directly proportional to, and in the same direction as, the net force acting on the body, and inversely proportional to its mass.

Newton's Third Law, Action-Reaction: When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction to that of the first body.

Pressure: The ratio of force to the area over which that force is distributed.

Speed: is the magnitude of the change of its position over time or the magnitude of the change of its position per unit of time.

Velocity: A vector quantity defined as the rate of change of the position of an object with respect to a given frame of reference. Velocity specifies both an object's speed and direction of motion (e.g. 60 kilometres per hour to the north).

Pedagogical glossary

Active Learning: A teaching and learning approach that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work."

Brainstorming: An instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative Learning: An umbrella term that covers many different methods in which students work together to solve aproblem, complete a task, or create a product. Collaborative learning is founded in the concept that learning and knowledge building is social and requires active engagement from students

Critical Thinking: The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

Cross Debate Technique: In this modality, each of the groups must defend a certain thesis, generally contrary to the other groups. The advantage of this technique is that participants need to hear opposing opinions, make them reflect on them and learn to compete in the field of ideas.

Debate Technique: A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Engagement: How a student does or does not feel toward learning and his or her learning environment.

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Group Work: Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Inclusive teaching: A mode of teaching that intentionally designs course content and curricula to engage with students of diverse backgrounds, abilities, and lived experiences. The ultimate goal of inclusive teaching is to create a learning environment where all students feel valued and supported to succeed.

Information: Facts, ideas, concepts and data that have been recorded, analysed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning: By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

Knowledge: a familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

Lifelong learning: A broad concept where education that is flexible, diverse and available at different times and places is pursued throughout life. It takes place at all levels—formal, non-formal and informal—utilizing various modalities such as distance learning and conventional learning.

Pedagogical techniques: Essential resources that the teacher uses to enhance the pedagogical relationship between the students and the teacher in order to ensure learning. Different forms of application to achieve the objectives of a class.

Project based learning: An instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Quiz: A form of student assessment, usually with fewer, less difficult questions than a test, and with less difficulty.

Research: The systematic process that looks to discover, interpret, and revise facts to produce a greater understanding of behaviors, events, and theories. It creates practical applications through theory and law. Research can also be used to describe information collected about a subject, most often associated with the scientific method.

Skill: The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

The 5E Model (engage; explore; explain; elaborate; evaluate): developed in 1987 by the Biological Sciences Curriculum Study, promotes collaborative, active learning in which students work together to solve problems and investigate new concepts by asking questions, observing, analyzing, and drawing conclusions.

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Competences / Learning Goals

Key Competences:
STEM / Personal, social and learning to learn, citizenship

Knowledge
Science concepts:
- The Haddon matrix.
- Task performance (walking, riding, driving)
- Movements and forces
-Distraction

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-Alcohol absorption and elimination by the human body
- Road safety indicators: road crash statistics (number of crashes, deaths, injuries, rates);
- Data-driven science study
-Survey
- Population, sample, and database.

Public health concepts:
- Public health.
- Major public health causes of death and disability.
- Contributing factors for road traffic crashes.
- Risk factors in traffic: speeding, driving under the influence of alcohol/drugs, fatigue, distraction, Safety equipment.
- Road safety countermeasures.
- Road safety – performance and indicators.
- Burden of road traffic accidents.

Social concepts and global concerns:
- Road safety, urbanisation trends.
- Sustainable Development Goal (SDG).

Knowledge - outcome assessment:
1. Recognizes that road traffic crashes are a leading cause of premature death and pose a significant economic and societal burden.
2. Recognizes major contributing factors for road traffic injury.
3. Identifies which and how road system elements can contribute to reduce road crashes and the severity of its consequences.
4. Explains how different risk factors influence task performance and increase the probability of an accident.
5. Knows the steps of a data-driven science study. Define population and sample.

Skills (abilities/competences):
General: critical thinking; curiosity; problem-based learning; teamwork; collaboration; argumentation; self-awareness; citizenship; public speaking and active debate/ participation.

Specific:

- Finding, analyzing, and interpreting scientific data, texts and dynamic graphical representations to characterize road crashes and contributing factors.
- Identifying and understanding the multifactorial nature of the causes and risk factors of road traffic crashes.
- Understanding the relevance of data and scientific evidence to explain phenomena related to road crashes.
- Collecting and organizing data and choosing appropriate instruments to present the results (e.g., tables, graphs, infographics).
- Obtaining, assessing, and communicating evidence related to road crashes risk factors.
- Mapping sources of risk, the dynamics between factors, behaviour, and outcomes in terms of road traffic injury.
- Analyzing personal and community risks, and patterns of risky and protective behaviour.
- Describing appropriate strategies to reduce personal and community risk and getting access to the relevant resources.

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Skills – outcome assessment:

1. Selects appropriate data sources and indicators to characterize road traffic injuries at different levels (international/national/local).
2. Can anticipates the consequences of inappropriate behaviours in traffic.
3. Rejects unsafe behaviours in traffic.
4. Can propose concrete action towards adopting safe behaviours in his/her routine.
5. Be able to influence others towards the adoption of safe behaviours and removes or mitigates sources of risk.
6. Can identify problems and challenges of the community in relation to road safety.
7. Can identify the type of countermeasures which increase the level of security at the school, community, and societal level.
8. Is able to carry out a data-driven science study.

Affective /Attitudes/ Behaviour (*beliefs)*

- Believing that human behaviour influences the risk of road crashes and the severity of the outcomes.
- Adopting general risk perception attitudes related to road crashes risk factors.
- Reproving patterns of risky behaviours in traffic.
- Influencing peers to adopt safe attitudes and behaviour.
- Adopting safe attitudes towards minimizing risks in traffic.
- Adopting a safe behaviour in traffic as a pedestrian, rider, driver or passenger.
- Creating community awareness on the global sources of risk based on the Haddon Matrix (host-agent-environment).

Affective, Attitudes and behaviour - outcome assessment:

1. Believes that road traffic injuries are preventable because the risk of crash is largely predictable.
2. Believes that the attitudes and behaviours of humans largely impact road safety.
3. Believes that individual choices impact themselves and others' safety.
4. Reproves patterns of risky behaviour in traffic.
5. Actively avoids exposure to risk factors.
6. Is committed to reduce the health and societal burdens of road traffic accidents.
7. Engages public speaking and debating of measures to reduce sources of risk connected with the host (human), agent (vehicles and equipment) and environment.

Learning goals and outcomes

- Characterizes health and societal burden of road traffic injuries.
- Identifies the main sources of risk and patterns of risky behaviour in traffic.
- Analyses the consequences of safe and unsafe behaviours in traffic.
- Identifies and deconstructs beliefs and myths associated to each crash risk factor through evidence-based thinking.
- Plans and executes a data science research project to assess performance on road safety indicators and communicates the results.
- Uses statistical evidence to propose measures that improve road safety at the community level.
- Identifies sources of risk in the school community.
- Obtains, evaluates, and communicates data and scientific information about road traffic crash risk factors.

Assessment methods

✓ Outcome assessment:

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- Quantitative – questionnaire in paper.
- Qualitative - students project.

✓ Process assessment - assessment of the teaching-learning sequence – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

- **STEM content**

The Haddon Matrix (risk factors of road traffic injuries).

20. Road traffic crash risk factors - physics:
    - Newton's First Law, Inertia law
    - Newton's Second Law, Dynamic law
    - Newton's Third Law, Action-Reaction
    - Speed
    - Inertia
    - Mass
    - Forces
    - Movement
    - Friction
    - Velocity
    - Acceleration
    - Deformation
    - Coefficient of kinetic friction
    - Collision
    - Pressure
    - Kinetic energy
    - Energy Dissipation

3. DUI - Driving under the influence:
    - Absorption of alcohol/drugs and medicines by the human body
    - Elimination of alcohol/drugs and medicines in the human body
    - Widmark formula (how BAC level is calculated)
    - Distraction (use of mobile phone):
    - Distraction (attention; Selective attention vs divided attention)
    - Types of distraction (cognitive, visual, manual, auditory)

Digital learning objects (DLO)
New (*developed by the project team*):

1. New DLO Stop distance (simulator)
2. New DLO – Run-over (Simulator)
3. New DLO – Speed (Quiz: True/False)
4. New DLO Forces calculator (excel sheet)

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5. New DLO – Crash force (simulator)
6. New DLO –Safety equipment - Myths and Beliefs (Quiz: True/False)
7. New DLO - BAC (simulator)
8. New DLO – risk of accident and effects of alcohol on the human body (interactive infographic)
9. New DLO New - Alcohol - Myths and Beliefs (Quiz: True/False)

Digital Educational Resources (DER)

1. New DER - Road crashes, the health and societal burden (infographic)
2. New DER – CAART – checking technique (infographic)
3. New DER Haddon Matrix (image)
4. New DER - Task performance in traffic (image)
5. New DER - Speed (infographic)
6. New DER – Field of view
7. New DER – Field of view, speed impact (interactive infographic)
8. DER – Old and new car crash test (video) https://www.youtube.com/watch?v=C_r5UJrxcck
9. DER – Crash test without seatbelt and with seatbelt (video) https://youtu.be/hNw1-OPwiKs
10. New DER – How many collisions do you think that happen in a crash accident? (image)
11. DER – Airbag Crash test (video) How do airbags work? - YouTube
12. New DER - collision interval time and pressure (image).
13. New DER – Attention game (image - calculation sequence + text - with a story + grid – accounting of errors and questions)
14. New DER –Distraction (infographic)
15. New DER – Fatigue (table)
16. New DER – Alcohol absorption and elimination (image of human body organs involved in alcohol absorption and elimination process)

Available resources (link) :
Road Traffic Crash Risk Factors Scenario - Google Drive

From other sources (only a few of these will be selected for the final scenario):

1. DER – Old and new car crash test (video) https://www.youtube.com/watch?v=C_r5UJrxcck
2. DER – Crash test without seatbelt and with seatbelt (video) https://youtu.be/hNw1-OPwiKs
3. DER – Airbag Crash test (video) How do airbags work? - YouTube

Complementary

Road Crashes:

Leading causes of death in the world

- Top ten causes of death worldwide (WHO): https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death; https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death
- Causes of Death (Our World in Data): https://ourworldindata.org/causes-of-death

Road safety statistics in the World/Europe/Countries

- Death on the Roads (WHO): https://extranet.who.int/roadsafety/death-on-the-roads/
- Road traffic mortality (WHO): https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/road-traffic-mortality

Road safety indicators based on survey data

- E-Survey of Road Users' Attitudes: Website; link to dashboard

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

The Global status report on road safety 2018*, launched by WHO in December 2018*
Global status report on road safety 2018 (who.int)
https://www.eltis.org/in-brief/news/new-ec-thematic-reports-and-facts-and-figures-road-safety-issues
Publications | ETSC

Road Traffic Crashes Risk Factors:
https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries (road traffic injuries; risk factors)
https://www.roadsafety-dss.eu/#/risk-factor-search (risk factors)
https://ec.europa.eu/transport/road_safety/statistics-and-analysis/data-and-analysis/thematic-reports_en (thematic reports - speed, alcohol, fatigue, …)
https://prp.pt/prevencao-rodoviaria/

Speed:
https://etsc.eu/reducing-speeding-in-europe-pin-flash-36/
Speed and Crash Risk | ITF (itf-oecd.org)
Managing speed (who.int)
https://ec.europa.eu/transport/road_safety/statistics-and-analysis/data-and-analysis/thematic-reports_en

Safety equipment's (Non- use of Seatbelt, Helmets, Headrest, Vehicle):
https://www.euroncap.com/en/vehicle-safety/the-ratings-explained/adult-occupant-protection/ (ratings explained)
https://etsc.eu/position-paper-vehicle-roadworthiness-package-implementation-reports/

Distraction (use of mobile phone):
https://www.swov.nl/en/publication/distraction-traffic-increasing-risk-factor
Publications | ETSC
https://ec.europa.eu/transport/road_safety/statistics-and-analysis/data-and-analysis/thematic-reports_en

Fatigue:
https://www.swov.nl/en/facts-figures/factsheet/fatigue

DUI - Driving under the influence (Alcohol/drugs):
https://www.labxchange.org/library/items/lb:LabXchange:31f6c5bb:video:1
https://etsc.eu/7-smart-ways-of-tackling-drink-driving-in-europe/
https://ec.europa.eu/transport/road_safety/statistics-and-analysis/data-and-analysis/thematic-reports_en

Other risk factors (the Handon Matrix):
Table 3.2, Risk Factors of Road Traffic Injuries: The Haddon Matrix - Injury Prevention and Environmental Health - NCBI Bookshelf (nih.gov)

Fact-checking
- The CRAAP Test - Evaluating Sources - Research Guides at Benedictine University Library
- https://southcentral.edu/webdocs/library/CRAAP%20Test%20Worksheet.pdf

Teaching -learning activities

Science classes – 9th grade – 4-6 sessions of 40-45 minutes
Science classes
9th grade (+/- 15 years old students)

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6 sessions/classes with the duration of 40-45 minutes
Science teachers integrate other colleagues in the enactment of the scenario (e.g., physics, chemistry, ICT, mathematics, citizenship and English teachers), as it aims to be interdisciplinary.

<u>Lesson 1 - Road crashes a public health problem</u>
Teacher divides the class into groups of students and each group works on one of the following topics:

- Road accidents as a public health issue (Why Road accidents are a public health issue?)
- Crash contributing risk factors (What are the major contributing factors for road crashes?)
- Why is it so important to verify factual information, in order to promote the veracity and correctness of reporting?

Then some links will be given to students to search, explore and collect the information about the topics.

Leading causes of death in the world

- Top ten causes of death worldwide (WHO): https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death; https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death
- Causes of Death (Our World in Data): https://ourworldindata.org/causes-of-death

Road Traffic Crashes Risk Factors:
- https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries (road traffic injuries; risk factors
- https://prp.pt/prevencao-rodoviaria/

Fact-checking
- The CRAAP Test - Evaluating Sources - Research Guides at Benedictine University Library
- https://southcentral.edu/webdocs/library/CRAAP%20Test%20Worksheet.pdf

After exploring and search information about the topics students will present their findings to the class and debate around the 3 topics is organised.

The teacher with the support of **New DER - Road crashes, the health and societal burden (infographic)** reinforces the economic and societal burden from road crashes with different sources of data (e.g.: WHO database, EUROSTAT, SDG tracker). Students understand that accidents are a major public health problem, a leading cause of death and disability, addressed by the Global Goals (SDG 3, target 3.6). and capture the major contributing factors for road crashes.
The teacher uses the **New DER – CAART – checking technique (infographic)** to highlight the importance of identifying and looking for trustful sources of information and shows the CAART checking technique.

Teacher launches the following question:

➢ Which elements does the road system comprises?

Teacher presents on the whiteboard an image of 3 empty interrelated circles. Teacher invites students to identify the three elements of the Road system (human factor, vehicles, infrastructure)**.** Then students are invited to assign to each element of the system, the percentage they consider that most contributes to road accidents. After some debate, the teacher will show the right answers and students will conclude that more than 90% of road crashes have human factor involved.

Then teacher launches another question:

➢ How do we reduce the risks of a road crash?

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The teacher will show the following image and invite students to fill this table:

Phases	Factors: Human	Vehicle and equipment	Environment
Precrash			
Crash			
Postcrash			

After debate the teacher will show the Haddon Matrix **New DER Haddon Matrix (image)** and compare student's contributions with the image identifying the right answers, The teacher reinforces that in order to reduce the risks of an accident, theoretically, we must improve the performance of the 3 road system elements.

FIGURE 1.3

The Haddon Matrix

PHASE		FACTORS: HUMAN	VEHICLES AND EQUIPMENT	ENVIRONMENT
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash-protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

WHO report 2004

<u>Lesson 2: Speed - Road Traffic Crash risk factor</u>

- The teacher launches the question: "What tasks does a person perform whilst walking, riding or driving?"

After debate the teacher presents an image **New DER - Task performance in traffic (image)** showing and explaining which tasks a person performs whilst walking, riding or driving (Collect information; Anticipation, Decision, Action) and how the road traffic risk factors previously identified influence task performance. Students understand that all tasks are interdependent and when one is affected, the performance of the following one is also influenced (e.g., if we are distracted by the mobile phone, we miss important information that comes from road environment, we will predict and decide with lack of

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information, which will in turn increase the likelihood of errors and inadequate decisions, also increasing reaction time to stimulus and thus the risk of a road crash).

The students are organized in groups with the purpose of answering the following questions:

- What is speed? What is the difference between average and instantaneous speed? Are speeding and inappropriate speed the same thing?
- What is the role of speed limits and how are speed limits set?

Through a debate each student gives their input whilst the group organizes their main ideas to present to the class.
In parallel, the teacher writes on the board, the main ideas of each group, distributing them to answer each question.

Teacher shows the correct definitions/answers and all reach the following conclusions after debate **New DER - Speed (infographic)**:

- ✓ Definition: speed, average and instantaneous speed, inappropriate speed.
- ✓ Speed limits are presented in km/h and reflect the instantaneous speed.
- ✓ Speed limit selection is a critical indicator determining safe travel speeds for different road types. The speed which is considered safe depends on the road design and its function, traffic volume, the composition of traffic and potential types of conflict amongst road users.
- ✓ Excessive speed: driving at a speed higher than the maximum allowed.
- ✓ Inappropriate speed: driving at too high a speed given the traffic situation, infrastructure, weather conditions, and/or other special circumstances

Teacher presents the **New DLO Stop distance (simulator)**. The simulator allows teacher/students to distinguish, explore and calculate stop distances = (reaction time/distance + breaking distance) at different speeds with different reaction times, different levels of friction (dry, rain, snow) and different distances to an obstacle. The simulator calculates speed at the time of collision and demonstrates the consequences if the driver was not using a seat belt.

- Teacher launches the following question to the same groups: What happens when a vehicle is moving, the driver sees an obstacle and needs to break?

Each student of each group is invited to explore the simulator and makes different simulations using different variables (reaction time, speed, pavement) and take notes of the results. Then among them they compare and discuss the different simulations results and the impact of variables in stop distances, reaction time/distance and breaking distance.

Each group will present their own conclusions and the teacher, supported by the simulator, should reinforce the following concepts:

- The higher the speed the breaking and stopping distance are also much longer
- Small differences in speed can lead to a road crash or run-over since the breaking and stop distance increases.
- The greater the friction, the shorter the braking and stopping distance
- When reaction time increases the reaction distance and stop distance increase as well which can lead to an increase of the risk of accident.
- Safety distance is the distance that allows a driver to stop the vehicle on a free space in front of him, avoiding any collision.

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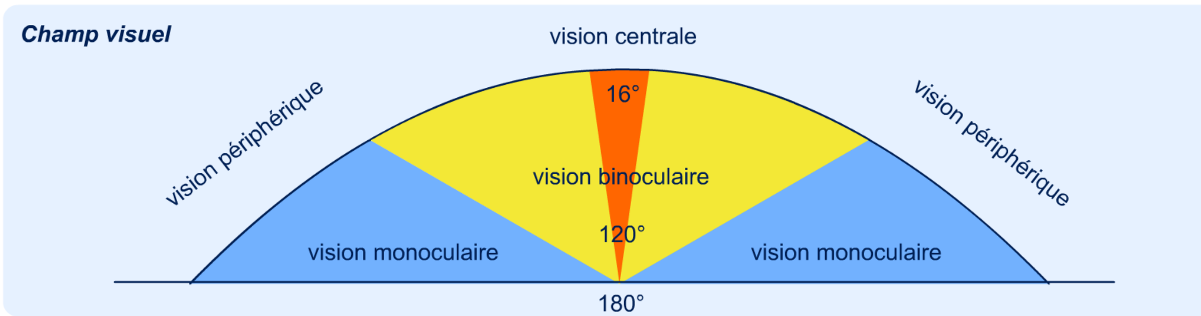
Lesson 3: Speed - Road Traffic Crash risk factor

The teacher launches the following questions and promotes a brainstorming:

- What is the field of view?

Students are invited to share their opinion and then teacher show and ask students to interpretate the following image. **New DER – Field of view**



Together, Teacher and students conclude the field of view is 180‘degrees, that central vision is used to focus on the details and peripheral vision to gather information about the surroundings.

Teacher launches the following questions:

- How is our field of view affected by speed?
- Which factors influence the field of view?

After a debate student's contributions are written in the whiteboard and teacher will invite students to explore the **New DER – Field of view, speed impact (interactive infographic).** This DLO will allow students to simulate the impact of different speeds in the field of view.
Students with the support of teacher should conclude the following:

- As speed increases, the field of view tends to decrease and the focal length increases.
- The drivers' field of view narrows as they drive faster, which means that drivers are less able to estimate potential hazards.
- Vision makes it possible to recognize a wide variety of information: colors, shapes, movements, distances and relief. When the scrolling speed is too high, the cells of our retina do not have time to separate the visual impressions. Our eyes cannot therefore follow and distinguish the details.
- The field of view is affected by many factors. The night reduces the visual field, at the same time as it reduces contrasts, the perception of colors, visual acuity... and it increases glare. Age and fatigue narrow the field of view. Diseases related to the eye or the processing of visual information. Alcohol narrows the field of view and changes the visual information.

The students are organized in groups with the purpose of exploring the **New DLO – Run-over (Simulator)** using different speeds and distances and fill the following table. Students will be asked to analyse the relationship between speed, collision speed and pedestrian probability of death in a run-over situation.

After simulations, students discuss results, reach conclusions and share with other groups the simulation's results.

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Vehicle Speed (km/h)	Impact Speed (Km/h)	Pedestrian - Probability of Death (%)

The teacher launches the debate through the following conclusions:

- The collision severity as a direct relationship with speed. In a high-speed impact, the risk of injury and death is much higher.
- The human body has shock resistance limits and after impact at a certain speed a person does not survive.
- Small excesses of speed in urban areas have major consequences for pedestrians, increasing the probability of death and injury.

To consolidate knowledge and deconstruct myths and beliefs associated to speed, students will be invited to answer the quiz **New DLO – Speed (Quiz: True/False)** Example: The use of a mobile phone during driving task doesn't have an impact on reaction time; The speed limit should decrease if the probability of a conflict with vulnerable users (pedestrians, cyclists, etc.) increases.

Lesson 4 - Safety equipment - Road Traffic Crash risk factor

The teacher launches the following questions and promotes a brainstorming:

- ➢ What kind of safety equipment do you know?
- ➢ Why is safety equipment so important when a road crash happens?

After brainstorming teacher shows the following video to students **DER – Old and new car crash test (video)** https://www.youtube.com/watch?v=C_r5UJrxcck (Road crash test between a new and old vehicle where differences in consequences for drivers are considerable)

Then students watch the video and the teacher launches a debate around the reasons beyond the differences in terms of consequences in both cars and passengers. During the debate importance of safety equipment such as the crumple zones, seat belt, airbag, headrest must be highlighted. Together teacher and students make the link to the following concepts, action-reaction law, kinetic energy, deformation, deceleration, energy dissipation, time interval that the collision lasts. The vehicle safety rating depends on the security systems and teacher shows where they can learn more about vehicles safety ratings https://www.euroncap.com/en

Students are invited to do an exercise to calculate the value of the force that an obstacle exerts on the car, if the time interval that the collision lasts is 1 second or 2 seconds and compare the differences.

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Example: A car with 1200 kg of mass, traveling on a level road at a speed of 90 km/h, collides with an obstacle and comes to a stop.
Students are asked and guided to calculate:
The car speed value before the collision, in SI units (The SI unit of pressure in the international system is the newton per square meter, N/m2 or pascal, Pa.)
Answer: v=25m/s

With the following formula **F = m * (Δv/Δt)** students will calculate the value of the force that the obstacle exerts on the car if the time interval that the collision lasts is:
Δ 1 second = 30000N
Δ 2 second = 15000N

Students conclude that despite increasing the time of collision, the force exerted on the car is smaller. The teacher explains that the existence of zones of deformable material in vehicles, seat belts, airbags, helmets make it possible to increase the collision time interval and, in this way, reduce in the event of a crash, the force exerted by the obstacle on the same vehicle.

The teacher launches the following question and promotes a debate:

- **Why are the seat belt and headrest in cars so important and how they work?**

After debate teacher makes the link with Law of Inertia or Newton's 1st Law and invites students to watch the video **DER – Crash test without seatbelt and with seatbelt (video)** https://youtu.be/hNw1-OPwiKs

Teacher presents and explains how **New DLO – Crash force (simulator)** works. Crash force simulator allows, by selecting variables such as collision speed and person's height, the calculation of the impact force to which a person is subjected in case of collision.
The teacher invites students in pairs, to calculate the impact force to which each of them is subjected in case of a collision at different speeds using their own height.
Teacher highlights the importance and explain that seat-belts reduce the risk of contact with the interior of the vehicle, reduce the severity of injuries if this occurs; distribute the forces of a crash over the strongest parts of the human body; prevent the occupant from being ejected from the vehicle in an impact; prevent injury to other occupants (for example in a frontal crash, unbelted rear-seated passengers can be catapulted forward and hit other occupants). The headrest helps to prevent the type of neck whiplash that leads to the majority of serious neck injuries.
Teacher shows **New DER – How many collisions do you think that happen in a crash accident? (image)** and explains the 3 collisions that occur when a road crash happens (first collision (vehicle/object), second collision (occupant/vehicle interior) and third collision (internal organs of the body hit against the chest wall or the skeletal structure).
Teacher launches the following question:
How do airbags work?

After debate teacher invites students to watch the following video - **DER – Airbag Crash test (video)**
How do airbags work? - YouTube

The teacher introduces and explains the concept of impulse and pressure and explain how safety equipment works (seat belt, airbag and helmet), the importance to reduce the pressure exerted by the forces during the collision. This can be done by increasing the area of surfaces on which the forces act. Seat belts, airbags and helmets reduce the pressure exerted on passengers, as the forces acting during a collision are distributed over a larger area.

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New DER - collision interval time and pressure (image). To conclude teacher shows an image explaining how do seatbelts, helmet and airbags work, and reinforces that:

- seat belts, airbags, helmets make it possible to increase the collision time interval and, in this way, reduce in the event of a crash, the force exerted by the obstacle on the same vehicle.
- Seat belts, airbags and helmets reduce the pressure exerted on passengers, as the forces acting during a collision are distributed over a larger area. Pressure formula **P=F/A**

To consolidate knowledge and deconstruct myths and beliefs associated to safety equipment students are invited to take the quiz. **New DLO –Safety equipment - Myths and Beliefs (Quiz: True/False)**
Example: "*The driver does not need to fasten his seat belt, because in the event of breaking or an accident he can hold on to the steering wheel and resist the collision.*"

Lesson 5: Distraction and Fatigue - Road Traffic Crash risk factor
Distraction

Students are divided in groups of 4 and the teacher will present and explain **New DER – Attention game (image - calculation sequence + text - with a story + grid – accounting of errors and questions)**
Each student has a specific role in the game:

1. Student nº1 reads the calculation sequence (1+5-7/2….)
2. Student nº2 - reads the text while student nº1 reads the calculation sequence
3. Student nº3 – is asked to make calculations whilst listening to the text and to retain as much information as possible.
4. Student nº4 – takes note of errors in calculations and by the end raise questions about the text to student nº3.

Teacher launches the following questions and promotes a debate:

What is attention?

Is it possible to do two things at once?

What happens when people try to do two things at once?

Students are asked about lessons learnt and take their conclusions on the activity. Students understand that it is impossible to do 2 tasks simultaneously, keeping high levels of performance and when two tasks compete with each other some information is missed, and errors occur. The link with the use of mobile phone whilst walking, riding or driving must be done.
After a discussion, the teacher with the support of **New DER –Distraction (infographic)** should give the definition and explore the concepts of:

- What is attention?
- Selective attention vs divided attention.
- What are the consequences when people try to walk, ride or drive whilst using their mobile phone making the link with Attention game?
- Types of distraction - Cognitive (divided attention, more errors); Visual (miss information); Manual (impact on driving performance, ex. swerve more); Auditory (not listening to emergency signs or a horn)

Fatigue

The teacher shares with students that fatigue whilst driving is estimated to contribute to around 10-20% of traffic accidents in the European Union.

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The teacher designs a table with 4 columns on the whiteboard or flipchart and students are asked and by the teacher to fill in the 4 columns answering the following questions:

- What are the causes, effects, symptoms of fatigue?
- Which groups are most at risk?

Fatigue			
Causes	**Symptoms**	**Effects**	**Risk groups**

After some discussion, the teacher presents or adds the missing elements in each column using **DER – Fatigue (table)**

Fatigue			
Causes	**Symptoms**	**Effects**	**Risk groups**
Lack of sleep or poor sleep • Internal body clock (circadian rhythm) • Time-on-task (long working hours) • Monotonous tasks (lack of stimulation) • Individual characteristics including medical conditions	Frequent yawns Staring at a single point on the road Numb legs (cramps), back pain and muscle pain Somnolence Blinking frequently/eye stinging and heavy eyelids Irritation and bad mood restlessness	Deterioration of driving performance: slower reaction time, diminished steering performance, lesser ability to keep distance to the car in front, and increased tendency to mentally withdraw from the driving task	Young drivers, Professional and truck drivers, Shift workers and Drivers with sleep-breathing disorders.

By the end, the teacher highlights that the only way to solve fatigue is by sleeping.

Lesson 6: DUI - Driving under the influence (Alcohol) - Road Crash Risk Factors

DUI (driving under the influence of alcohol) impact on road crashes

Teacher launches to the classroom the following questions:

- What is the presence of alcohol in the body?
- How can bac level be calculated?

After debate teacher and students must conclude the presence of alcohol in the body is calculated through the blood alcohol concentration (B.A.C.) that is usually expressed in grams of alcohol per litre of blood (g/l). The quantification of the level of alcohol in the blood is carried out by a test on the expired air, carried out in a quantitative analyzer or by blood analysis. A Breathalyzer is an instrument intended to measure the mass concentration of alcohol per unit volume in expired alveolar air.

Teacher invites students to explore the **New DLO - BAC (simulator)**. The BAC simulator allows to calculate BAC levels by doing simulations with different types and amounts of beverages and using different variables that influence alcohol absorption and elimination in the human body such as gender, weight, meal. The simulator will be developed based on the 'Widmark formula'. The Widmark formula provides only an approximate indicator of the TAS (ERSO, 2006).

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Teacher invites students to use the simulator and calculate BAC levels using their own data, gender, height, and try different simulations with different amounts of alcohol consumption, different beverages, with and without a meal.

Teacher should promote a debate about what the blood alcohol level depends on, such as number of beverages, type of drink, weight, gender, type of ingestion, presence/absence of food, individual drinking habits and why the variables interfere with BAC level.

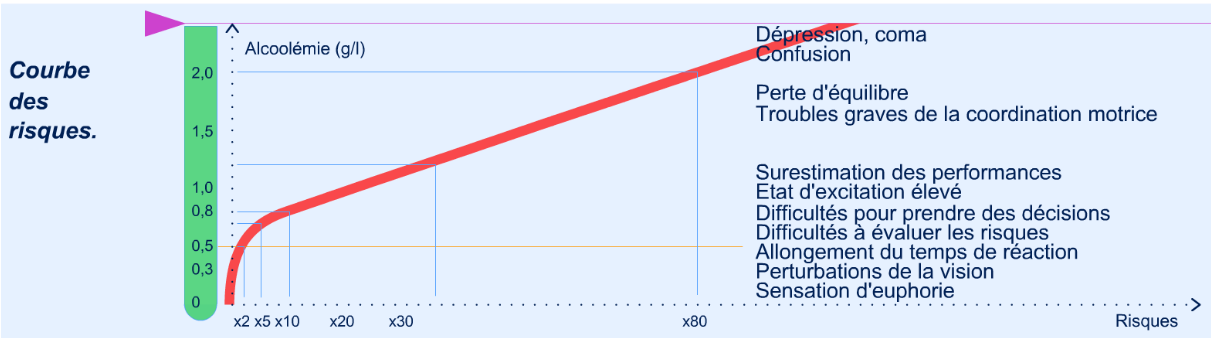
Teacher divides the class into groups.

- Some groups will be invited to answer the questions “How alcohol is absorbed by the human body? What factors influence the rate of absorption of alcohol?
- Others groups will be invited to answer the questions “How alcohol is eliminated by the human body?” What factors influence the rate of elimination of alcohol? Can we intervene in the alcohol elimination process?
-

After debating these topics, the teacher with the support of **New DER – Alcohol absorption and elimination (image of human body organs involved in alcohol absorption and elimination process)** consolidates the following concepts:

- ✓ how alcohol is absorbed by the mucous membranes of the mouth and oesophagus, the stomach and large intestine and by the proximal portion of the small intestine - absorption takes between 15-20 minutes, and there are factors that can change the speed of absorption;
- ✓ how alcohol is eliminated through sweat, urine, saliva and breath. The rest (90% to 98%) is metabolized by the liver to acetaldehyde.
- ✓ The liver metabolizes concentrated ethanol in the blood at an average of 0.1g/l per hour. It's a very slow process. Some studies show that women have lower amounts of the enzyme alcohol dehydrogenase (ALDH) than men (Pedrosa, 2013).

Teacher invites students to explore the **New DLO – risk of accident and effects of alcohol on the human body (interactive infographic)**



They should conclude that risk of accident increases with the increase of BAC level.

Teacher together with students makes the relationship with task performance phases:

- ✓ Collect information: decreased psycho-sensory abilities; poor collection of information; stimulus detection.
- ✓ Anticipation: difficulty in data processing.
- ✓ Decision: difficulties in deciding what to do; bad decisions.

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✓ Action: longer reaction time; incoordination and suddenness of movements, disturbance of psychomotor abilities.

Teacher should also highlight that drug also deteriorate considerably the task performance while walking, riding or driving.

To consolidate knowledge and deconstruct myths and beliefs associated to alcohol, students will be invited carry out a quiz **New DLO - Alcohol - Myths and Beliefs (Quiz: True/False).** Example: Food lessens the effects of alcohol; There are substances that accelerate the elimination of alcohol.

For further information students are invited to watch the following video

https://etsc.eu/issues/drink-driving/blood-alcohol-content-bac-drink-driving-limits-across-europe/

Supplementary learning resources and educational activities

During the sessions devoted to the development of the research project is organized:
1. **Teleconference with STEM professionals** (e.g., road safety experts, engineers, medical experts, policy makers, public health authorities, officers of the municipality working on traffic management, data scientists or technology developers, researchers of PAFSE consortium).
   Students question experts with a particular focus on: a) future academic choices and career paths; b) identifications of countermeasures to tackle road crashes contributing factors and how to increase safety levels in the local community.
2. **Visits to research centres** (face to face or virtual) – examples in Lisbon: Road Safety National Authority, National Laboratory for Civil Engineering (LNEC), General Directorate for Intervention on Addictive Behaviours and Dependencies (SICAD), Wingdriver
3. **Competition** and reward of best outcome (poster/infographic).

School Research Project

Challenge: plan, design and carry out a data science research project to characterize road safety in the school community

Goal: Analyze self-declared road safety indicators through a survey for risky behaviours concerning road traffic crash risk factors (speed, safety equipment; distraction, fatigue, alcohol, drugs) among school community.

Development process:
The project is based on guided research on road traffic crash risk factors and data obtained through a questionnaire. To address this challenge, students can draw their first ideas about topics to explore from the lessons discussed in the classroom in this scenario and the supplementary educational activities. After understanding the importance of adopting safe behaviours in traffic, students will be invited to brainstorm about how they can contribute to improving road safety levels in the school community and what steps they should follow. With the teacher’s support students will conclude that to improve road safety and identify specific road safety countermeasures, they first need to identify and understand the problem.

Students will be invited to explore and identify what are the phases of a research process. They will present and debate their findings and teacher will compare student´s contributions with the **New DLO (Step by step Road traffic Crash risk factors survey)**, which includes all the information needed for the different phases of the project development:

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- ✓ the steps of building a survey.
- ✓ definitions and examples of population, sample, sample size, and associated margin of error.
- ✓ examples of surveys: online forms (if possible, online forms should be used – e.g.: Google Forms, Microsoft Forms, …).
- ✓ a survey based on a crash risk factor (helmet) using a spreadsheet (Microsoft excel, Google sheets, or other) and explains the functions needed for calculating performance indicators based on survey data collected (percentage of cyclists who do not wear the helmet while cycling);
- ✓ discuss the limitations of scientific evidence obtained with the survey.

After exploring the examples and definitions, students are organized in groups. Each group must choose a traffic crash risk factor (speed, distraction, safety equipment, alcohol, etc) and carry out the following tasks:

- ✓ *First task:* select questions about opinions, attitudes and behaviours concerning road traffic crash risk factors exploring the following website https://www.esranet.eu/
- ✓ *Second task*: define a population, a sample, the sample size, and the associated margin of error. Explain how the margin of error is related to the sample size.
- ✓ *Third task*: build a database using a spreadsheet (Microsoft excel, Google sheets, or other), enter fictitious data into the database, calculate the road safety indicator and the error associated.
- ✓ *Fourth task*: build an app (online form with Microsoft forms, Google forms, or other) for survey data collection

Teacher together with students and supported by the **New DER - Road traffic Crash risk factors survey (pdf)** will complete and close the questionnaire. Teacher should encourage students to include in the questionnaire questions regarding accessibility, disability and equity.
Questions (examples):

- ✓ Over the last 30 days, how often did you, as a car passenger, travel without wearing your seatbelt in the back seat?
- ✓ Over the last 30 days, how often did you, as a cyclist, cycle without a helmet?
- ✓ To what extent do you agree with each of the following statements?
- ✓ I use a mobile phone while driving, because I always want to be available
- ✓ Respecting speed limits is boring or dull.
- ✓ Is the infrastructure around school safe for disable people?

Once the questionnaire is completed, to address opinions, attitudes and behaviours concerning road traffic crash risk factors students and school community are asked to fill the questionnaire.
Based on collected reliable data and real-life cases to propose measures, students will advocate for action that promote safe behaviours in the school community by organizing at school the Road Safety Day where each group will present the research project results by topic through infographics inviting local community, experts, researchers and parents for a broad discussion about how to improve road safety at community level.

During this phase they are invited to explore https://www.roadsafety-dss.eu/#/

"The SafetyCube DSS is the European Road Safety Decision Support System, which has been produced within the European research project SafetyCube, funded within the Horizons 2020 Programme of the European Commission, aiming to support evidence-based policy making. The SafetyCube Decision Support System provides detailed interactive information on a large list of road accident risk factors and related road safety countermeasures."

During the learning process:

1. Students will be able to carry out a data-driven science study through surveying the community.

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2. Students will take awareness and analyze quantitative evidence on risky behaviours in traffic and propose policy measures to increase road safety in the community.

Teaching-learning process milestones:
1. Students will be able to incorporate evidence in their poster/infographic coming from a data-driven science study to support their ideas and show media literacy.
2. Students will be able to identify and communicate evidence-based policy measures to help promote road safety in both school and community settings.
3. Students will be able to suggest and advocate for action by different stakeholders, though scientific-based data and information.

Teaching-learning process for school project (summary):
1. Planning: define topics concerning road traffic crash risk factors to include in the project (speed, safety equipment, distraction, fatigue, alcohol, drugs); build the instruments for data collection with the selected indicators; define population, the sample size, and other details of the data collection process.
2. Data collection: carrying out the survey.
3. Data analysis: organizing the data and calculating road safety indicators.
4. Produce posters/infographics with main findings.
5. Present the poster/infographic in open schooling event.

Organization of the open schooling event:
1. Each project output (poster/infographic) is presented by students in a community setting (e.g., exposition center, municipality, garden, museum, science fair).
2. Students will communicate policy measures using science-based argumentation. Students will appeal to the action of all on behalf of the health and safety of the community, providing great understanding that road safety promotion is a responsibility of all.
3. Students, families, school communities and relevant local stakeholders attend the event and understand how important it is to change behaviour in traffic. They also get high-level understanding on strategies to improve road safety - and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community level).

Data Analysis and Reporting
Report, presentation, poster, or infographic based on science-driven data research.

Target Audience for Recommendations
School community and local stakeholders: students, parents, municipalities, healthcare providers, local enterprises, road safety authorities.

Public Debate and Recommendations (based on research results)
Public presentation of the self-declared road safety indicators by students in a community setting and dissemination of evidence-based recommendations via social, community and conventional media.

Main partner responsible
Portuguese Road Safety Association – PRP

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: Road traffic crash risk factors

Knowledge	
1.Recognizes that road traffic crashes are a leading cause of premature death and pose a significant economic and societal burden.	**Question 1.1.** According to the World Health Organization, what is the leading cause of death for children and young adults aged 5-29 years worldwide? A) road traffic injuries; B) cancer; C) cardiovascular diseases. **Question 1.2.** How many people died in car accidents each year around the world? A) Approximately 1.3 thousand people die each year as a result of road traffic crashes. B) Approximately 3 million people die each year as a result of road traffic crashes. C) Approximately 13 million people die each year as a result of road traffic crashes. **Question 1.3.** How much do road accidents cost? A) Road traffic crashes cost most countries 3% of their gross domestic product B) Road traffic crashes cost most countries 1% of their gross domestic product C) Road traffic crashes cost most countries 0.5% of their gross domestic product
2. Identifies which and how road system elements can contribute to reduce road crashes and the severity of its consequences.	**Question 2.1**. A road system can be intervened to increase road safety. Which elements should be considered? A) Human, environment and vehicle; B) Environment, infrastructure and vehicle; C) Human, vehicle and education. **Question 2.2.** The performance of the 3 road system elements can be improved to reduce the risks of an accident. In which situation? A) Before, during and after the crash; B) During the crash; C) Before the crash.
3. Explains how different risk factors influence task performance and increase the probability of an accident.	**Question 3.1.** A person is walking, riding or driving. Which tasks can be affected by risk factors? A) Collect information, anticipation, decision and action B) Collect information, decision and action C) Collect information, anticipation and action
3. Recognizes major contributing factors for road traffic injury.	**Question 3.1.** Which of the following conditions increase the risk of a road crash most? A) risky behaviour of the road users (drivers, pedestrians); B) unsafe roads; C) unsafe vehicles (cars, motorcycles, bicycles, …). **Question 3.2.** What is the effect of speeding, driving after drinking alcohol, driving when tired, and using the mobile phone while driving, in the reaction time? A) increase the reaction time; B) reduce the reaction time; C) do not affect the reaction time. **Question 3.3.** How is field of view affected by speed? A) As speed increases, the field of view tends to decrease and the focal length increases

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	B) As speed increases, the field of view tends to increase and the focal length decreases; C) do not affect the field of view **Question 3.4.** Seat belts, airbags and helmets create conditions to: A) Increase the collision time interval and reduce the pressure exerted on passengers; B) Reduce the pressure exerted on passengers C) none of the above **Question 3.5.** What kind of distraction is the most dangerous? A) Cognitive B) Visual C) Manual **Question 3.6.** Which of the following sentences is correct? A) the absorption time of alcohol by the human body is much faster than the elimination time B) the absorption time of alcohol by the human body is much slower than the elimination time C) the absorption time of alcohol by the human body is equal than the elimination time
4. Knows the steps of a data-driven science study. Defines population and sample.	**Question 4.1.** Which of the following options shows the steps of a data-driven science study in a correct order? A) 1º - define the research goal, 2º - collect data, 3º - analyse the data, 4º - draw conclusions; B) 1º - collect data, 2º - analyse the data, 3º - draw conclusions, 4º - define the research goal; C) 1º - define the research goal, 2º - draw conclusions, 3º - collect data, 4º - analyse the data. **Question 4.2.** Which of the following sentences is correct in the context of a statistical study? A) a population is the entire group that a researcher wants to study. A sample is a subset of the population from which the data are collected; B) a sample is the entire group that a researcher wants to study. A population is a subset of the sample from which the data are collected; C) none of the above.
SKILLS	
1. Selects appropriate data sources and indicators to characterize road traffic injuries at different levels (international/national/local).	**Question 1.1.** Which data sources may you use to proper characterize the road safety situation? A) International Institutions such as World Health Organization, European Commission, World Bank; B) Social media publications from unreliable sources; C) Data retrieved by google searches. **Question 1.2.** To find scientific information about road safety I should consult the following sources. A) researchers, scientific publications and national and international experts' institutions. B) friends, journalists, social media; C) google, radio, newspapers.

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2. Anticipates the consequences of risky behaviour in traffic.	**2.** What level of risk do you perceive in… 1) low risk... 5) high risk. **Question 2.1.** travel as a car passenger without wearing the seatbelt. **Question 2.2.** as a pedestrian, use the mobile phone while crossing the road. **Question 2.3.** as a pedestrian, cross the road when the pedestrian light is red. **Question 2.4.** as a pedestrian, cross the road outside a crosswalk. **Question 2.5** cycle without a helmet; **Question 2.6.** not respecting the traffic rules while cycling (e.g. don’t stop when the traffic light is red or before the “STOP” sign); **Question 2.7.** use the mobile phone while cycling.
3. Rejects unsafe behaviours in traffic.	**3. Answer scale:** 1) definitely true... 5) definitively false. **Question 3.1.** I will never use the mobile phone while crossing the road. **Question 3.2.** I will never cross the road when the pedestrian light is red. **Question 3.3.** I will always use the seat belt while travelling as a passenger in a car. **Question 3.4.** I will always use the helmet while cycling. **Question 3.5.** I will never use the mobile phone while cycling.
4. Can identify problems and challenges of the community in relation to road safety.	**Question 4.1.** I feel able to identify the main problems my community faces in relation to road safety. 1) definitely false… 5) definitely true. **Question 4.2.** I feel capable of proposing actions that address road safety challenges in my community. 1) definitely true... 5) definitively false.
Beliefs, attitudes and behavior	*Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.*
1. Believes that individual choices impact themselves and others’ safety.	**1. Answer scale:** 1) strongly disagree… 5) strongly agree **Question 1.1.** As a pedestrian, using the mobile phone while crossing the road increases the risk of being run over by a vehicle; **Question 1.2.** As a pedestrian, crossing the road when the pedestrian light is red increases the risk of being run over by a vehicle; **Question 1.3.** As a pedestrian, crossing the road outside a crosswalk increases the risk of being run over by a vehicle; **Question 1.4.** Using the seat belt while travelling in a car may save my life in case of a crash; **Question 1.5.** Cycle with a helmet decreases the risk of serious injuries in case of a crash; **Question 1.6.** Using the mobile phone while cycling is safe; **Question 1.7.** Not respecting the traffic rules while cycling (e.g. don’t stop when the traffic light is red or before the “STOP” sign) is dangerous;

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	Question 1.8. Driving after drinking alcohol increases de risk of a road traffic crash; **Question 1.9.** Speeding on the road with a car or moped/motorcycle is dangerous; **Question 1.10**. As a driver, pedestrian or passenger, my behaviour has no impact on the safety of others
2. Actively avoids exposure to risk factors.	**2. During the last 30 days, how often have you…?** 1) never… 5) (almost) always (*add option "not applicable"*) **Question 2.1.** travelled as a car passenger without wearing the seatbelt. **Question 2.2.** as a pedestrian, used the mobile phone while crossing the road. **Question 2.3.** as a pedestrian, crossed the road when the pedestrian light was red. **Question 2.4.** as a pedestrian, crossed the road outside a crosswalk, when there was a crosswalk nearby. **Question 2.5.** cycled without a helmet; **Question 2.6.** ignored the traffic rules while cycling (e.g. did not stop when the traffic light was red or before the "STOP" sign); **Question 2.7.** used the mobile phone while cycling.
3. Reproves patterns of risky behaviour in traffic.	**Question 3.1.** The adoption of safe behaviours in traffic will ruin my image 1) strongly disagree… 5) strongly agree **Question 3.2.** For me, the adoption of a safe behaviours in traffic (e.g.: always use the seat belt, not use the mobile phone while crossing the road, always cross the road in the crosswalk, always wear the helmet while cycling) in the next 3 months, would be: 1) bad... 5) good **Question 3.3.** For me, to adopt safe behaviours in traffic, in the next three months, would be: 1) useless... 5) useful **Question 3.4.** I don't accept patterns of risky behaviours in traffic even if I'm with my family and friends. 1) definitely true... 5) definitively false.
4. Is committed to reduce the health and societal burden of road traffic accidents.	**Question 4.1.** I intend to identify problems of my community in relation to road safety in the next three months. 1) extremely unlikely... 5) extremely likely **Question 4.2.** I intend to address the challenges of my community in relation to road safety in the next three months. 1) extremely unlikely... 5) extremely likely **Question 4.3.** Among the following statements, choose the one that best describes what you currently think. 1) I am not contributing to the road safety of my community, and I also have no intention of doing so; 2) I am not contributing the road safety of my community, but I have been thinking about the possibility of starting to do so; 3) I am never or rarely have been contributing to the road safety of my community, but soon I will start doing it on a regular basis; 4) I am contributing to the road safety of my community regularly;

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	5) For more than six months I have always or almost always been contributing to the road safety of my community; 6) For several years now, I have been contributing to the road safety of my community, and I will continue to do so.
5. Attitude towards safe behaviours in traffic	**Question 5.** For me to adopt safe behaviours in traffic is: **5.1**. harmful :_____:_____:_____:_____:_____: beneficial **5.2**. pleasant :_____:_____:_____:_____:_____: unpleasant **5.3**. good :_____:_____:_____:_____:_____: bad **5.4**. worthless :_____:_____:_____:_____:_____: valuable **5.5**. enjoyable :_____:_____:_____:_____:_____: unenjoyable

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13. Specifications for an educational scenario on the topic of "3D modelling to address pandemic challenges."

Main partner responsible: INESC-TEC

Context and relevance for public health education

As technology continues to evolve, virtual / augmented reality and 3D models are becoming much more common across all industries, particularly healthcare. 3D modelling is getting a more prominent role in rehabilitation and health, from improving surgical training to creating better treatment plans. Indeed, it is used intensively in the design of assistive technologies, e.g., prosthetics, orthosis, or even simpler tools/materials to aid in specific activities. Also, modelling is the first concept to be learned regarding 3D printing.

The 3D field is transforming how products are designed, produced, and serviced; and there are many benefits to embrace this field, such as improving an effective and efficient patient care, providing a teaching tool for professionals at all stages of their careers, from students to interdisciplinary teams, planning medical and surgical cases, identifying issues, or demonstrating them to healthcare professionals, improving follow up care, among others. So, how we leverage the potential of 3D modelling to drive innovation is a mandatory topic in science/technology curriculum.

The scenario supports 8th grade science and ICT teachers in exploring 3D environments using updated scientific/technical evidence. The learning experience supports youths in understanding and reaching high-level comprehension on how STEM (science, technology, engineering, mathematics) may contribute to address these issues, contributing to evidence-based personal decision-making, and public policy.

Estimated Duration

7 classes of 40-45 minutes (lesson 1 – lesson 7)
4 sessions of 40-45 minutes for supplementary learning activities and school project (session 8 – session 11)

Prerequisite knowledge and skills

Basic ICT notions

Classroom organization requirements

ICT classroom with access to computers.

To carry out the research project, students will work in groups of 4 or 5 elements. It is necessary to have a computer/tablet with internet access.

Content glossary

3D Environment. 3D environment is the generation of realistic computer-controlled digital settings for games, film, architectural renderings, and advertising using specialized computer software.

3D Modelling. 3D modeling is the process of creating a 3D representation of any surface or object by manipulating polygons, edges, and vertices in simulated 3D space. 3D modeling is achieved manually with specialized 3D production software that lets an artist create and deform polygonal surfaces, or by scanning real-world objects into a set of data points used to represent the objects digitally.

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Collaboration. A recognized relationship among different sectors or groups, which have been formed to take action on an issue in a way that is more effective or sustainable than might be achieved by the public health sector acting alone.

Equity/equitable. Equity means fairness. Equity in health means that peoples' needs guide the distribution of opportunities for well-being. Inequities occur as a consequence of differences in opportunity, which result, for example in unequal access to health services, nutritious food or adequate housing. In such cases, inequalities in health status arise as a consequence of inequities in opportunities in life.

Health. A state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.

Multimedia Contents. Multimedia refers to various types of media content, used together. Multimedia content includes text, graphic image files, audio files, video clips.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Rendering Process. 3D rendering is the process of using a computer to generate a 2D image from a digital three-dimensional scene. To generate an image, specific methodologies and special software and hardware are used.

Research. Activities designed to develop or contribute to knowledge, e.g., theories, principles, relationships, or the information on which these are based. Research may be conducted simply by observation and inference, or by using experiment, in which the researcher alters or manipulates conditions in order to observe and study the consequences of doing so.

Virtual Reality. Virtual reality is the use of computer technology to create simulated environments. Virtual reality places the user inside a three-dimensional experience and, instead of viewing a screen in front of them, users are immersed in and interact with 3D worlds by using special equipment.

Pedagogical glossary

Active Learning. A teaching and learning approach that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work".

Brainstorming: An instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Critical Thinking. The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

Collaborative Learning. An umbrella term that covers many different methods in which students work together to solve a problem, complete a task, or create a product. Collaborative learning is founded in the concept that learning and knowledge building is social and requires active engagement from students.

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Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organization, variable handling, data driven conclusion making and communicating over scientific issues.

Knowledge. A familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

Pedagogical Techniques. Essential resources that the teacher uses to enhance the pedagogical relationship between the students and the teacher in order to ensure learning. Different forms of application to achieve the objectives of a class.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Skill. The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

Sources: EuroHealthNet; Lifewire

Indicative literature

- Ami Chopine, "3D Art Essentials: The Fundamentals of 3D Modeling, Texturing, and Animation"
- Bruna de Freitas Escudeiro e Diego Martins De Pinho, "O Básico da Modelagem 3D com o Blender"
- Flávio Andaló, "Modelagem E Animação 2D E 3D Para Jogos", ISBN: 8536512059

Principal target:

Science and ICT classes
8th grade (+/- 14 years old students)
ICT teachers integrate other colleagues in the enactment of the scenario (e.g., ICT, visual education, mathematics and English teachers), as it aims to be interdisciplinary.

Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn

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Knowledge
3D modeling concepts:
- 3D technical principles and workflows.
- Tools for creating 3D models.
- Shortcuts for fast modeling.

Knowledge - outcome assessment:
1. Understands the 3D technical principles and workflows.
2. Recognizes software basic features regarding the interface.
3. Recognizes software basic features regarding shapes.
4. Recognizes software basic features regarding textures and illumination.
5. Recognizes software basic features regarding rendering.
6. Is able to understand the importance of 3D environments to address pandemic challenges and ensure public health.
7. Is able to understand the importance of 3D environments in the health care industry in order to decrease inequality and improve inclusion.

Skills (abilities/competences)
General: Imagination, creativity, 3D basics.
Specific:
- ✓ Designing 3D elements by combining process knowledge, computational design tools, and application requirements.
- ✓ Technical usage of 3D software.

Skills – outcome assessment:
1. Recognizes appropriate proficiencies necessary for 3D modelling.
2. Is able to understand the virtual environment.
3. Can create specific 3D objects and sets.
4. Is able to identify the differences of multiple 3D modelling software.

Affective/Attitudes Behaviour (*beliefs)*
- ✓ Using imagination for designing real tools and materials.
- ✓ Using creativity skills on new technologies in the development process of the solution.

Attitudes and behavior - outcome assessment:
1. Recognizes the importance of raising awareness on how 3D modelling can help the community.
2. Has intention to continue extending the skills and knowledge regarding 3D modelling.
3. Is aware of the democratization of 3D modelling.
4. Has a positive attitude towards 3D modelling.
5. Believes that is important to improve one’s own personal capabilities regarding 3D modelling.

Learning goals and outcomes
- Uses online tools for 3D modelling.
- Analyzes pre-designed models.
- Identifies 3D environments and basic features.
- Designs basic shapes and elements in a 3D environment.
- Exports modeling objects.
- Describes different approaches to create 3D objects for positively influencing global health.
- Gives examples of how 3D models can contribute to improve healthcare environments.

Assessment methods

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- ✓ Outcome assessment
  - Qualitative - project: modeling a given 3D object.
  - Quantitative – questionnaire – impact assessment in terms of students knowledge, skills, attitudes and behaviour

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do / how fun would be to do again / how could it be better").

<u>Content (relevant to learning goals & research topics)</u>

STEM content

- How to use 3D shapes.
- Modelling 3D shapes in digital works. Basic modeling programs.

Non-STEM content

- Brainstorming on 3D approaches and applications in public health.
- Group and public debates.

<u>Digital learning objects</u>

<u>New:</u>

1. 3D modelling software basic features: INTERFACE (video and tutorial).
2. 3D modelling software basic features: SHAPES (video and tutorial).
3. 3D modelling software basic features: TEXTURES and ILLUMINATION (video and tutorial).
4. 3D modelling software basic features: RENDERING (video tutorial).
5. Questionnaire – quantitative assessment of learnings.
6. Template for students to design the infographics

<u>Digital educational resources</u>

<u>New:</u>

1. Introduction of virtual environments (video and PowerPoint).
2. Introduction of 3D modelling and principles (infographic).
3. Benefits of 3D modelling in healthcare environments (infographic).
4. Introduction of 3D modelling for product design in healthcare (infographic).
5. Pedagogical glossary for technical terms and definitions (infographic).

Available resources (link) :
https://drive.google.com/drive/folders/1I6DbhytMuTK1wI0KCeatXOajUd9_ge_y?usp=sharing

<u>Teaching-learning activities</u>

<u>Lesson 1: Introduction of virtual environments</u>

The teaching-learning script starts with a question "what is a virtual environment (V.E.)"?

- ➢ brainstorming on the questions: "what is a virtual environment?" and "how can modelling be a convergence point for STEM?".

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Students are divided into groups and asked to Google key definitions of virtual environments and their impact on STEM. Each group should produce at least three different sentences; read them and select the main keywords for sharing. Then, students are asked to go to the flipchart or whiteboard and write the main keywords selected.
The next step is a video presentation about virtual environments. After, a discussion is mandatory about their previous definitions and keywords and their recent new knowledge about the topic learned.

Lesson 2: The benefits of 3D modelling in healthcare during / after a pandemic event

After a short conversation about the previous lesson, the benefits of 3D modelling in healthcare are presented.

- digital educational resources: benefits of 3D modelling in healthcare environments; introduction of 3D modelling for product design in healthcare.

After the brainstorm on what is a virtual environment, students are provided with infographics on how these environments can contribute positively to the healthcare industry. Examples: in rehabilitation, surgical training, treatment plans, assistive technologies, (prosthetics, orthosis), product design and production, patient care.

- group discussion around the question "What did Covid-19 change in my life?"

Students are asked to share their own experiences during and after the first outbreak of Covid-19. The main goal is to understand their awareness of the depth the pandemic event had in their lives and channel their responses towards the demands of the healthcare sector, to help them understand how virtual environments could help mitigate issues / challenges in healthcare.

- debate around the question "How can 3D modelling help with pandemic challenges?"

Students are asked to break into groups and each group must provide an example on how 3D modelling can tackle one specific pandemic issue, namely identify specific products that can be modelled and produced for that end, supporting arguments and counter-arguments. Example: products for improving health care and quality of life after a pandemic event, e.g., help in the treatment of depressive symptoms, prolonged stress, anxiety, insomnia, denial, fear, and anger.

Lesson 3: Introduction 3D modelling and principles

After a short conversation about the previous lesson, 3D principles and approaches are presented to be discussed.

- digital educational resource: 3d modelling introduction (PowerPoint)

Introduction on 3D modelling with a small PowerPoint presentation with several examples. Students will experiment a virtual environment using a headset apparatus and proper software. Furthermore, several videos regarding 3D models and environments will be presented.

- digital educational resource: pedagogical glossary for technical terms and definitions
- digital educational resource: 6 Key principles for 3D (video)

Six principles for 3D modelling will be revealed: 1. FORM; 2. DETAIL; 3. SCALE; 4. ADAPTATION; 5. REUSE; 6. SURFACE QUALITY.

Basic variables (X, Y, Z) are presented and correlated with horizontality, verticality and depth. Simple exercises will be done, and replicated by the students, demonstrating the variables.

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- group discussion: “How can we design this object in 3D? E.g., surgical mask.”

The aim is to show different basic objects and discuss and reveal which basic elements can be used to model the objects shown. Students may compare different models of the same object and be aware of: the differences they have in the meshes; what benefits and limitations each one has; what situations each model are more suitable for. Also, they must recognize the limitations of scientific models and their differences between real-world objects.

Lesson 4: 3D modelling software basic features: INTERFACE

The teaching-learning script starts with the presentation of the software interface, providing an individual hands-on approach.

- digital educational resource: 3D modelling tutorial about software interface (video)

A video on the software’s interface and major features will be shown. After, individually, students will replicate some basic functionalities in the computer: first approach of the software environment and features.

- learning object: learning object: 3D modelling tutorial about software interface (Tutorial)

After this first approach, a simple tutorial will be provided and students will autonomously and individually follow it, step by step.

- debate around the questions:
  “What were the software presented?”
  “Are there only paid software for 3D modelling?”
  “Which are the major features of the software?”

Lesson 5: 3D modelling software basic features: SHAPES

Students are introduced to geometric representation of models in 3D environment.

- digital educational resource: types of shapes (infographic)
- learning object: tutorial (step by step)
- group work (the availability of laptops or tablets for group work is required)

Students are organized in groups (1 group – 1 Object) and invited to explore shapes in the creation of simple daily objects. After, they will present their work to the colleagues.

Lesson 6: 3D modelling software basic features: TEXTURES and ILLUMINATION

- learning objects: 3D modelling tutorial about textures (video and tutorial)

Students have an overview about the application of simple textures in objects by watching a video. Then, following a step-by-step tutorial, they will experiment to apply texture in objects previously modelled.

- digital educational resource: 3D modelling illumination (video)

As illumination plays a major role in realism on 3D environments, some basic aspects about illumination will be presented to the students.

Lesson 7: 3D modelling software basic features: RENDERING

To finalize the first complete exercise in 3D modelling environment, students will learn what is the process of RENDER.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

- digital educational resource: 3D RENDER (manual)
- Quantitative assessment – questionnaire – impact assessment in terms of students knowledge, skills, attitudes and behaviour
- Presentation and Activity in groups (also works as qualitative assessment):

Students must present their modelling objects in groups and, for each presentation, the other colleagues will need to identify which features, shapes and textures were used or which other solutions may be used to improve to object presented.

Lesson 7-forward:
After building and presenting their work, students are challenged to model other 3D objects in groupwork. This is the **School Project** described below.

Supplementary educational activities

Lesson 8, devoted to the preparation of the school project, includes:

1. Teleconference with STEM professionals (e.g., Engineers, Designers Medical Doctors, or researchers of PAFSE consortium):
Students make questions to experts with a particular focus on: a) future academic choices and career paths; b) identifying new professions in new fields of industry 4.0.

2. Visit to FABLAB:
Students make questions to experts with a particular focus on tools and materials to create 3D scenarios. These activities are relevant for students' connections with possible STEM curriculums and careers. Students are shown the working environment and dynamic of a FABLAB.

School Research Project

Topics
Importance of 3D modelling
Technical features and principles of 3D modelling
Possible applications of 3D modelling in public health

Challenge: Model a 3D object to address communicable diseases challenges.

Method: Lesson 8 to 11 will be dedicated to the school research project. Students are organized in groups; each group addresses 1 object based on the daily pandemic challenges lived. The project challenges each group of students to: 1) identify and represent their progress in the form of essay responses and using Likert scales to show their improvement from the first lesson to the last; 2) model and present an object with what they have learned throughout the teaching-learning sequences and the ideas that emerged during the teleconference with experts. A competition and reward for the best 3D objects will take place.

Teaching-learning process milestones:

1. Students will be able to propose solutions for 3D modelling basic objects (masks, ventilators…).
2. Students will be able to communicate the findings, motivations and limitations of various 3D elements and shapes considered in the working process.
3. Students will be able to identify and communicate the importance of 3D modelling to address pandemic challenges but also the role of Innovation.
4. Students will be able to use technical argumentation to justify policy choices.

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Teaching-learning process for school project (summary):

6. Development of materials (videos, tutorials, pictures).
7. 3D modelling objects.
8. Presentation of the 3D objects in an open schooling event.

Organization of the open schooling event:

3. Each project output (3D object) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair) in a 3D prepared environment (all apparatus included).
4. Students will prepare a pitch on how 3D modelling can address pandemic challenges. Technical talks to motivate peers regarding new technologies and environments are also implemented.
5. Students, parents, the school community and relevant local stakeholders attend the event and are introduced on the topic on how 3D modelling can be used to address pandemic challenges. Furthermore, a multidisciplinary approach is also taken into account, such as the focus on art, design, engineering and mathematics.

Data Analysis and Reporting
Content Analysis.
Presentation formats.
Report writing.
Development of presentation.

Target Audience for Recommendations
School community and local stakeholders: students, parents, municipalities, designers, engineers, and local enterprises.

Public Debate and Recommendations (based on research results)
Presentation of the 3D printing produced by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: 3D modelling

Knowledge	
1. Understands the 3D technical principles and workflows	**Question 1.1:** How many axes can we manipulate in a 3D environment? A) 1. B) 2. C) 3. **Question 1.2:** What is the coordinate system used in the 3D modelling software? A) Polar coordinate system. B) Cartesian coordinate system. C) Cylindrical and spherical coordinate system. **Question 1.3:** What are the six key principles for 3D modelling? A) Form, detail, scale, adaptation, reuse, surface quality. B) Scale, reuse, mesh, object, lighting, render. C) Surface quality, texture, image, depth, presentation, apparatus. **Question 1.4:** Which of the following types of transforms is NOT used in 3D object manipulation: A) Rotation.

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	B) Projection. C) Scale.
2. Recognizes software basic features regarding the interface.	**Question 2.1:** What is a 3D Viewport? A) It is the area showing objects in rendering-device-specific coordinates, in which the objects of interest are going to be rendered. B) It is a collection of settings that determine model display. C) It is the setup that is required to change the settings of the objects. **Question 2.2:** What areas of interest are visible in the workspace? A) The viewport and the properties editor. B) The system's preferences and settings. C) All of the above. **Question 2.3:** Where is the timeline usually displayed? A) At the top. B) At the right sidebar. C) At the bottom.
3. Recognizes software basic features regarding shapes.	**Question 3.1:** Which one of the following definitions is NOT true. A) A mesh is a 3D object that is made up of components used to form geometric polygons. B) A mesh is the most common type of object in 3D. C) A mesh is an empty object that doesn't have any components attached to it. **Question 3.2:** Identify the three basic components of a mesh. A) Vertices, edges and faces. B) Perspectives, blueprints and vertices. C) Faces, blenders and edges.
4. Recognizes software basic features regarding textures and illumination.	**Question 4.1**: What are textures in 3D Modelling? A) Textures are flat images that get applied to 3D objects. B) Textures are three-dimensional images that simulate the look of an object. C) Textures are complex images that manipulate lighting. **Question 4.2**: Is it possible to import different textures simultaneously? A) Yes, using a specific script. B) Yes, using the import specific menu. C) No. **Question 4.3**: Which are the three types of illumination in 3D? A) Yellow, white and black. B) Light, dark and medium. C) Direct, indirect and global. **Question 4.4**: What are the names of the three lights in the 3-point lighting technique? A) Overview, spot and shine. B) Key, fill and rim. C) Saturation, contrast and color.
5. Recognizes software basic features regarding rendering.	**Question 5.1**: What is the goal of the render process? A) To replace real objects with digital information. B) To create objects that will be displayed in the metaverse. C) To simulate digital objects as closer to reality as possible. **Question 5.2**: Is it possible to render only a portion of the viewport? A) Yes, by choosing the render area option. B) Yes, by choosing the crop image area option. C) No. **Question 5.3**: Which of the following daily activities can be improved by 3D rendering? A) An architect showing a realistic design of a building.

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	B) A mechanic engineer explaining the shape of a specific motor part. C) All of the above.
6. Is able to understand the importance of 3D environments to address pandemic challenges and ensure public health.	**Question 6.1**: What artifacts can 3D modelling help design and accelerate their prototyping? A) Personal protective equipment. B) Ventilatory support, diagnostic and consumable products. C) All of the above. **Question 6.2**: Which of the following sentences is NOT true? A) The role of 3D modelling in the hospital environment provides custom-made adaptation of equipment's specifications. B) 3D modelling helps design custom-made solutions that would otherwise be very expensive to prototype. C) None of the above. **Question 6.2**: Which of the following sentences represent an advantage of 3D modelling in public health? A) 3D modeling offers a way to create detailed spatial representations, achieved quickly and at little cost, and increases resource mapping more effortless. B) 3D modeling helps the designers and end users visualize space requirements, but it reduces drawing efficiency and accuracy. C) 3D modelling only enhances productivity and reduces costs. **Question 6.3**: Which of the following sentences is NOT true? A) 3D modelling helps improving an effective and efficient patient care through the modelling of custom-made assistive technologies (prosthetics, orthosis, etc). B) 3D modelling helps providing a teaching tool for professionals at all stages of their careers, from students to interdisciplinary teams, planning medical and surgical cases, identifying issues, or demonstrating them to healthcare professionals. C) 3D modelling is a tool much more focused on healthcare industries, but not very commonly used in other fields of interest.
7. Is able to understand the importance of 3D environments in the health care industry in order to decrease inequality and improve inclusion.	**Question 7.1**: What is the main challenge 3D modelling must overcome in order to help decrease inequality in low-income communities' healthcare institutions? A) Lack of trained and skilled modellers that cannot make use of their knowledge for modelling objects that could bring value to the patient care. B) The lack of practical applications of the technology. C) The lack (or inexistence) of free 3D modelling software to accommodate the creation of the designs. **Question 7.2**: Which of the following sentences represent the truth about the 3D modelling' advantages in education? A) 3D modelling can only be taught to people in high-income communities. B) There is a strong and decisive factor that determines if a person can, or cannot, learn how to 3D model, because not everyone can be taught. C) Everyone can learn how to 3D model, even if they have no background on the matter. **Question 7.3**: Which of the following sentences is NOT true? A) Only people with paid healthcare plans can benefit from 3D modelling if they need a custom-made assistive technology design. B) Every patient can benefit from the 3D model of custom-made assistive technology designs. C) 3D modelling can help accelerate the creation of assistive technology designs during pandemic events and, thus, decrease treatment plans.
SKILLS	
1. Recognizes appropriate proficiencies necessary for 3D modelling.	**Question 1.1:** Which of the following responsibilities is NOT required to be a 3D modeller? A) To create 3D objects based on provided specifications. B) To calculate effort estimations of the objects. C) To refine, optimize or correct 3D models.

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	Question 1.2: Which of the following skills is NOT needed for 3D modelling? A) Knowledge of coding. B) An eye for detail and good visualization skills. C) Knowledge of 3D design tools such as 3DS Max, Maya, Zbrush, Blender. **Question 1.3:** Which of the following is NOT a type of object that can be 3D modelled? A) Engineering parts. B) Organic objects. C) None of the above. **Question 1.4:** Which of the following is NOT a benefit of 3D modelling? A) Spot design and drawing errors. B) Quick and accurate visualization. C) Is faster than drawing a sketch.
2. Is able to understand the virtual environment.	**Question 2.1:** I feel able to understand the coordinate system used in 3D modelling software. 1) definitely true... 5) definitively false. **Question 2.2:** I feel able to navigate the software interface and choose the right tools for the work. 1) definitely true... 5) definitively false. **Question 2.3:** I feel able to adopt 3D modelling to help people visualize abstract concepts. 1) definitely true... 5) definitively false. **Question 2.4:** Which dimensions of spatial context can be considered when modelling 3D objects? A) Spatial context focused specifically on object properties, object relationships and perception of space. B) Comparison of 2D and 3D map variants. C) Cost of the 3D object's materials and components. **Question 2.5:** What types of virtual environments are most used to create immersive experiences? A) Virtual reality and mixed reality. B) 2D Videos. C) Social media accounts. **Question 2.6:** Which of the following is NOT a feature of a 3D interactive environment? A) Create a virtual habitat. B) Have a figurative appearance. C) Create a persona.
3. Can create specific 3D objects and sets.	**Question 3.1:** I feel able to create a 3D object from scratch. 1) definitely true... 5) definitively false. **Question 3.2:** I feel able to modify object's properties, such as color, texture, shape or size. 1) definitely true... 5) definitively false. **Question 3.3:** I feel able to create low poly objects, as well as more complex meshes. 1) definitely true... 5) definitively false. **Question 3.4:** I feel able to determine / alter the lighting setup for 3D objects. 1) definitely true... 5) definitively false **Question 3.5:** I feel able to create a whole set / scenery involving different 3D elements. 1) definitely true... 5) definitively false. **Question 3.6:** In order to create a complex object, which of the following solid primitives can be used? A) Cylinder, sphere and torus.

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	B) Pyramid, box and cone. C) All of the above. **Question 3.7:** Which of the following sentences is NOT true? A) Some actions modify the geometry of the Mesh without changing the overall shape. B) Some actions modify both the geometry of the Mesh and the overall shape. C) It is not possible to modify the geometry of the Mesh nor the overall shape.
4. Is able to identify the differences of multiple 3D modelling software.	**Question 4.1:** I feel able to identify the differences in the layout / options of distinctive 3D modelling software. 1) strongly disagree… 5) strongly agree. **Question 4.2:** I feel able to work with / use different 3D modelling software. 1) strongly disagree… 5) strongly agree **Question 4.3:** I feel able to identify the main limitations, as well as advantages of each distinctive software. 1) definitely true... 5) definitively false. **Question 4.4:** Which of the following 3D modelling software is more adequate for creating organic objects? A) 3D Studio Max. B) Blender. C) All of the above. **Question 4.5:** Which of the following 3D modelling software is more adequate for prototyping? A) Maya. B) Solidworks. C) Cinema4D. **Question 4.5:** Which of the following 3D modelling software is more adequate for creating technical drawings and architectural simulations? A) AutoCAD. B) 3D Studio Max. C) Solid Edge. **Question 4.6:** Which of the following 3D modelling software is more adequate for creating characters and projecting video games? A) Blender. B) Solid Edge. C) ZBrush.
Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Recognizes the importance of raising awareness on how 3D modelling can help the community.	**Question 1.1:** The creation of 3D objects of my own can contribute to the global society's awareness about the importance of 3D modelling. 1) Extremely unlikely... 5) Extremely likely. **Question 1.2:** I am able to explain to my family and friends the importance of 3D modelling. 1) strongly disagree… 5) strongly agree. **Question 1.3:** I feel society takes for granted the benefits of 3D modelling. 1) strongly disagree… 5) strongly agree. **Question 1.4:** I think society still does not fully understand the importance of 3D modelling. 1) strongly disagree… 5) strongly agree. **Question 1.5:** I believe that 3D modelling is important / useful in our daily lives. 1) strongly disagree… 5) strongly agree.

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2. Has intention to continue extending the skills and knowledge regarding 3D modelling	**Question 2.1:** I feel that the 3D modelling process is pleasant and exciting. 1) strongly disagree… 5) strongly agree. **Question 2.2:** I can imagine a bright future for 3D modelers. 1) Extremely unlikely... 5) Extremely likely. **Question 2.3:** I feel I have the right profile and attitude to be a 3D modeler in the future. 1) strongly disagree… 5) strongly agree. **Question 2.4:** I feel highly motivated to pursue a project in this field of expertise. 1) strongly disagree… 5) strongly agree. **Question 2.5:** I feel curiosity to know more about 3D modelling and improve my skills. 1) Extremely unlikely... 5) Extremely likely.
3. Is aware of the democratization of 3D modelling.	**Question 3.1:** I feel that the massification of 3D objects is beneficial for society. 1) strongly disagree… 5) strongly agree. **Question 3.2:** I feel highly motivated to start contributing with my own 3D objects and share them with others with an open-source agreement. 1) Extremely unlikely... 5) Extremely likely. **Question 3.3:** I agree with the dissemination of 3D objects, free of royalties, to the empowerment of society, as all models should be free to use regardless of the scope. 1) strongly disagree… 5) strongly agree.
4. Has a positive attitude towards 3D modelling.	**Question 4.1:** For me, the process of 3D modelling is: pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable
5. Believes that is important to improve one's own personal capabilities regarding 3D modelling.	**Question 5.1:** I feel 3D modelling helps me improve my visual perception. 1) strongly disagree… 5) strongly agree. **Question 5.2:** I feel 3D modelling helps me expand my knowledge of art. 1) strongly disagree… 5) strongly agree. **Question 5.3:** I feel 3D modelling helps me to develop my creativity. 1) strongly disagree… 5) strongly agree. **Question 5.4:** I feel 3D modelling helps me lose my fear of making mistakes. 1) strongly disagree… 5) strongly agree.

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14. Specifications for an educational scenario on the topic of "3D printing to address pandemic challenges"

Main partner responsible: INESC-TEC

Context and relevance for public health education

Additive manufacturing (AM), broadly known as 3D printing, is transforming how products are designed, produced, and serviced in public health. "AM enables on-demand production without dedicated equipment or tooling, unlocks digital design tools, and offers breakthrough performance and unparalleled flexibility across industries".

Recent advances on 3D printing in healthcare have led to lighter, stronger and safer products, reduced lead times and lower costs. Also, custom parts and objects can be tailored to each patient and each situation. Medical applications for 3D printing are expanding rapidly and this technology is expected to revolutionize health care. The application of 3D printing in the medical sector can provide several benefits, such as the customization and personalization of medical products or equipment. However, literature refers that knowledge remains one of the greatest barriers to AM's wider adoption. So, how we leverage the potential of AM to drive innovation is a mandatory topic in science/technology curriculum.

The scenario supports science and ICT teachers in exploring 3D environments using updated scientific/technical evidences. The learning experience supports youths in understanding and reach high-level comprehension on how STEM (science, technology, engineering, mathematics) may contribute to address these issues and contribute to evidence-based personal decision-making.

Estimated Duration

7 classes of 40-45 minutes (lesson 1 – lesson 7)
4 sessions of 40-45 minutes for supplementary learning activities and school project (session 8 – session 11)

Prerequisite knowledge and skills

Basic ICT notions

Classroom organization requirements

ICT classroom with access to computers and a 3D printer.

To carry out the research project, students will work in groups of 4 or 5 elements. It is necessary to have a computer/tablet with internet access.

Content glossary

Additive manufacturing. Additive manufacturing is the process of creating an object by building it one layer at a time. It is the opposite of subtractive manufacturing, in which an object is created by cutting away at a solid block of material until the final product is complete. Technically, additive manufacturing can refer to any process where a product is created by building something up, such as molding, but it typically refers to 3-D printing.

3D Printer. A machine allowing the creation of a physical object from a three-dimensional digital model, typically by laying down many thin layers of a material in succession.

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3D Environment. 3D environment is the generation of realistic computer-controlled digital settings for games, film, architectural renderings, and advertising using specialized computer software.

3D printing process. 3D printing, in full three-dimensional printing, in manufacturing, any of several processes for fabricating three-dimensional objects, is the process of layering two-dimensional cross sections sequentially, one on top of another. The process is analogous to the fusing of ink or toner onto paper in a printer (hence the term *printing*) but is actually the solidifying or binding of a liquid or powder at each spot in the horizontal cross section where solid material is desired.

Collaboration. A recognized relationship among different sectors or groups, which have been formed to take action on an issue in a way that is more effective or sustainable than might be achieved by the public health sector acting alone.

Equity/equitable. Equity means fairness. Equity in health means that peoples' needs guide the distribution of opportunities for well-being. Inequities occur as a consequence of differences in opportunity, which result, for example in unequal access to health services, nutritious food or adequate housing. In such cases, inequalities in health status arise as a consequence of inequities in opportunities in life.

Extruder. The extruder is a part of the 3D printer where material is ejected in liquid or semi-liquid form. It is deposited in successive layers within the 3D printing volume.

Filaments. Are *thermoplastics*, which are plastics (aka polymers) that melt rather than burn when heated, can be shaped and molded, and solidify when cooled. Filament is the heart of Fused Deposition Modeling (FDM) 3D printing. The filament is fed into the extruder, heated, and deposited in specific locations layer by layer.

Fused Deposition Modeling (FDM). The fused deposition modeling (FDM) is one of the additive manufacturing techniques which is largely used for printing of metal/thermoplastic materials with ease of design flexibilities. It has been utilized in the automobile industry, ranging from testing models, lightweight tools to final functional components.

Health. A state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.

Multimedia Contents. Multimedia refers to various types of media content, used together. Multimedia content includes text, graphic image files, audio files, video clips.

Polymers. A substance which has a molecular structure built up chiefly or completely from a large number of similar units bonded together, e.g., many synthetic organic materials used as plastics and resins.

Post-printing Process. Once the printing process is over, we proceed to our final stage of finishing, where an array of post-printing services such as cutting, folding, creasing, punching, die-cutting, perforating, laminating, foil stamping, embossing, addressing, inserting, sewing and collating are performed to meet product requirements.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Research. Activities designed to develop or contribute to knowledge, e.g., theories, principles, relationships, or the information on which these are based. Research may be conducted simply by observation and inference, or by using experiment, in which the researcher alters or manipulates conditions in order to observe and study the consequences of doing so.

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Pedagogical glossary

Active Learning. A teaching and learning approach that “engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work”.

Brainstorming: An instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative Learning. An umbrella term that covers many different methods in which students work together to solve a problem, complete a task, or create a product. Collaborative learning is founded in the concept that learning and knowledge building is social and requires active engagement from students.

Critical Thinking. The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a “general commitment” of all.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organization, variable handling, data driven conclusion making and communicating over scientific issues.

Knowledge. A familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

Pedagogical Techniques. Essential resources that the teacher uses to enhance the pedagogical relationship between the students and the teacher in order to ensure learning. Different forms of application to achieve the objectives of a class.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Skill. The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

Sources: EuroHealthNet; Mitsloan; OxfordLanguages; Sciencedirect

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Indicative literature

- Liza Wallach Kloski e Nick Kloski, “Getting Started with 3D Printing”
- Carlos Relvas, “O Mundo da Impressão 3D e o Fabrico Digital”
- Sergio Gómez González, “Impresión 3D”

Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn

Knowledge
3D printing concepts:

- ✓ 3D technical principles and workflows.
- ✓ Tools for printing 3D models.
- ✓ Hardware for 3D printing.
- ✓ Supplies and materials for 3D printing.

Knowledge - outcome assessment:

1. Understands the importance of printed 3D artifacts to address pandemic challenges.
2. Recognizes the 3D printing process.
3. Recognizes 3D printer’s main features.

Skills (abilities/competences)

General: 3D basics, Imagination, creativity
Specific:

- Printing 3D models by combining process knowledge and application requirements.
- Technical usage of 3D printing hardware, supplies and software.
- Post-process knowledge of 3D printing.

Skills – outcome assessment:

1. Recognizes hardware basic features.
2. Recognizes printer’s materials and supplies.
3. Recognizes post-printing processes.
4. Is able to identify the differences of multiple 3D printers.
5. Can print specific 3D objects.
6. Is able to print artifacts that improve public health.

Affective /Attitudes/Behaviour *(beliefs)*

- ✓ Using imagination for designing real tools and materials, focusing on the printing of artifacts.
- ✓ Using creativity skills on new technologies in the development process of the solution.

Affective, Attitudes and behavior - outcome assessment:

1. Believes that is important to raise awareness on how 3D printing can help the community.
2. Believes that is an important tool during a pandemic.
3. Has intention to continue extending the skills and knowledge regarding 3D printing.

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4. Is aware of the democratization of 3D printing for public health.
5. Attitude towards 3D printing.
6. Believes that is important to improve one's own personal capabilities.

Learning goals and outcomes

- ✓ Uses online tools to open and print 3D models.
- ✓ Analyzes pre-designed models.
- ✓ Identifies the printers' basic features.
- ✓ Identifies the proper materials for printing different objects for different contexts of use.

Assessment methods

- ✓ Outcome assessment
    - Qualitative - project: printing a given 3D object.
    - Quantitative – questionnaire - – impact assessment in terms of students knowledge, skills, attitudes and behaviour
- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content

- Use of 3D printers.
- Printing 3D objects and using the materials / supplies.

Non-STEM content

- Brainstorming on 3D printers and materials.
- Group and public debates.

Digital learning objects

New:

- Introduction of types of printers (*video and PowerPoint*).
- Printers' basic features: the HARDWARE (*video and tutorial*).
- Printers' basic features: the MATERIALS / SUPPLIES (*infographic and tutorial*).
- Introduction of the printing process (*video and tutorial*).
- Introduction of the post-printing process (*infographic and tutorial*).
- Questionnaire – quantitative assessment of learnings.

Digital educational resources

New:

- Introduction of the different printing methods (video).
- Pedagogical glossary for technical terms and definitions (infographic).

Available resources (link):
https://drive.google.com/drive/folders/1I6DbhytMuTK1wI0KCeatXOajUd9_ge_y?usp=sharing

Teaching -learning activities (lesson plan/ learning trajectory)

Principal target:
Science and ICT classes
9th grade (+/- 15 years old students)
ICT teachers integrate other colleagues in the enactment of the scenario (e.g., visual education, mathematics and English teachers), as it aims to be interdisciplinary.

Lesson 1: Introduction of types of printers

The teaching-learning script starts with a question “what is 3D printing?”.

- group discussion around the question “What is 3D printing?”

Students are divided into groups and asked to share their thoughts on what 3D printing means. This activity will contribute to reveal the students’ initial ideas of the topic, helping teachers understand their skills and knowledge on the subject. Also, this activity should be presented to the students as a theoretical background of the 3D printing practical applications (3D printers, printing methods and materials) and will be important for teachers to introduce the subject on what involves 3D printing and the current limitations of scientific evidence. Example: energy consumption for operation, the costs, time-consuming for mass production, piracy and counterfeiting.

- group discussion around the question “What applications may it have?”

3D printing technology, as an environmentally friendly derivative, is used increasingly in healthcare; thus it is important for the students to correlate this technology (print an object layer by layer deposition of material directly from a computer aided design) with public health and their interactive parameters. Example: 3D printing technology can be used to visualization, education, and communication (e.g., print 3D skin, drug and pharmaceutical research, bone and cartilage, etc.).

- brainstorming on the question “what is a 3D printer?”

Students are divided into groups and asked to Google key definitions of 3D printers and the different types of hardware. Each group should gather at least two different printer models; identify them and select the main brands for sharing (e.g. the RepRap printers, a.k.a. a self-replicating 3D printer that uses lines (filaments) for printing). Then, they go to the flipchart or whiteboard and write the main keywords.

Next step is a video presentation about the 3D printing process. After, a discussion is mandatory about their previous models and brands and their recent new knowledge about the topic learned.

Lesson 2: Introduction of the different printing methods

After a short conversation about the previous lesson, 3D printing methods and approaches are presented to be discussed.

- digital educational resource: pedagogical glossary for technical terms and definitions

The proper references to scientific terms and topics are presented, such as solid state physics, chemistry, polymers, geometry, geometrical representation, photopolymerization. This will help students gain a holistic interdisciplinary approach regarding the topic.

- digital educational resource: 3d printer introduction (video)

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

Introducing 3D printing by presenting a short video with several examples of printers. Students will experiment the printer using the proper hardware. Furthermore, will be presented several videos made using different printing methodologies.

- debate: “How can print this 3D model? E.g., a surgical mask.”

The aim is to show different printing methods and discuss and reveal which ones can be used to print the objects shown.

Lesson 3: Printers’ basic features: the HARDWARE

The teaching-learning script starts with the presentation of the hardware, providing an individual hands-on approach.

- digital educational resource: models of 3D printers (video)

A video on hardware models showing major features will be shown. And after, individually, students will replicate some basic functionalities in the printer. First approach of the hardware (equipment and features).

- digital educational resource: Key factors and features of 3D printers (video)

Key factors of 3D printers will be revealed (1. PRICE-PERFORMANCE RATIO, 2. VERSATILITY, 3. RELIABILITY). The main features to be observed are evaluated (e.g. if the printers enable the use of different types of filaments (tougher filaments like Polycarbonate); if the printers work with lower / higher extruder temperatures). Simple exercises will be done, and replicated by the students, demonstrating the variables.

- learning object: 3D printing tutorial (Tutorial)

After this first approach, a simple tutorial will be provided and students will autonomously and individually perform it.

- debate around the questions
  “What was the hardware presented?”
  “Are there only a few models for 3D printing?”
  “Which are the major features of the hardware?”
  “What should be the process when using the hardware?”

Lesson 4: Printers’ basic features: the MATERIALS / SUPPLIES

Students are introduced to the different materials / supplies when using the 3D printer.

- digital educational resource: types of materials (infographic)
- digital educational resource: scenarios of use for the materials (infographic)
- learning object: tutorial of how to handle the materials, e.g. storage and usage (step by step)
- group work (the availability of different types of materials for group work is required, as well as the equipment itself)

Students are organized in groups (1 group – 1 material) and invited to explore the hardware and the supplies. After, they will present their findings to the colleagues. Beforehand, teachers will be made aware of the materials / supplies provided, in order to prepare the educational activities, including ceramic, metallic, polymers and their combinations in form of hybrid, composites or functionally graded materials.

Lesson 5: Introduction of the printing process

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- learning objects on 3D printing tutorial (video and tutorial)

Students have an overview about the printing of simple objects by watching a video. Then, by doing a step-by-step tutorial will experiment to print a given objects previously modelled.

- group work (the availability of laptops for group work is required, as well as the printer itself)

Students are organized in groups (1 group – 1 Object) and invited to perform the printing of a simple daily object. After, they will present their work to the colleagues.

Lesson 6: Introduction of the post-printing process

- digital educational resource: finishing of the printed objects (infographic)

Depending on the technology and the materials used for printing, the printed artifacts may require post-process handling. Examples of such situations are: rinsing to remove any uncured resin from the printed artifact's surface, post-curing to stabilize mechanical properties, manual work to remove support structures, cleaning with compressed air to remove excess powder. Some of these processes can be automated with accessories.

- learning objects on 3D post-printing techniques (video and tutorial)

Students have an overview about the post-printing techniques for the finishes of the printed artifacts by watching a video. Then, by doing a step-by-step tutorial will experiment to "clean" and give the finishes to the given objects previously printed.

- group work

Students are organized in groups (1 group – 1 Object) and invited to perform the finishes on the printed objects. After, they will present their work to the colleagues.

Lesson 7-forward:

After building and presenting the printing process map, students are challenged to print other 3D object in groupwork. This is the **School Project** described down.

Supplementary learning resources and educational activities

Lesson 8, devoted to the preparation of the school project, includes:

1. Teleconference with STEM professionals (e.g., Engineers, Designers Medical Doctors, or researchers of PAFSE consortium):
Students make questions to experts with a particular focus on: a) future academic choices and career paths; b) identifying new professions in new fields of industry 4.0.

2. Visit to FABLAB:
Students make questions to experts with a particular focus on tools and materials to create 3D scenarios. These activities are relevant for students' connections with possible STEM curriculums and careers. Students are shown the working environment and dynamic of a FABLAB.

School Research Project

Topics

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

- Importance of 3D printing
- Technical features and principles of 3D printing
- Possible applications of 3D printing in public health

Research management, design and administration

Challenge: To print a 3D object to address communicable diseases challenges

Method: Lesson 8 to 11 will be dedicated to the school research project. Students are organized in groups; each group addresses 1 object based on the daily pandemic challenges lived. The project challenges each group of students to: 1) identify and represent their progress in the form of essay responses and using Likert scales to show their improvement from the first lesson to the last; 2) print and present an object with what they have learned throughout the teaching-learning sequences and the ideas that emerged during the teleconference with experts. A competition and reward for the best 3D objects will take place.

Teaching-learning process milestones:

1. Students will be able to propose solutions for 3D printing basic objects (masks, ventilators…).
2. Students will be able to communicate the findings, motivations and limitations of various 3D elements and shapes considered in the work process.
3. Students will be able to identify and communicate the importance of 3D modelling to address pandemic challenges but also the role Innovation.
4. Students will be able to use technical argumentation to justify policy choices.

Teaching-learning process for school project (summary):

1. Development of materials (videos, tutorials, pictures).
2. 3D printing objects.
3. Presentation of the physical 3D objects in open schooling event.

Organization of the open schooling event:
1. Each project output (physical 3D object) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair).
2. Students will prepare a pitch on how 3D printing can address pandemic challenges. Technical speeches to motivate peers to new technologies and environments.
3. Students, parents, school community and relevant local stakeholders attend the event and are introduced on the topic on how 3D printing can be used to address pandemic challenges. Furthermore, has a multidisciplinary approach, such as in art, design, engineering and mathematics.

Data Analysis and Reporting

Content Analysis.
Presentation formats.
Report writing.
Development of presentation.

Target Audience for Recommendations
School community and local stakeholders: students, parents, municipalities, designers, engineers, and local enterprises.

Public Debate and Recommendations (based on research results)
Presentation of the 3D printing produced by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: 3D PRINTING”

Knowledge	
1. Understands the importance of printed 3D artifacts to address pandemic challenges	**Question 1.1**: 3D printing can help accelerate the prototyping process of which artifacts? A) Personal protective equipment. B) Ventilatory support, diagnostic and consumable products. C) All of the above. **Question 1.2:** Which of the following sentences is NOT true? A) 3D printing and distributed manufacturing represent a paradigm shift in the health system. B) 3D printing is able to provide a production model that has a fast response to stock needs, being able to adapt almost in real time. C) All of the above. **Question 1.3**: Which of the following sentences represent an advantage of 3D printing in public health? A) 3D printing reduces efficiency and accuracy. B) 3D printing helps to quickly create medical equipment prototypes. C) 3D printing only reduces costs. **Question 1.4**: Which of the following sentences is NOT true? A) 3D printer machines fabricated numerous medical kits and accessories during the COVID-19 pandemic, from face shields, specimen collectors, personalized face masks, ventilators, protective eyewear, personal protection equipment (PPE). B) During the pandemic, medical artifacts were fabricated in a short period of time, as requirements and shortage of materials were increasing expressively. C) The cooperation of 3D printing knowledge with the worldwide healthcare community will not develop innovative and essential prospects in the future.
2. Recognizes the 3D printing process.	**Question 2.1:** Which of the following sentences is NOT true? A) 3D printing can take only a few days from design to final production over hundreds from a traditional process. B) 3D printing cannot create detailed objects and takes days to finish an object. C) None of the above. **Question 2.2**: Which of the following printing processes is the most common in the market for home use? A) Additive manufacturing. B) Extrusive manufacturing. C) Sheet lamination manufacturing.
3. Recognizes 3D printer’s main features.	**Question 3.1**: Which of the following sentences are NOT true? A) The role of 3D printing provides custom-made adaptation of equipment’s specifications. B) 3D printing helps design custom-made solutions that would otherwise be very expensive to prototype. C) All of the above.
SKILLS	
1. Recognizes hardware basic features.	**Question 1.1:** The printing platform moves in which axis? A) X. B) Y. C) Z. **Question 1.2:** The printing head moves in which axis? A) X and Y.

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	B) Y and Z. C) X, Y and Z. **Question 1.3:** How are the printed layers organized? A) The layers are printed on top of each other. B) The layers are printed side by side. C) There is no orientation during the process. **Question 1.4:** The prices of the 3D printers vary according to which factors? A) Material and model complexity. B) Labor intensity. C) All of the above. **Question 1.5:** What is the advantage of a 3D material extrusion system printer? A) Extended use and filament's low cost. B) Limited to metals. C) Limited printing size. **Question 1.6:** What is the most common type of 3D printing technique? A) Sheet lamination. B) Material extrusion. C) Binder jetting.
2. Recognizes printer's materials and supplies.	**Question 2.1:** During printing, the supplies go through what process? A) Heated and melted. B) Heated and pressurized. C) Frozen. **Question 2.2:** In a 3D printer, what is the material that is heated and melted in the printing head? A) Filament. B) Metal. C) Dust. **Question 2.3:** Which of the following sentences is NOT true? A) The type of filament used in the printing process can highly impact the final object quality. B) There are multiple colors of filament available in the market. C) The filament can be melted over and over again to print multiple artifacts. **Question 2.4:** Which of the following filaments are the most commonly used in 3D printing? A) PLA and ABS. B) Wood and stone. C) Ceramic and metallic.
3. Recognizes post-printing processes.	**Question 3.1**: Which of the following sentences is NOT true? A) The printed artifact is perfect at the end of the printing session, not needing further work. B) The printed artifact needs to be sanded or polished afterwards. C) The printed artifact can be drilled or milled afterwards.
4. Is able to identify the differences of multiple 3D printers.	**Question 4.1:** I feel able to identify the differences in the distinctive 3D printers available on the market. 1) strongly disagree… 5) strongly agree. **Question 4.2:** I feel able to work with / use different 3D printers. 1) strongly disagree… 5) strongly agree **Question 4.3:** I feel able to identify the main limitations, as well as advantages of each distinctive printer. 1) strongly disagree… 5) strongly agree. **Question 4.4:** What are the two most common types of 3D Printers for plastics parts? A) Stereolithography (SLA) and Selective laser sintering (SLS). B) Selective laser sintering (SLS) and Fused deposition modeling (FDM). C) Stereolithography (SLA) and Fused deposition modeling (FDM). **Question 4.5:** Which of the following is NOT the goal of fused deposition modeling (FDM) printers? A) Simple prototyping. B) Basic proof-of-concept models. C) End-use parts.

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5. Can print specific 3D objects.	**Question 5.1:** I feel able to print a 3D object from scratch. 1) definitely true... 5) definitively false. **Question 5.2:** I feel able to choose the right type of filament to print. 1) definitely true... 5) definitively false. **Question 5.3:** I feel able to print low detailed artifacts, as well as more complex ones. 1) definitely true... 5) definitively false. **Question 5.4:** Which of the following is the right format used by computer aided design systems for 3D printable parts? A) STL File. B) AI file. C) SVG file. **Question 5.5:** How much does the resolution of the pintable file impact the quality of the 3D printed parts? A) Is a minor detail with low impact. B) If the file resolution is too high the triangle may overlap and if it is too low the model will have gaps. C) None of the above.
6. Is able to print artifacts that improve public health.	**Question 6.1:** I feel able to print daily artifacts that are useful for the community's quality of life. 1) strongly disagree… 5) strongly agree. **Question 6.2:** I feel able to print artifacts for my school to help ensure better teaching methodologies and dynamics. 1) strongly disagree… 5) strongly agree. **Question 6.3:** Which of the following artifacts can be printed using stereolithography? A) Face shields and protective eyewear. B) Specimen collectors and ventilators. C) All of the above.
Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that is important to raise awareness on how 3D printing can help the community.	**Question 1.1:** The printing of 3D objects of my own can contribute to the global society's awareness about the importance of 3D printing. 1) Extremely unlikely... 5) Extremely likely. **Question 1.2:** I am able to explain to my family and friends the importance of 3D printing. 1) strongly disagree… 5) strongly agree. **Question 1.3:** I think society still does not fully understand the importance of 3D printing. 1) strongly disagree… 5) strongly agree. **Question 1.4:** I feel 3D printing has great potential for changing the mindsets of the communities regarding the importance of a rapid prototyping process of artifacts. 1) strongly disagree… 5) strongly agree. **Question 1.5:** I believe that 3D printing is important / useful in our daily lives. 1) strongly disagree… 5) strongly agree **Question 1.6:** I understand that 3D printing technology allows a rapid progress from design to production. 1) strongly disagree… 5) strongly agree. **Question 1.7:** I feel that the free use and dynamization of a 3D printing equipment in my community can be extremely important. 1) strongly disagree… 5) strongly agree.

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	Question 1.8: I feel that 3D printing can be a valuable tool for under-developed countries, where they lack basic day-to-day objects. 1) strongly disagree… 5) strongly agree. **Question 1.9:** I feel that 3D printing can be a valuable tool for countries going through a post-war situation. 1) strongly disagree… 5) strongly agree.
2. Believes that is an important tool during a pandemic.	**Question 2.1:** 3D printing is a critical tool for managing the shortage of personal protective equipment (PPE), ventilators, and other medical equipment in the communities. 1) strongly disagree… 5) strongly agree. **Question 2.2:** I feel that everyone can play a part in the creation of 3D objects to help address the shortage of materials in the community, as students, professors, hobbyists, inventors, designers, and engineers scattered across the globe can initiate their own 3D printing projects. 1) strongly disagree… 5) strongly agree. **Question 2.3:** I believe that community fabrication labs (“Fab Labs”), that use supported materials and processes, can help increase the creation of health and medical artifacts in a secured environment and decrease inequalities of access to such equipment. 1) strongly disagree… 5) strongly agree. **Question 2.3:** I believe 3D printing technology has influenced the healthcare and medical sector during the COVID-19 pandemic. 1) strongly disagree… 5) strongly agree.
3. Has intention to continue extending the skills and knowledge regarding 3D printing	**Question 3.1:** I feel that the 3D printing process is pleasant and exciting. 1) strongly disagree… 5) strongly agree. **Question 3.2:** I feel that the 3D printing equipment is easy to use. 1) strongly disagree… 5) strongly agree. **Question 3.3:** I feel highly motivated to pursue a career in 3D printing. 1) strongly disagree… 5) strongly agree. **Question 3.4:** I feel curiosity to know more about 3D printing and improve my skills. 1) Extremely unlikely... 5) Extremely likely.
4. Is aware of the democratization of 3D printing for public health.	**Question 4.1:** I feel that the massification of printed 3D objects is beneficial for society. 1) strongly disagree… 5) strongly agree. **Question 4.2:** I feel highly motivated to start contributing with my own printed 3D objects. 1) Extremely unlikely... 5) Extremely likely. **Question 4.3:** I agree with the massification of printed 3D objects, as it can prevent an imminent collapse of medical supply chains across global economies. 1) strongly disagree… 5) strongly agree. **Question 4.4:** I understand that 3D printing technology provides an opportunity to escape the cycle of traditional production and accelerate the response to public health emergencies. 1) strongly disagree… 5) strongly agree. **Question 4.5:** I feel that the 3D printer can be, in the future, considered a common household appliance to meet our needs. 1) Extremely unlikely... 5) Extremely likely.
5. Attitude towards 3D printing.	**Question 5.1:** For me, the process of 3D printing is: pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable

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	enjoyable :_____:_____:_____:_____:_____: unenjoyable
6. Believes that is important to improve one's own personal capabilities.	**Question 6.1:** I feel 3D printing helps me expand my knowledge of art. 1) strongly disagree… 5) strongly agree. **Question 6.2:** I feel 3D printing helps me to develop my creativity. 1) strongly disagree… 5) strongly agree. **Question 6.3:** I feel 3D printing helps me lose my fear of making mistakes. 1) strongly disagree… 5) strongly agree.

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15. Specifications for an educational scenario on the topic of “3D animation to address pandemic challenges”

Main partner responsible: INESC-TEC

Context and relevance for public health education

3D animation can be a useful resource to study typical objects that otherwise could not be visually perceived. 3D animations can be a dynamic way of creating a visual explanation of things based on different media (i.e., multimedia contents) that could be difficult for students to understand or build a mental model of, with only text or still imagery content.

The use of 3D animations in medical education is becoming increasingly popular. Indeed, animations are an efficient way to present complex information, reducing time spent reading textbooks. Thus, in the educational contexts, animations can help students learn more efficiently, retain and better understand information. In addition to improving the learning experience, medical education is a highly important and necessary endeavor, as it can directly affect the lives of patients. These videos can be useful in emergency care instructions and provide information about how to administer CPR to a patient, or help in forensic reconstructions; a doctor might explain a medical term to a patient in a friendly way, and they can also help patients understand complex procedures.

Highly engaging educational content is becoming essential to improving the overall learning experience. A plethora of data exists that confirms what many health care professionals know intuitively: that multimedia content, including 3D animation education, is superior to text-based or static image education content. When culturally suitable images and language are added, the efficacy is increased and the outcomes improve.

This scenario supports science and ICT teachers in exploring 3D animation. The learning experience supports youths in understanding how Art and Technology may contribute to have high-quality 3D models useful for public health purposes.

Estimated Duration

7 classes of 40-45 minutes (lesson 1 – lesson 7)
4 sessions of 40-45 minutes for supplementary learning activities and school project (session 8 – session 11)

Prerequisite knowledge and skills

Basic ICT notions

Classroom organization requirements

ICT classroom with access to computers.

To carry out the research project, students will work in groups of 4 or 5 elements. It is necessary to have a computer/tablet with internet access.

Content glossary

2D Animation. 2D, or two-dimensional animation, is a combination of artistic technique and media design that creates the illusion of movement in a two-dimensional environment. By sequencing individual drawings together over time, characters, backgrounds, objects, and effects look as if they are moving.

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This is commonly done for animated movies and television, but it is also seen in video games, websites, mobile apps, and advertisements.

3D Animation. 3D animation is a graphic technique that utilizes motion in order to bring characters, objects, props, and more to life, placing them into a digital environment. 3D animation has become widely used: gaming, TV shows, movies, corporate ad campaigns, architectural modeling, medical research. 3D animations are used across many industries and for diverse purposes.

3D Environment. 3D environment is the generation of realistic computer-controlled digital settings for games, film, architectural renderings, and advertising using specialized computer software.

Animation Parameters. Animation Parameters are variables that are defined within an Animator Controller that can be accessed and assigned values from scripts. This is how a script can control or affect the flow of the state machine.

Augmented Reality. Augmented reality (AR) is the integration of digital information with the user's environment in real time. Unlike virtual reality (VR), which creates a totally artificial environment, AR users experience a real-world environment with generated perceptual information overlaid on top of it.

Camera Angles. Is the direction in which the camera is pointed in relation to the action being recorded.

Collaboration. A recognized relationship among different sectors or groups, which have been formed to take action on an issue in a way that is more effective or sustainable than might be achieved by the public health sector acting alone.

Equity/equitable. Equity means fairness. Equity in health means that peoples' needs guide the distribution of opportunities for well-being. Inequities occur as a consequence of differences in opportunity, which result, for example in unequal access to health services, nutritious food or adequate housing. In such cases, inequalities in health status arise as a consequence of inequities in opportunities in life.

Health. A state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.

Multimedia Contents. Multimedia refers to various types of media content, used together. Multimedia content includes text, graphic image files, audio files, video clips.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences,

Rendering Process. 3D rendering is the process of using a computer to generate a 2D image from a digital three-dimensional scene. To generate an image, specific methodologies and special software and hardware are used.

Research. Activities designed to develop or contribute to knowledge, e.g., theories, principles, relationships, or the information on which these are based. Research may be conducted simply by observation and inference, or by using experiment, in which the researcher alters or manipulates conditions in order to observe and study the consequences of doing so.

Rigging Process. Rigging is a technique used in skeletal animation for representing a 3D character model using a series of interconnected digital bones. Specifically, rigging refers to the process of creating the bone structure of a 3D model. This bone structure is used to manipulate the 3D model like a puppet for animation.

Skinning Process. Skinning is the process of binding the actual 3D mesh to the joint setup created. This means that the joints will have influence on the vertices of the model and move them accordingly.

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Special VFX. Visual effects (VFX) is a term used to describe imagery created, manipulated, or enhanced for any film, or other moving media that doesn't take place during live-action shooting. VFX often involves the integration between actual footage and this manipulated imagery to create realistic looking environments for the context.

Storyboard. A storyboard is a visual representation of a film sequence and breaks down the action into individual panels. It is a series of ordered drawings, with camera direction, dialogue, or other pertinent details. It sketches out how a video will unfold, shot by shot.

Video Editing. Video editing is the process of manipulating and rearranging video shots to create a new work. Editing is usually considered to be one part of the post production process — other post-production tasks include titling, color correction, sound mixing, etc.

Virtual Reality. Virtual reality is the use of computer technology to create simulated environments. Virtual reality places the user inside a three-dimensional experience and, instead of viewing a screen in front of them, users are immersed in and interact with 3D worlds by using special equipment.

Pedagogical glossary

Active Learning. A teaching and learning approach that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work".

Brainstorming: An instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative Learning. An umbrella term that covers many different methods in which students work together to solve a problem, complete a task, or create a product. Collaborative learning is founded in the concept that learning and knowledge building is social and requires active engagement from students.

Critical Thinking. The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments,

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data collection and organization, variable handling, data driven conclusion making and communicating over scientific issues.

Knowledge. A familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

Pedagogical Techniques. Essential resources that the teacher uses to enhance the pedagogical relationship between the students and the teacher in order to ensure learning. Different forms of application to achieve the objectives of a class.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Skill. The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

Sources: EuroHealthNet; Learn.org; Techtarget; Studiobinder; Mediacollege; Conceptartempire; Unity3d

Indicative literature

- Richard Williams, "O Kit de Sobrevivência do Animador"
- Isaac Kerlow, "The Art of 3D Computer Animation and Effects"
- Allan Brito, "Blender 2.8 - Guia Rápido"

Competences / Learning Goals

Key Competences
STEM / 3D Animation / Innovation

Knowledge
3D animation concepts:

- ✓ 3D animations' technical principles and workflows.
- ✓ Tools for creating 3D animations.
- ✓ Shortcuts for fast animations.

Knowledge – outcome assessment:
1. Understands the importance of 3D animations to address public health.
2. Understands the 3D animation technical principles and workflows.
3. Recognizes software basic features regarding rendering.
4. Is able to understand the importance of 3D animations to address pandemic challenges.

Skills (abilities/competences):
General: 3D animation basics, Imagination, Creativity
Specific:

- ✓ Animation of 3D elements by combining process knowledge, computational design tools and application requirements.
- ✓ Technical usage of 3D animation software.

Skills – outcome assessment:
1. Recognizes appropriate proficiencies necessary for 3D animation.

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2. Is able to understand the virtual environment.
3. Is able to identify the differences of multiple 3D animation software.
4. Can animate specific 3D objects.
5. Recognizes that 3D animation can improve public health.

Affective /Attitudes/Behaviour (*beliefs)*

- ✓ Make use of intellectual curiosity to solve problems.
- ✓ Using creativity skills on new technologies in the development process of the solution.
- ✓ Using imagination for designing real tools and materials.

Affective, Attitudes and behavior - *outcome assessment:*

1. Believes that is important to create awareness on how 3D animation can help the community.
2. Has intention to continue extending the skills and knowledge regarding 3D animation.
3. Is aware of the democratization of 3D animation for public health.
4. Attitude towards 3D animation.
5. Believes that is important to improve one's own personal capabilities.

Learning goals and outcomes

- ✓ Uses online tools to 3D animation.
- ✓ Analyzes models.
- ✓ Identifies 3D environments and basic features.
- ✓ Animates basic elements in a 3D environment.
- ✓ Exports animations.

Assessment methods

- ✓ Outcome assessment
    - Qualitative - project: creation of a 3D animation within a STEM context.
    - Quantitative – questionnaire - – impact assessment in terms of students' knowledge, skills, attitudes and behaviors

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content

- Animations in 3D environment
- Animate 3D objects. Basic animation programs.

Non-STEM content

- Brainstorming on 3D animation approaches.
- Group and public debates.

Digital learning objects

New:

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- 3D animation basic features: RIGGING and SKINNING (video and tutorial).
- 3D animation basic features: ANIMATION PARAMETERS (video and tutorial).
- 3D animation basic features: CAMERA ANGLES and TECHNIQUES (video and tutorial).
- 3D modelling software basic features: EXPORTING/RENDERING (video tutorial).
- Questionnaire – quantitative assessment of learnings.

Digital educational resources

New:
- Introduction of 3D animation (video and PowerPoint).
- Pedagogical glossary for technical terms and definitions (infographic).

Available resources (link):
https://drive.google.com/drive/folders/1I6DbhytMuTK1wI0KCeatXOajUd9_ge_y?usp=sharing

Teaching – Learning activities (lesson plan/ learning trajectory)

Principal target:
ICT classes.
8th grade (+/- 14 years old students).
ICT teachers integrate other colleagues in the enactment of the scenario (e.g., ICT, visual education, science and English teachers), as it aims to be interdisciplinary.

Lesson 1: Introduction of 3D animation

The teaching-learning script starts with a question "what is a 3D animation"?

- group discussion around the question "What is a 3D animation?"

Students are divided into groups and asked to share their thoughts on what 3D animation means. This activity will contribute to reveal the students' initial ideas of the topic, helping teachers understand their skills and knowledge on the subject. Also, this activity should be presented to the students as a theoretical background of the 3D animation and its practical applications, and will be important for teachers to introduce the subject on what involves 3D animation and the current limitations of scientific evidence. Examples: level of skill required for professional and complex animations, 3D animations can be more limiting regarding styles and shapes than 2D ones in some situations, the resource consumption of the rendering process.

- digital educational resource: pedagogical glossary for technical terms and definitions
- digital educational resource: 3d animation introduction (PowerPoint)

Introduction of 3D animations using a PowerPoint presentation with several examples in different fields of study: Architectural 3D Animations; 3D Character Animation; 3D Graphics; 3D Product Visualizations; Website 3D Animated Intros. Furthermore, several videos made with 3D objects in 3D environments will be presented.

Lesson 2: The democratization of 3D animation

- brainstorming on the question "what can 3D animations represent"?

Students are asked to search on GOOGLE, in groups, key definitions of a 3D animation and in which situations it can be used. Each group should produce at least three different sentences and examples; read them and select the main keywords for sharing, regarding the areas of expertise where 3D animations can

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be used. Then, they go to the flipchart or whiteboard and write the main keywords. The next step is a video presentation about the different types of animations. After, a discussion is mandatory about their previous definitions and keywords and their recent new knowledge about the topic learned. After a short conversation about the previous lesson, 3D animation and approaches are presented to be discussed. Also, this activity is important to provide awareness on public health challenges, their impact on STEM and their interactive parameters with specific examples, presenting ideas on how to tackle these issues resorting to 3D animation.

Lesson 3: The key principals of 3D animation

- digital educational resource: Key principles for 3D animation (video)

The principles for 3D animation will be presented: from concept and storyboards, compositing and special VFX, to editing and final output. Simple exercises will be done, and replicated by the students, demonstrating the steps for creating an animation.

- debate: "How can we 3D animate this object? E.g., a car engine."

The aim is to show different basic objects and discuss and reveal which basic elements can be used to animate the objects shown.

Lesson 4: 3D animation basic features: RIGGING AND SKINNING

The teaching-learning script starts with the presentation of the what is the animation rigging process, providing an individual hands-on approach.

- learning object: 3D animation tutorial about rigging (video tutorial)

A step-by-step video on how to complete the rigging process will be shown. And after, individually, students will replicate the basic functionality in the computer.

- learning object: 3D animation tutorial about skinning (video tutorial)

After a first approach on object rigging, a simple step-by-step tutorial will be provided explaining the skinning process and students will autonomously and individually do it.

- debate around the questions
  "What does rigging do?"
  "Why is the process of rigging important?"
  "How can we complete the skinning process?"

Lesson 5: 3D animation basic features: ANIMATION PARAMETERS

Students are introduced to parameters in 3D animation.

- learning object: types of parameters (video tutorial)
- learning object: tutorial (step by step)
- group work (the availability of laptops or tablets for group work is required)

Students are organized in groups (1 group – 1 Animation) and invited to create simple daily objects animation. After, they will present their work to the colleagues.

Lesson 6: 3D animation basic features: CAMERA ANGLES AND TECHNIQUES

Students are introduced to camera angles and techniques in 3D animation.

- learning object: camera settings (video tutorial)

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Students are shown the different settings to mimic real camera features, as focal length, depth of field, etc.

- learning object: techniques (step-by-step tutorial)

Other options for moving a 3D camera are similar to those in movie making, including truck, dolly, motion blur, orbit and pan.

- group work (the availability of laptops or tablets for group work is required)

Lesson 7: 3D animation basic features: EXPORTING/RENDERING

To finalize the first complete exercise in 3D animation environment, students will learn what is the process of EXPOR/RENDER, which differs from the normal process regarding 3D modelling.

- digital educational resource: 3D ANIMATION EXPOR/RENDER (manual)
- Quantitative assessment - questionnaire
- Presentation and Activity in groups (also works as qualitative assessment):

Students must present their animated objects and for each presentation, in groups, the other students need to identify which features used or which other solutions maybe used to improve to animation presented.

Lesson 7-forward:

After building and presenting their work, students are challenged to model other 3D objects in groupwork. This is the **School Project** described below.

Supplementary educational activities

Lesson 8, devoted to the preparation of the school project, includes:

1. Teleconference with STEM professionals (e.g., Engineers, Designers Medical Doctors, or researchers of PAFSE consortium):
Students make questions to experts with a particular focus on: a) future academic choices and career paths; b) identifying new professions in new fields of industry 4.0.

2. Visit to FABLAB:
Students make questions to experts with a particular focus on tools to create 3D animations. These activities are relevant for students' connections with possible STEM curriculums and careers. Students are shown the working environment and dynamic of a FABLAB.

School Research Project

Topics

- Importance of 3D animation.
- Technical features and principles of 3D animation.
- Possible applications of 3D animation in public health topic.

Research management, design and administration

Challenge: To animate an 3D object to address communicable diseases challenges

Method: Lesson 8 to 11 will be dedicated to the school research project. Students are organized in groups; each group addresses 1 object based on the daily pandemic challenges lived. The project challenges each group of students to: 1) identify and represent their progress in the form of essay responses and using Likert

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scales to show their improvement from the first lesson to the last; 2) animate and present an object with what they have learned throughout the teaching-learning sequences and the ideas that emerged during the teleconference with experts. A competition and reward for the best 3D objects will take place.

Teaching-learning process milestones:

1. Students will be able to propose solutions for 3D animation of basic objects.
2. Students will be able to communicate the findings, motivations and limitations of various 3D animations considered in the work process.
3. Students will be able to identify and communicate the importance of 3D animation to address pandemic challenges but also the role Innovation.
4. Students will be able to use technical argumentation to justify policy choices.

Teaching-learning process for school project (summary):

1. Development of materials (videos, tutorials, pictures).
2. 3D animation objects.
3. Presentation of the 3D animations in open schooling event.

Organization of the open schooling event:

1. Each project output (3D animation) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair) in a 3D prepared environment (all apparatus included).
2. Students will prepare a pitch on how 3D animation can address pandemic challenges. Technical speeches to motivate peers to new technologies and environments.
3. Students, parents, school community and relevant local stakeholders attend the event and are introduced on the topic on how 3D animation can be used to address pandemic challenges. Furthermore, the scenario has a multidisciplinary approach, such as in art, design, engineering and mathematics.

Data Analysis and Reporting

- Content Analysis.
- Presentation formats.
- Report writing.
- Development of presentation.

Target Audience for Recommendations

School community and local stakeholders: students, parents, municipalities, designers, engineers, and local enterprises.

Public Debate and Recommendations (based on research results)
Presentation of the 3D animations produced by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: 3D ANIMATION

Knowledge	
1. Understands the importance of 3D animations to address public health	**Question 1.1:** Which of the following sentences is NOT true? A) 3D animations are a useful resource to help raise awareness on appropriate behaviors during the pandemic, such as teaching how to put the mask and disinfect our hands often. B) 3D animations can make a person more aware of the environment and the community. C) 3D animations play an important role in increasing the digital footprint. **Question 1.2:** Which of the following sentences is NOT true? A) 3D animations represent a paradigm shift in public awareness. B) 3D animations are able to provide a model to improve the community's understanding on different abstract concepts. C) All of the above. **Question 1.3:** Which of the following applications of 3D animation regarding heath purposes is correct? A) Perform safer and more efficient diagnosis and treatments. B) Make treatment processes slower. C) Hamper the communication between professionals and patients. **Question 1.4:** Which of the following sentences is correct? A) 3D animation does not allow to create complex scenarios. B) 3D animation cannot portray the right scaling of objects. C) 3D animation is useful for virtual surgical planning. **Question 1.5**: Which public health emergencies can 3D animation be useful for? A) Create replicas of organs and skeleton parts for education purposes. B) Plan surgeries. C) All of the above.
2. Understands the 3D animation technical principles and workflows.	**Question 2.1:** How many axes can we manipulate in a 3D animation? A) 1. B) 2. C) 3. **Question 2.2:** What is the coordinate system used in the 3D animation software? A) Polar coordinate system. B) Cartesian coordinate system. C) Cylindrical and spherical coordinate system. **Question 2.3:** Where is the timeline usually displayed? A) At the top. B) At the right sidebar. C) At the bottom. **Question 2.4:** What is a 3D Viewport? A) It is the area showing objects in rendering-device-specific coordinates, in which the objects of interest are going to be animated and rendered. B) It is a collection of settings that determine model display. C) It is the setup that is required to change the settings of the animation. **Question 2.5:** What areas of interest are visible in the workspace? A) The viewport and the properties editor. B) The system's preferences and settings. C) All of the above.
3. Recognizes software basic features regarding rendering.	**Question 3.1**: What is the goal of the animation render process? A) To replace real objects with digital information. B) To create objects that will be displayed in the metaverse. C) To animate digital objects as closer to reality as possible. **Question 3.2**: Is it possible to render only a portion of the animation? A) Yes, by choosing the animation section option. B) Yes, by choosing the crop image area option. C) No.

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	Question 3.3: Which of the following daily activities can be improved by 3D animation? A) An architect showing a realistic design of a building. B) A mechanic engineer explaining how a specific motor part works. C) All of the above.
4. Is able to understand the importance of 3D animations to address pandemic challenges.	**Question 4.1**: Which of the following sentences is NOT true? A) The role of 3D animation in the hospital environment provides custom-made animations of equipment's specifications and medical procedure's processes to facilitate the learning curve. B) 3D animation helps show custom-made solutions that would otherwise be very expensive to prototype. C) All of the above. **Question 4.2**: Which of the following sentences represent an advantage of 3D animation in public health? A) 3D animation offers a way to create detailed spatial representations, achieved quickly and at little cost, and increases resource mapping more effortless. B) 3D animation helps the designers and end users visualize requirements, but it reduces accuracy. C) 3D animation only reduces costs. **Question 4.3**: Which of the following sentences is NOT true, regarding 3D animations during a pandemic? A) 3D animation is a powerful tool for providing a visual aid about the virus and help educate the communities. B) 3D animation can help people visualize the virus and help objectify a pandemic, from animating the virus itself, to how it spreads, how it functions, etc. C) 3D animation is not suitable to express something abstract in a concrete form. **Question 4.4**: In what situations can 3D animation help address pandemic challenges? A) Create 3D medical animations to explain what a pandemic is, rates of infection and ways to protect against infections. B) Help demonstrate the biology and mechanism of action (MoA) that viruses use to infect and destroy human cells. C) All of the above.
SKILLS	
1. Recognizes appropriate proficiencies necessary for 3D animation.	**Question 1.1:** Which of the following responsibilities is NOT required to be a 3D animator? A) To animate 3D objects based on provided specifications. B) To calculate effort estimations of the objects. C) To refine, optimize or correct 3D models. **Question 1.2:** Which of the following skills is NOT needed for 3D animation? A) Knowledge of coding. B) An eye for detail and good visualization skills. C) Knowledge of 3D animation tools such as 3DS Max, Maya, Zbrush, Blender. **Question 1.3:** Which of the following is NOT a type of object that can be animated? A) Engineering parts. B) Organic objects. C) None of the above. **Question 1.4:** Which of the following is NOT a benefit of 3D animation? A) Produce realistic objects' animations that can be solid to a spectator. B) Create scenes for a fraction of the cost compared to traditional recording methods. C) Provide simple views of objects with low detail.
2. Is able to understand the virtual environment.	**Question 2.1:** I feel able to understand the coordinate system used in 3D animation software. 1) definitely true... 5) definitively false. **Question 2.2:** I feel able to navigate the software interface and choose the right tools for the work. 1) definitely true... 5) definitively false. **Question 2.3:** I feel able to adopt 3D animation to help people visualize abstract concepts. 1) definitely true... 5) definitively false.

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	Question 2.4: Which dimensions of spatial context can be considered when animating 3D objects? A) Spatial context focused specifically on object properties, object relationships and perception of space. B) Comparison of 2D and 3D map variants. C) The cost of the 3D object's materials and components. **Question 2.5:** What types of virtual environments are most used to create immersive 3D experiences? A) Virtual reality and mixed reality. B) 2D Videos. C) Social media accounts. **Question 2.6:** Which of the following is NOT a feature of a 3D animation environment? A) Create a virtual habitat. B) Have a figurative appearance. C) Create a persona.
3. Is able to identify the differences of multiple 3D animation software.	**Question 3.1:** I feel able to identify the differences in the layout / options of distinctive 3D animation software. 1) strongly disagree… 5) strongly agree. **Question 3.2:** I feel able to work with / use different 3D animation software. 1) strongly disagree… 5) strongly agree **Question 3.3:** I feel able to identify the main limitations, as well as advantages of each distinctive animation software. 1) strongly disagree… 5) strongly agree. **Question 3.4:** Which of the following 3D animation software is more adequate for video game character design? A) Maya. B) Solidworks. C) ZBrush. **Question 3.5:** Which of the following 3D animation software is more adequate for prototypes' animations? A) Blender. B) Solid Edge. C) All of the above.
4. Can animate specific 3D objects.	**Question 4.1:** I feel able to create a 3D animation from scratch. 1) definitely true... 5) definitively false. **Question 4.2:** I feel able to modify the camera's properties for rendering an animation. 1) definitely true... 5) definitively false. **Question 4.3:** I feel able to animate low poly objects, as well as more complex meshes. 1) definitely true... 5) definitively false. **Question 4.4:** I feel able to determine / alter the lighting setup for 3D animation. 1) definitely true... 5) definitively false **Question 4.5:** I feel able to animate a whole set / scenery involving different 3D elements. 1) definitely true... 5) definitively false. **Question 4.6:** Which of the following stages is in the correct order? A) 1. Rigging & skinning, 2. Rendering, 3. Compositing & VFX. B) 1. Animation, 2. Rendering, 3. Compositing & VFX. C) 1. Rendering, 2. Animation, 3. Rigging & skinning. **Question 4.7:** Which of the following features is not required for 3D animation? A) Cameras. B) Lighting. C) Vectors.
5. Recognizes that 3D animation can improve public health.	**Question 5.1:** I feel able to create 3D animations that can help educate my community on specific subjects. 1) strongly disagree… 5) strongly agree. **Question 5.2:** I feel able to animate daily objects that can improve the community's quality of life. 1) strongly disagree… 5) strongly agree. **Question 5.3:** I feel able to create complex animations for my school to help ensure better teaching environments.

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	1) strongly disagree… 5) strongly agree. **Question 5.4:** Which of the following scenarios can take advantage of 3D animation? A) Zoom in on a molecular level. B) Deconstruct a medical device to show how it works from the inside. C) All of the above. **Question 5.5:** Which of the following objects can be animated in order to show how they work to the community? A) Face shields and protective eyewear. B) Specimen collectors and ventilators. C) All of the above.
Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that is important to create awareness on how 3D animation can help the community.	**Question 1.1:** The animation of 3D objects of my own can contribute to the global society's awareness about the importance of this field. 1) Extremely unlikely... 5) Extremely likely. **Question 1.2:** I am able to explain to my family and friends the importance of 3D animation. 1) strongly disagree… 5) strongly agree. **Question 1.3:** I think society still does not fully understand the importance of 3D animation. 1) strongly disagree… 5) strongly agree. **Question 1.4:** I feel 3D animation has great potential for changing the mindsets of the communities. 1) strongly disagree… 5) strongly agree. **Question 1.5:** I believe that 3D animation is important / useful in our daily lives. 1) strongly disagree… 5) strongly agree **Question 1.6:** I feel that the free use and dynamization of 3D animations in my community can be extremely important for educating the public on specific behaviours and decisions. 1) strongly disagree… 5) strongly agree.
2. Has intention to continue extending the skills and knowledge regarding 3D animation	**Question 2.1:** I feel that the 3D animation process is pleasant and exciting. 1) strongly disagree… 5) strongly agree. **Question 2.2:** I feel that the 3D animation is easy to accomplish. 1) strongly disagree… 5) strongly agree. **Question 2.3:** I feel highly motivated to pursue a career in this field of expertise. 1) strongly disagree… 5) strongly agree. **Question 2.4:** I feel curiosity to know more about 3D animation and improve my skills. 1) Extremely unlikely... 5) Extremely likely.
3. Is aware of the democratization of 3D animation for public health.	**Question 3.1:** I feel that the massification of 3D animation is beneficial for society, specifically regarding public health. 1) strongly disagree… 5) strongly agree. **Question 3.2:** I feel highly motivated to start contributing with my own 3D animations and share them with others with an open-source agreement. 1) Extremely unlikely... 5) Extremely likely. **Question 3.3:** I agree with the dissemination of 3D animations, free of royalties, to the empowerment of society regarding a better / smarter response of the health market in public health emergencies (like a pandemic). 1) strongly disagree… 5) strongly agree. **Question 3.4:** I agree that 3D animation can help people visualize abstract concepts (like viruses) and help objectify a pandemic, from animating the virus itself, to how it spreads, how it functions, etc. 1) strongly disagree… 5) strongly agree.
4. Attitude towards 3D animation.	**Question 4.1:** For me, the process of 3D animation is: pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad

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	worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable
5. Believes that is important to improve one's own personal capabilities.	**Question 5.1:** I feel 3D animation helps me expand my knowledge of art. 1) strongly disagree… 5) strongly agree. **Question 5.2:** I feel 3D animation helps me to develop my creativity. 1) strongly disagree… 5) strongly agree. **Question 5.3:** I feel 3D animation helps me lose my fear of making mistakes. 1) strongly disagree… 5) strongly agree.

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16. Specifications for an educational scenario on the topic "Vaccinations - how does the immune system learn?”

Main partner responsible

Adam Mickiewicz University, Poznań, Poland

Overview

Vaccinations are considered the most effective weapon that humanity has created to fight infectious diseases. However, researchers note that immunization has become a victim of its own success. Thanks to population vaccinations, we are unfamiliar with high mortality due to infectious diseases in childhood and severe complications following re-exposure to various diseases.

Scientific content and its relevance to public health education

Understanding the decisive importance of personal behavior for the societal good during an epidemic.
- Visualization and active inquiry of epidemiological parameters such as cases, deaths, asymptomatic cases, infectivity, healthcare system capacity, and the epidemic curve, which are commonly referred to in the public sphere during an epidemic.
- Understanding the importance of vaccination and conducting it according to medical professionals' orders.

Awareness of the meaning of herd immunity and how public behavior can influence it (e.g., not vaccinating their children, engagement in antivaccination movements)

Estimated duration

Six teaching hours, organized in continuous two-hour periods if possible. Proposed lessons should be conducted during biology lessons..

STEM Content

- Fundamental concepts of biomedical sciences (e.g., communicable diseases, infectivity, epidemic).
- Function, use, and nature of scientific models.
- Introduction to transdisciplinary issues, such us scientific modelling – Convergence of sciences to handling with complex problems.
- Use of mathematics in natural sciences.
- Scientific work on authentic problems.
- Authentic scientific data-driven decision making.
- Importance of scientific work for civic decision-making.
- Explains the differences between specific and non-specific parts of the immunological system
- Presents the vital functions of the immunological system and possibilities of gaining immunity and protection through vaccination;
- Shows the composition of the vaccines
- Shows the importance of vaccination programs and herd immunity
- Presents the importance of vaccination in society, also in historical aspect in protecting from epidemics and the high death rate from infectious diseases.

Content glossary

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A vaccine is a preparation that, by assumption, mimics a natural infection and leads to the development of immune memory analogous to that obtained by the body during the first contact with a natural pathogen (bacteria or virus).

Antibody (synonymous term: immunoglobulin) **-** a type of protein secreted by plasma cells (i.e. stimulated B lymphocytes) in the course of a humoral immune response. It is characterized by the ability to bind to a specific antigen. As part of the immune system in humans and other vertebrates, antibodies play an essential role in promoting defence responses of the body against bacteria, viruses, and extracellular parasites, and to a much lesser extent, fungi and intracellular parasites and bacteria.

Antigen - In immunology, an antigen (Ag) is a molecule or molecular structure (this could be of foreign or self nature) that can bind to a specific antibody or T-cell receptor. Most self antigens will not elicit an active immune response characterised by antibody production, in contast to most foreign antigens that will induce antibody production and elicit an active immune response. The latter are classified as an immunogens. The presence of such antigens in the body may trigger an immune response. The term antigen originally referred to a substance that is an antibody generator. Antigens can be proteins, peptides (amino acid chains), polysaccharides (chains of monosaccharides/simple sugars), lipids, or nucleic acids. In a more general sense, an antigen is any chemical that specific antibodies can detect in a variety of diagnostic methods. The concept of an antigen is broad and context-dependent - an antigen can be defined as an entire bacterial cell which carry vast number of antigens or only one of the proteins on its surface.

Cellular immunity - conditioned by cells (T lymphocytes), consisting in a direct attack of pathogens by lymphocytes, but also the regulation of humoral immune responses of B cells.

Herd immunity (also known as population immunity, or group immunity) protects those who are not immune, by vaccinating a high percentage of the population. This concept is known as artificial herd-immunity and was created based on the observation that the presence of people immunized against a given disease in the population reduces the likelihood of spreading this disease also in non-immunized people. This concept applies to diseases transmitted from person to person (not including diseases such as tetanus, tick-borne encephalitis, rabies, etc).

Humoral immunity - is the aspect of immunity mediated by macromolecules - including secreted antibodies, complement proteins, and specific antimicrobial peptides - located in extracellular fluids. Humoral immunity is named because it involves substances found in the humors or body fluids. It contrasts with cell-mediated immunity. Humoral immunity is also referred to as antibody-mediated immunity.

Immune amnesia is when the wild measles virus "resets" previously acquired anti-infective immunity by eliminating immune memory T-cells. During this, the virus eliminates regulatory antigen-specific T cells that provide a vital role in regulating antigen-specific cellular and humoral memory responses.

Immune memory is the ability of the immune system to respond rapidly and efficiently towards a given pathogen, based on the targeted action of antigen-specific memory T and B cells. Immune memory is long-lived and subjected to constant updating via natural and/or artificial re-exposure to the specific pathogen/pathogenic components.

Immune serum - serum with a high content of natural or artificially produced antibodies specific to a given antigen, obtained from natural or artificial immunization with a specific antigen (viral, bacterial, toxins, cellular, tissue fragments, soluble antigens such as proteins, polysaccharides, etc.). The antiserum is sometimes used for diagnostic and therapeutic purposes in serology, microbiology and molecular biology as a reagent for studying the homologues of antigens. It is also a preparation containing ready-made antibodies that immediately destroy hostile antigens, which is obtained from human or animal sources.

Primary immune response - the immune response following the first exposure to an antigen within 3-14 days. A primary immune response ceases after a few weeks following primary exposure to a pathogen.

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Repeated exposure to the same antigen/pathogen induces a secondary immune response that is much faster and stronger than the primary. This is know as immunological memory.

Specific immunity (specific immune response system, acquired resistance) - the type of immunity dependent on the recognition of antigens by antibodies and antygen-specific receptors on T lymphocytes (T-cell receptor, TCR) and B lymphocytes (B-cell receptor, BCR). It takes several days to develop this type of immunity, but the mechanisms, once activated, effectively fight pathogens, and upon second and further encounter with the same antygen this respons is rapid and very efficient in clearing out the antygen in less than 24-48h. The process is specific, i.e., it acts on a specific pathogen factors. Specific immunity is divided depending on the duration of action, i.e., passive (temporary) and active (permanent). Both are purchased in two ways: natural (e.g., passive - antibodies from the mother, active – following exposure to the pathogen during infection) and artificial (passive - antibodies in transfused serum, active - following vaccination with given antigen/s).

The herd immunity threshold is defined as the percentage of people that needs to be vaccinated/immunised in a population so as to stop the spreading of disease. Typically, 90-95% of the immune population is required. Also this percentage will vary as it depends on the type of the disease, pre-existing immunity of the population and the rout of tits transmission. However, the percentage of immunized persons varies from disease to disease. For example, in the case of measles, this "safety threshold" is as high as 95%, for whooping cough, it is estimated at 92-94%, diphtheria and rubella at 83-86%, mumps at 75-86%, which means that the number of people in the population it must be resistant to the disease to prevent infections on a larger scale

The non-specific immune response, which occurs not only in humans and vertebrates but also in all multicellular organisms, is based on mechanisms developed early in phylogenesis. After pathogenic microorganisms cross the physical barrier of the body, which is the skin (e.g., as a result of wounds, burns) and the mucosal epithelium, numerous and complex defense mechanisms are activated. The non-specific immune response is the direct and immediate line of defense of organisms against pathogens. This could include cellular non-specific immune responses as well as barrier/chemical non-specific immune responses.

Vaccination calendar - the preventive vaccination program, popularly known as the vaccination calendar, is developed by the Chief Sanitary Inspectorate each year. It contains a list of compulsory and recommended vaccinations and the rules for carrying them out. In some cases, e.g., due to a delay in the implementation of vaccinations due to the patient's health condition, or the child's return from another country, it is necessary to develop an individual vaccination schedule determined by the doctor for the child.

Pedagogical glossary

Argument - In logic and philosophy, an argument is a series of statements, called the premises, intended to determine the degree of truth of another statement, the conclusion. The logical form in a natural language can be represented in a formal symbolic language. Instead of natural language, formally defined "arguments" can be made in math and computer science. (https://en.wikipedia.org/wiki/Argument). In science education, argumentation is considered a core skill that can empower young people to attain scientific literacy, develop critical thinking, reasoning, communicative and metacognitive skills, and other subsidiary skills. (https://www.sciencedirect.com/science/article/pii/S0883035516300313). Argumentation refers to the process of constructing and negotiating arguments (Osborne et al., 2004), either individually or cooperatively, which can be expressed either verbally or in writing (Driver et al., 2000). In its simplest form, an argument typically involves a clearly stated claim about a specific issue, along with supporting evidence and articulated reasoning, connecting the claim with the evidence (Jimenez–Aleixandre et al. 2000).

Claim – Evidence – Reasoning
In Toulmin's Model of argument, we might find:

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Claim: Statement of an opinion/position.
Data: Evidence in support of the claim
Warrant: Explicates a connection between the data and the claim. e.g., Assumptions
Backing: Strengthens the warrant.
Rebuttal: Acknowledges (and if possible weakens) possible counter-claims and counter-arguments.

Brainstorming - is a technique derived from social psychology that aims to improve group decisions. Brainstorming is also a form of didactic discussion used as one of the teaching methods. Then it is included in the activating methods, which is a subgroup of problem methods. It is one of the so-called heuristic methods. Brainstorming is used to generate ideas to solve problems that are generally new and to which most participants do not know the answers. In one version, it consists of two stages:

- Participants are encouraged to freely submit ideas and exchange views in the first stage, subject to no criticism whatsoever. All ideas are saved, or the session is recorded on tape.
- In the second stage, an expert or a group of experts not participating in the first stage reviews the results and tries to filter out ideas that make sense.

Research has shown that while brainstorming can be very effective, its effectiveness can also be easily lost. In particular, among factors damaging its effectiveness are, for example, the presence of a powerful, dominant personality in the first stage, too high ambition of some participants, preventing others from having a say, little openness to new ideas of experts evaluating arguments, the participant's willingness to change the topic to something unrelated to the task, etc. (see group thinking syndrome).

Content analysis is, by definition, the study of textual messages, both written (books, newspapers, documents, websites) and oral (broadcast via radio and television). The purpose of the analysis is to reduce the content of the entire text to its most essential meanings: the most frequent words, key threads, prevailing grammatical and semantic forms, etc. This method is also used in didactics as a tool that allows you to find answers to a given question by reducing the content of the entire message to crucial information. It allows you to search for key terms or concepts important from the point of view of the discussed content.

Discussion - allows you to prevent misunderstandings, solve problems - or at least understand them better. Discussion - Discussion (this is a term of Latin origin: discutere - to break up, spread out) - is an oral or written exchange of views on a specific topic aimed at reaching common conclusions. Discussion is an activity carried out in a group of two or more people and aimed at solving a problem. It does not have a structured form like the Oxford debate, but well-structured arguments are the essence of a good discussion.

It is a process by which theses are presented, supported by competent arguments, and allows other people to test their views or present counter-arguments.
Discussion allows you to prevent misunderstandings, solve problems, or understand them better.

Elevator pitch - a presentation in an elevator - is a brief description of an idea, product, or company that explains the concept so that every listener can understand it in a short time (approximately 3 minutes). This description usually explains who it is intended for, what it is for, why it is needed, and how it will be implemented. Finally, when describing an idea, a person also presents their skills and goals and arguments for why they would be productive and the best person to have in a team, company, or project. An elevator showcase doesn't have to cover all of these but usually at least explains what an idea, product, company, or person is and its value.

Flipped classroom - The flipped or inverted classroom is a new and popular instructional model in which activities traditionally conducted in the classroom (e.g., content presentation) become home activities. Activities typically constituting homework become classroom activities. The teacher helps the students instead of merely delivering information in the flipped classroom. In contrast, the students become

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responsible for their learning process and must govern their own learning pace (Lai & Hwang, 2016). It offers more opportunities for a teacher to engage students in the process of learning but also shifts more responsibility for learning from a teacher to the students. At the same time, there is a shift in a perception of a teacher who is not a sage on a stage; now, a teacher is more like a guide from the side. https://www.sciencedirect.com/science/article/pii/S0360131518302045

IBSE – inquiry-based science education, inductive approach in teaching and learning science and technology. Inquiry-based learning is based on recognizing that science is essentially a question-driven, open-ended process of constructing coherent conceptual frameworks with predictive capabilities. Students must have personal experience with scientific inquiry and engage in its practices to be enculturated in these fundamental aspects of science. Inquiry learning refers to the active learning processes in which students are inevitably engaged. Inquiry-based teaching is a bit more flickering term and less precise in literature. IBST is a process connected with involving students in inquiry activities with questions that are meaningful to them (e.g. generated from their own experiences) and with the explicit aim to develop coherent knowledge and rigorous understanding of phenomena, as well as an understanding of how scientists study the natural world and what ideas they have developed in the process. To achieve that, the teacher needs to prepare an ingenious and planned scaffolding for assisting the students through modeling and coaching, particularly by using questioning strategies.

Mind maps and concept maps - are techniques for visualizing information in the teaching process. Some of them are conceptual maps, mind maps, conceptual diagrams, visual metaphors, semantic networks, etc. (Eppler, 2006; Parikh, 2015). A concept map is a top-down diagram showing the relationships between concepts, including cross-connections and manifestations (Eppler, 2006). Since concepts are very clearly connected, concept maps represent knowledge structures as a whole (Nousiainen, 2012). According to Usta and Ültay (2016), McClure, Sonak and Suen have emphasized that concept maps can be used as a learning strategy, as a teaching strategy, as a strategy for planning curriculum, and as a means of assessing students' understanding of science concepts (Usta & Ültay, 2016). Mind maps were first constructed by T. Buzan (Buzan & Buzan, 1996). Buzan used Habert's ideas to develop mind mapping as a method of note-taking based on making notes as brief as possible and as "interesting to the eye" as possible by using visual effects (Abi-El-Mona & Adb-El-Khalick, 2008). Mind mapping represents knowledge by organizing it in the form of a network or other non-linear diagram (Dhindsa & Anderson, 2011). Mind maps are composed of a central idea, keywords (edges), and nodes (Kedaj, Pavlíček, & Hanzlík, 2014). The main idea can be a physical phenomenon or a concept treated during a particular class. The keywords branch from the central idea, showing connections between the main concept and specific details. These elements can be presented in the form of images, formulas, or experiment sketches. Images or sketches are most often represented in color. In this way, both brain hemisphere activation is achieved (Buzan & Buzan, 1996; Seyihoglu & Kartal, 2010). Mind maps are used in all situations involving the need for learning and any form of thinking (Kovačević & Segedinac, 2007).

Models and the process of scientific modeling are core components of human cognition and scientific inquiry. Models as tools are used in the classroom for exploration, synthesis, prediction, and knowledge construction. Building models can help students improve their understanding of natural phenomena or complex systems. Still, it can also facilitate their understanding of the nature of science as an enterprise that is primarily concerned with extending and refining models (Gilbert and Rutherford 1998, Linn, 2003). In its simplest form model is a representation of a phenomenon or object.

Oxford debate is a type of argument exchange that helps discuss a thesis. The opponents of the thesis and its defenders are debating. They are chaired by the marshal, assisted by a secretary who watches over the time and sequence of statements. It comes from the University of Oxford. Its crucial element is an adequate selection of arguments and counter-arguments. Its course includes:

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Commencement - when the Speaker starts a debate, he informs the parties about its principles and subject.
The debate between arguing parties - The floor is given alternately to individual parties. The side that defends the thesis begins. Statements are structured as arguments.
The audience's voice - to be admitted to the debate, one has to attract the marshal's attention. If they give the floor, the person introduces himself (which is written down by the secretary) and only starts to express his opinion.
Summary - both sides summarize all the speeches. They can provide answers to the counter-arguments of the opposing parties and support their views with additional arguments.
Vote - the final part of the debate is voting. Traditionally in Oxford, it is done through an exit through a door. Nowadays, the most common vote is by show of hands in other cases.

Project-based learning - Project-based learning (PBL) or project-based instruction is an instructional approach designed to give students the opportunity to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world. Project-based learning is more than just "doing a project," in the way you might remember from your school days. As the Buck Institute for Education (BIE) explains, with PBL, students "investigate and respond to an authentic, engaging, and complex problem or challenge" with deep and sustained attention.1 ArchForKids, an organization that provides STEAM programs for young learners, puts it even more succinctly: PBL is "learning by doing."

Problem-based learning - Problem-based learning (PBL) is a student-centered approach in which students learn about a subject by working in groups to solve an open-ended problem. This problem is what drives motivation and learning. Rather than teaching relevant material and subsequently having students apply the knowledge to solve problems, the problem is presented first. PBL assignments can be short, or they can be more involved and take a whole semester. PBL is often group-oriented, so it is beneficial to set aside classroom time to prepare students to work in groups and to allow them to engage in their PBL project.

Scientific modeling is a process that allows students to use a model in a way that model serves three functions: represents, explains the phenomena or object, and allows for predictions. Scientific modeling seems to be promising in scaffolding learners' understanding of the complex processes of science through a building, testing, revising, and applying models. Scientific modeling is connected with:

I Modeling skills, and this involves
• Model formulation
• Identification of model components
• Comparing and contrasting models of the same phenomenon
• Model evaluation and formulating ideas for improvement
• Model validation through comparison with phenomena in the same class
II. Metacognitive knowledge about the modeling process: explicit description and reflection on the significant steps of the modeling-based cycle
III. Meta-modeling knowledge: epistemic knowledge about the
• Nature of models (3 elements – representation, explanation, and prediction)
• Purpose or utility of models

According to them, this can be: planning, organizing, analyzing, and solving problems, designing projects, preparing speeches and presentations, writing, making notes, lecturing, and similar

Visualization - In short, Visualization is the graphical display of information. Its purpose is to provide the viewer with a visual means of processing the data or information. It is important to note that for a visualization to be effective, it must draw upon the knowledge base of the viewer. If the viewer does not possess the knowledge to understand the graphical entities and their relations, the Visualization does not achieve its goal. Visualization has many applications. For the most part, they can be classified into two categories:

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- Data Exploration
- Communicating Information

Visualization is creating or recreating imaginary or natural scenes within one's mind. However, the term "visualization" can be misleading because visualizing involves more than just imagery. The more senses utilized, such as touch, sound, and taste, the more influential the result.
In the Visualization of ideas and the expression or representation of our ideas, we can bring something more clearly into consciousness. A drawing might be seen as an externalization of a concept or idea. Drawing, and the related visualization that results from drawing, helped children construct meaning for themselves and share their ideas with others and across contexts.
The terms "visual" and "visualization" are often used in external representations, from depictive ones like photographs, videos, and 3D models, to simplified and abstracted line drawings and even transient visual referents such as gestures. Formal and relatively well-developed visual codes such as flow charts, networks, and sign languages employ symbols that may be remote from their visual referents, with a vocabulary and grammar of their own.

Competences / Learning Goals

I. Knowledge (Core Concepts)
a) Transdisciplinary concepts: scientific modeling, graphs in science.
b) Specific content concepts: communicable diseases, epidemic, pandemic, disease transmission route, vaccination, viral diseases, bacterial diseases.

II. Skills
a) General skills: critical thinking, reflective thinking, problem-solving, decision making, collaboration and communication within small groups, and presentation skills.
b) Specific skills: use of scientific models, scientific data collection, analysis and interpretation, variable distinction and handling, scientific hypotheses testing and question answering, data-driven conclusions making, discussing science topics, scientific conclusions presentation and interpretation, and constructing an argument.

III. Attitudes (Affective domain)
a) Attitudes and values: appreciation of vaccination – positive meaning of it for society, appreciation of the vital importance of pharmaceutical and non-pharmaceutical interventions for the limitation of disease spreading, appreciation of the importance of models in scientific research, shaping of positive attitudes towards science during a health crisis, roughly empathizing with scientists in terms of the complex nature of their work and the necessary decision making, upgrading of the position of science in students' personal value systems, comprehension of the role of discussion and disagreements within the scientific community.
b) Behaviours: Constant application of scientific argumentation towards a discussion about bacteria.

Classroom organization requirements

All special classroom organization requirements are proposed below directly in the lesson's activity.

Prerequisite knowledge and skills

- Microbial nature of contagion by communicable diseases.
- Examples of historical and modern cases of epidemics and pandemics – viral and bacterial diseases and how vaccinations helped with protection before them.
- Fundamental hygiene rules as pharmaceutical interventions with the use of vaccination.
- Ability to interpret infographics.

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- Ease in making digital presentations.
- Ease in constructing an argument.

School research project

Topics and inquiry processes

A. Introduction - viruses and pathogenic bacteria are everywhere - why don't we get sick constantly?
B. Antibodies - the most sophisticated form of fighting pathogens. Why do antibodies sometimes not match antigens?
C. Vaccines - What Are They?
D. The panic virus - vaccination in the social dimension.

I. Research management and design
Social research - surveying your community:
Who in the family and against what diseases were vaccinated, and how many times?
Was the immunization schedule different in the parents' day and now? What are the differences? Where do they come from? Are these changes good?
What are vaccinations - for what purpose do we carry them out (protection against severe course and death, not complete protection against infection)?
A problem for social research - what is the perception of vaccination in the immediate area?
What arguments are used by those who are against, and what are those for?
Argument types - infographics and https://zpe.gov.pl/a/rozpoznwanie-argumentow/D5X5kOOV0

II. Data analysis and reporting
Students gather data for the following questions and analyze it with the help of a teacher.

III. Target audience for recommendations
The rest of the class, maybe teachers and students of the entire school, proves the project is presented at a school event.

IV. Public debates and recommendations
Presentation of the project outcomes within a school event.

Teacher professional development actions

Teacher professional development on:

- Inquiry-based teaching and learning in accordance with the learning objective areas involved (content knowledge, inquiry skills, nature of science).
- Issues concerning the use of models in science and STEM education.
- STEM literacy aspects are promoted through the educational scenario (use of scientific models, authentic problem solving, inquiry-based teaching and learning, attitudes towards science, science within the societal contexts) and the issues of scientific and health numeracy.
- Project-based teaching and learning and principles and techniques of collaborative learning.
- Argumentation – structure and use of it in debates and discussions.
- The utilization of Digital Learning Objects in the learning process.
- The main idea of introducing scenarios into the school – presenting to the teachers the possibility of doing only the chosen activities from the scenario which answer to the needs of their group.

Digital Learning Objects (DLOs) and Digital Learning Resources (DERs)

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DREs created especially for the needs of the PAFSE project

I. What we owe to vaccinations (infographics)
II. Vaccination calendar (infographics)
III. Covid and obesity (infographics)
IV. Covid and sex (infographics)
V. Covid and age (infographics)
VI. Epidemic, pandemic, and endemic (infographics)
VII. Vaccine ingredients (infographics)
VIII. Vaccines and collective resistance (infographics)

Available resources (link) :
https://www.dropbox.com/sh/bebi3dkm6n9ng37/AADskxkANKBEwIP6OLv-yz_ma?dl=0

Supplementary Educational Resources (SERs)

Lesson 1

how the immune system adapts, dendritic cells
https://vimeo.com/227178817
how the immune system works
https://www.youtube.com/watch?v=lXfEK8G8CUI
you are immune to any disease
https://www.youtube.com/watch?v=LmpuerlbJu0
the immune system in covid infection and gender
https://www.science.org/doi/10.1126/science.abe7199?.
resistance and gender
https://www.nature.com/articles/nri.2016.90
lifestyle and the immune system
https://www.mp.pl/pacjent/dieta/wywiady/90034,od-czy-zalezy-odpornosc
obesity and the immune system and susceptibility to infections (COVID)
https://www.frontiersin.org/articles/10.3389/fnut.2020.597600/full
How stress (cortisol) has an immunosuppressive effect
https://www.frontiersin.org/files/Articles/691480/fimmu-12-691480-HTML/image_m/fimmu-12-691480-g001.jpg
Immunodeficiencies
https://www.mp.pl/pacjent/hematologia/choroby/273884,niedobory-odpornosci

Lesson 2

how antibodies work, animation
https://vimeo.com/227176366
innate immunity
https://vimeo.com/227178345
designing antibodies (too scientific, so far I do not have better)
http://opig.stats.ox.ac.uk/webapps/newsabdab/sabpred/abodybuilder_results/20220125_0874392/

Lesson 3-4

COVID vaccinations, types of vaccines, stage of clinical trials, etc.
https://covid19.trackvaccines.org/
how we make attenuated vaccines
https://vimeo.com/227180098

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Information on the types of vaccines
https://szczepienia.pzh.gov.pl/wszystko-o-szczepieni/jakie-sa-rodzaje-szczepionek-2/
Vaccines against covid19
https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/treatments-vaccines/covid-19-vaccines

Lesson 5-6

Balance of profits and losses against vaccinations
https://www.youtube.com/watch?v=zBkVCpbNnkU
vaccine wars, vaccinations through the years
https://www.science.org/content/article/here-s-visual-proof-why-vaccines-do-more-good-harm?.
vaccinations and autism, a comic book about Wakefield
https://thenib.com/vaccines-work-here-are-the-facts-5de3d0f9ffd0
metal and salt:
https://twitter.com/qtent2016/status/916764089644453890?lang=de
how much formaldehyde is in the pear:
https://skeptics.stackexchange.com/questions/32562/does-a-pear-contain-600-times-more-formaldehyde-than-a-vaccine
immune amnesia
Are we at risk of measles?
https://www.mp.pl/szczepienia/specjalne/230391,amnezja-immunologiczna
https://www.science.org/content/article/how-measles-causes-body-forget-past-infections-other-microbes
the effectiveness of vaccinations in protection against hospitalization and death
https://pbs.twimg.com/media/FJeaMC5XEAQWsbg?format=jpg&name=large
variolacja / variolizacja-more information https://pl.wikipedia.org/wiki/Wariolizacja
vaccine safety
https://szczepienia.pzh.gov.pl/wyniki-bezpieczenstwa-podania-dawki-przypominajacej-szczepionki-prasz-covid-19-u-doroslych/
From the EMA COVID-19 vaccines: development, evaluation, approval and monitoring (https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/) treatments-vaccines / vaccines-covid-19 / covid-19-vaccines-development-evaluation-approval-monitoring)
conspiracy theories - link to the textbook of conspiracy theories https://www.climatechangecommunication.org/wp-content/uploads/2021/12/ConspiracyTheoryHandbook_Polish.pdf
recognizing arguments
https://zpe.gov.pl/a/rozpoznwanie-argumentow/D5X5kOOV0
tuberculosis vaccination programs
https://www.mp.pl/szczepienia/specjalne/190810,programy-szczepien-paniemko-gruzlicy-w-europie

Teaching - learning activities

Lesson 1 - introduction - viruses and pathogenic bacteria are everywhere - why don't we get sick constantly?

Teaching phase according to the inquiry & project-based instructional model: Engagement – Externalisation of students' initial conceptions – Initiation of reconstruction/completion of students' initial conceptions

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Objectives
In terms of knowledge
Student:

- *defines the functions of the immune system,*
- *lists the blood counts involved in the immune reaction,*
- *lists factors that increase the probability of contracting infectious diseases*

In terms of skills
Student:

- *analyzes the mechanism of action of the cellular and humoral immune system,*
- *designs an immune system cell character card,*

In terms of attitudes
Student:

- *recognizes the importance of immune system responses in fighting bacterial and viral infections.*

Teaching methods

- *visualization,*
- *group work*
- *discussion*
- *model building*
- *Content analysis*

Course of the lesson:

Activity 1
Discussin about immunity.
Creation of a mind map representing the immune system's role

Activity 2
Searchig for and listing factors that influence the likelihood of contracting infectious diseases.
Uses of DLO

- age (infographics)
- sometimes sex (infographics)
- obesity (infographics)
- diet:

https://www.mp.pl/pacjent/dieta/wywiady/90034,od-czy-zalezy-odpornosc

- lifestyle (e.g. getting enough sleep)
- genetic factors
- stress

Activity 3
Problem – based learning - Problem question: What can we do to limit the spread of infectious diseases?
Brainstorming on proposals for measures to reduce the spread of infectious diseases.
Task analysis - case study (based on materials from: https://public.tableau.com/app/profile/panoptical/viz/1854CholeraOutbreak-SnowsMap/CholeraAnalysis and https://medium.com/public-health/john- snow-early-big-data-science-d62b4dacd71b)

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Activity 4

The immune system can be visualized as a team of superheroes whose task is to ensure the smooth functioning of the city. Each of the superheroes has specific skills - they can perform specific tasks. In the beginning, students create superheroes by creating a character sheet (EXAMPLE). Later, they form teams that will meet with various guests in the city. Their task will be to recognize whether a given visitor is a friend (e.g., intestinal microbiome) and when to get rid of the visitor (pathogens).

What does the immune system do when it comes into contact with a pathogen?

humoral and cellular immunity (division according to the mechanism of action of the immune system)

division according to the degree of involvement of the immune system (active and passive, natural and artificial)

antibodies

immune memory cells

mechanisms of non-specific and specific defense

Education materials

Covid and obesity - infographic,

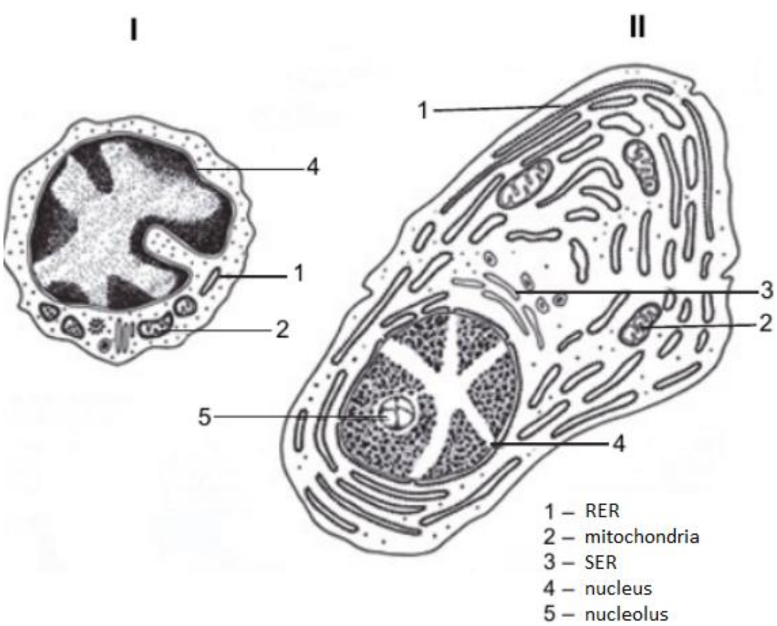
Covid and sex - infographic,

Covid and age – infographic.

Evaluation task

Task 1

Figure I shows the structure of the B lymphocyte, and Figure II shows the structure of the plasmocyte formed from this lymphocyte. The functions of the plasmocyte are the production and secretion of antibodies. Both cells were stained to visualize cellular structures. Note: The size proportions of both cells were respected in the figures.



a) based on the analysis of the figures, indicate two differences in the internal structure of the plasmocyte in comparison to the B lymphocyte.

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b) pick one feature, and show the relationship between the structure of the plasmocyte and its function related to the production of antibodies.
c) Select and mark the three characteristics of humans' immunity from administering serum containing antibodies from the listed characteristics.
specific
non-specific
passive
active
natural
Artificial
Solution:
a) Sample responses
In the nucleus of the plasma cell, there is a large nucleolus that cannot be seen in the B lymphocyte. In the nucleus of the plasma cell, a more relaxed chromatin is visible.
More extensive coarse endoplasmic reticulum in the plasmacyte compared to the B lymphocyte.
The B lymphocyte has a small amount of cytoplasm and cell organelles, while in the plasmacyte, they are expanded. The plasmocyte has a greater ratio of cell volume to nucleus volume.
b) (0−1) Exemplary responses
A plasma cell has a very strongly developed rough endoplasmic reticulum, where proteins are produced (for export), and the antibodies produced and secreted by this cell are proteins.
There is a large nucleolus in the nucleus of the plasma cell, indicating the intensive production of ribosome subunits necessary for synthesizing proteins/antibodies.
c) (0−1) Correct answer A, C, F

Lesson 2 Antibodies - the most sophisticated form of fighting pathogens. Why do antibodies sometimes do not match antigens?

According to the inquiry & project-based instructional model, the teaching phase: Continue the inquiry phase.

Objectives
In terms of knowledge
Student:
- *describes the structure of an antibody (light chain, heavy chain, hypervariable region, epitope, paratope)*
- *defines immunity: natural and artificial, active and passive.*
- *lists examples of natural and artificial resistance.*

In terms of skills
Student:
- *designs antibodies,*
- *plans a scheme of how the immune system works in case of being bitten by a dog or a snake,*

In terms of attitudes
Student:
- *shapes pro-health attitudes for the proper use of serum and vaccinations.*

Methods
- *Brainstorming,*
- *visualization,*
- *Content analysis.*

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The course of the lesson:

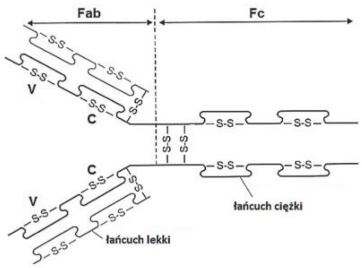
Activity 1
Students create a definition of antigen and antibody, then watch an animation on this:
https://www.youtube.com/watch?v=_N1xX49AqwQ

Activity 2
Students draw antigens. They are then asked to (genially) design their antibody for attaching to the randomly selected antigen.
https://view.genial.ly/62a4d597ad3b5100188cd91b/presentation-antigens-and-antibodies

Activity 3
Intoduction to types of immunity
Students maintain different cases - dog bite, snake bite, getting ready for a trip to Africa, and their task is to develop their immune system work pattern.

Evaluation tasks

Task 1. M 2019
The diagram shows the structure of the antibody molecule - IgG immunoglobulin. This molecule consists of four polypeptide chains linked by disulfide bridges:
• two of the same heavy chains
• two same light chains.
The part of the Fab fragment marked with the letter V in the diagram is characterized by high structure variability - each type of antibody has a different spatial structure in this area. In contrast, the Fc fragment is constant, i.e., the same for all antibodies in a given class.



Based on: J. Gołąb, M. Jakóbisiak, W. Lasek, Immunologia, Warsaw 2002.

1.1Based on the information provided and your knowledge, determine the role of the Fab fragment and the role of the Fc fragment of this antibody. Choose an answer from 1–3. and write it in the designated place.
Fab fragment ……………
Fragment Fc …………… ..
1. binds specifically to specific antigens.
2. binds to the light chains of other antibodies.
3. it attaches to receptors on the membrane of effector cells of the immune system.
Solution Fab Fragment - 1. Fc Fragment - 3.

1.2. Enter the number of disulfide bridges that stabilize the 4-order structure of the immunoglobulin shown. Indicate them in the drawing.
Solution: four / 4 (disulfide bridges)

1.3. Mark the correct ending of the sentence - choose an answer from AB and an answer from 1 to 4.

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A.	Vaccine	the administration of which induces immunity	1. active natural.
			2. artificial active
B.	Immune serum		3. passive natural
			4. artificial passive

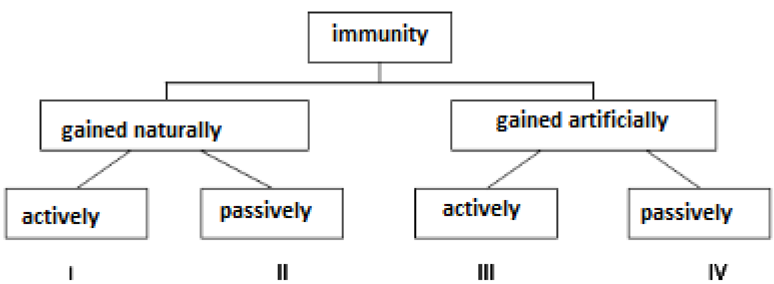
Solution: B4

Task 2. (0–1) 1.4 / NF, June 2016
Select and mark in the table answer A or B, which is the correct ending of the sentence below, and its justification from answers 1–3.
Immunity is obtained as a result of immunization

A.	specific	because	1.	this type of immunity is acquired through natural contact with the antigen after the disease has passed.	
			2.	this immunity is obtained after introducing into the organism ready-made antibodies produced for this purpose in another organism.	
B.	not specific		3.	this resistance arises when antibodies are made in response to antigens introduced into the body.	

Solution: A3

Task 3 (0-2) 15a / pp, July2020 changed
The diagram provides an overview of the different types of immunity obtained by the human body.



For each of the situations A – D described below, assign the appropriate type of obtained resistance, selected from I – IV in the diagram.
A. Administering the tetanus serum to the patient: ………………………… .. ……………… ..
B. History of chicken pox: ……… .. ………………………………………. ……… ..… ..…
C. Fall flu vaccination: …… .. ……………………… ..….
D. Receipt of antibodies by the child through the placenta and with the mother's milk: ………………….
Solution
A. - IV, B. - I, C. - III, D. - II.

Task 4
Immunity is the body's ability to counteract the adverse effects of pathogens entering it. Immunity can be increased by administering a serum or a vaccine.
1. Complete the table showing the differences between the vaccine and serum's composition and mode of action - fill in the appropriate cells with the information selected from those listed.

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	Composition	**action**
Vaccine		
serum		

Solution

	Composition	**action**
Vaccine	contains antigens	stimulates the production of antibodies
serum	contains antibodies	provides the body with antibodies

2. Explain why detecting antibodies in a patient's blood can be used in diagnosing whether a patient has had a particular infectious disease.

Sample solutions

Antibody detection can be used to diagnose whether a patient has had an infectious disease because:

their presence indicates the contact of the examined person with a specific antigen/pathogen.

Antibodies made in the body in response to a particular antigen are specific for that antigen.

Antibodies remain in the blood for many years after the infection and may indicate a past disease.

Educational materials

Genially game

Lesson 3-4 Vaccines - What Are They?

Objectives

In terms of knowledge

Student:

- *lists the types of vaccines,*
- *lists the ingredients of vaccines,*
- *explains the social role of vaccines,*

In terms of skills

Student:

- *Compares the preservatives found in vaccines and the preservatives in the pear,*
- *converts the number of preservatives in vaccines to the same chemical compounds found in e.g., pears (formaldehyde) or table salt,*
- *develops a presentation advertising a specific type of vaccine,*
- *plans an effective way to break the circulation of the virus among the potential ones*

In terms of attitudes

Student:

- *shapes pro-health attitudes in the context of the importance of vaccinations and their widespread use.*

Methods of teaching

- *scientific project*
- *mind map*
- *scientific modelling*
- *brainstorming*
- *discussion*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

The course of the lesson:

Activity 1

Brainstorming - How can we protect ourselves against infectious diseases? Students list various ways of transmitting diseases and what methods of protection against them.

They then receive material about a certain disease that is not known how it spreads. Analyze the data and decide what you think may be the source of infection.

Activity 2

The students are representatives of pharmaceutical companies who advertise different types of vaccines - they receive materials and make a presentation about them to advertise their vaccine. They present in front of other groups and the investor (teacher) - after each presentation, there is time for insightful questions (e.g., effectiveness, unplanned vaccine reactions, ease and conditions of vaccine distribution) and discussion. At the end of the class, the investor chooses one group to receive his funds.

Reccomended websites:

https://szczepienia.pzh.gov.pl/wszystko-o-szczepieni/jakie-sa-rodzaje-szczepionek-2/

https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/treatments-vaccines/covid-19-vaccines

Activity 3

Students are asked to analyze infographics that show the chemical composition of the pear and the vaccine and then construct at least three conclusions.

Task:

Compare the information contained in the infographic and in the text of the article: Vaccine ingredients - what do they actually contain and based on the analysis of the blog text, give your definition of what they are:

The factor determining the immune response,

Adjuvants

Specify what the vaccine stabilizers are used for. Give examples of such stabilizers

Activity 4

Ball and shield exercise - the viral circulation - and breaking the viral circulation chain

Evaluation tasks

Task 1

To induce immunity to pathogenic microorganisms, doctors recommend protective vaccinations. Traditional vaccines contain reduced virulence, dead or alive, of pathogens, and it is most often administered by injection (injection). The development of genetic engineering techniques makes it possible to replace traditional vaccines with vaccines produced in genetically modified plants, as illustrated in the diagram.

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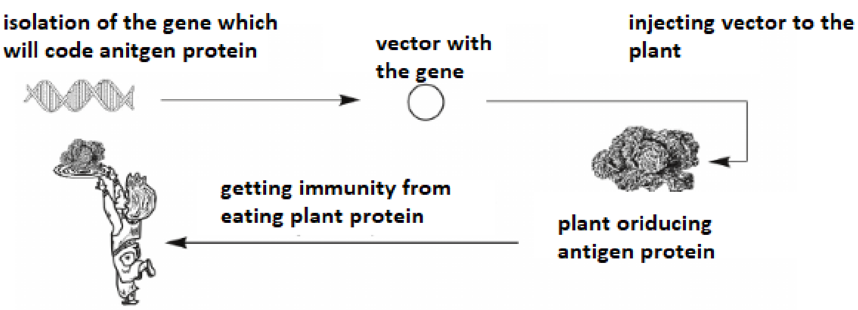

Na podstawie: *Biologia molekularna w medycynie, elementy genetyki klinicznej*, pod red. J. Bala, Warszawa 2001.

a) Justify, taking into account the vaccine's contents and the method of its administration, that the described "biotechnological" vaccine is safer than the traditional vaccine.
Vaccine content
Method of administration
b) Highlight the three characteristics of the body's immunity that the administration of this vaccine will trigger.
non-specific, specific, artificial, natural, passive, active
Solution:
a) (0-2) Example of a correct answer:
Vaccine content:
In such a vaccine, there is only the antigenic protein of the germ (which a human can easily fight with antibodies). In the traditional vaccine, there are also other proteins or metabolites of the germ (which may cause, e.g., allergies or other disorders).
Method of administration: This vaccine is administered with food therefore:
painlessly (and the conventional vaccine is usually administered by injection) without the risk of infection (and the conventional vaccine is usually administered by injection, which carries the risk of infection).
b) (0-1) Correct answer: specific, artificial, active.

Task 2
American scientists have developed a melanoma vaccine. But it is not a classic vaccine - prophylactic but curative, administered to a sick person. Researchers sequenced the genomes of cells taken from patients with advanced melanoma. The aim was to identify mutant proteins - neoantigens - unique to a particular patient's melanoma cells. It then investigated which neoantigens elicited the most robust immune system response.
After the preparation was developed, it was administered to patients. The vaccine prevented the spread of melanoma cells in the first patients. However, this vaccine is still an experimental therapy. Melanoma, detected early and quickly removed, is now almost 100% curable.
Adapted from: B. Carreno, G. Linette, A dendritic cell vaccine increases the breadth and diversity of melanoma neoantigen-specific T cells. Science, May 2015.
1. Explain why this vaccine may be ineffective for others when administered to one patient. In response, consider the mechanism of the immune response.

....
Solution
The vaccine used for the described patient has been developed for his specific neoantigens. These will not be recognized by the antibodies of another patient and, therefore, may be ineffective for that patient.
2. Give an example of human behavior that reduces the likelihood of developing melanoma.

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....
Sample solutions
avoiding prolonged exposure to the sun
the use of creams with filters to protect against UV rays
control visits of people with moles to a dermatologist
limiting the use of the solarium.

Task 3
A human becomes infected with rabies occurs due to contact with the saliva of an infected animal, e.g., when bitten by such an animal. Patients bitten by a sick (or suspected rabies) animal are administered antisera containing rabies virus antigens as soon as possible, followed by three vaccinations containing inactivated viral particles.
Based on: J.D. Ostrowska, T. Hermanowska-Szpakowicz, Wścieklizna and its prevention in humans, "Medycyna Wet", 53 (3) 1991; www.mp.pl/szczepienia

1. Justify that the described scheme of dealing with persons potentially infected with rabies virus can be described as passive-active immunization. In response, refer to both types of immunity.

Sample solution
Administration of serum to people potentially infected with rabies virus causes passive immunity, as it is given antibodies (from outside the body). Administration of the vaccine to people potentially contaminated with rabies virus causes active immunity because the patient's body produces antibodies.

2. Assess whether the following statements about the immune responses triggered in the human body during passive immunization are correct. Mark T if the statement is true or F if it is false.

1.	The administration of serum containing anti-rabies immunoglobulins provides the patient with a longer immunity to the disease than administration of the vaccine.	**T**	**F**
2.	In response to the administration of serum, the patient's body begins to produce antibodies to the rabies virus on its own.	**T**	**F**
3.	The administration of the second and third doses of the rabies vaccine triggers a secondary immune response in the body of the vaccinated person.	**T**	**F**

Solution:
1. F 2. F 3. T

Education materials
Vaccine ingredients - infographic

Lesson 5-6. The panic virus - vaccination in the social dimension

Objectives
In terms of knowledge
Student:
- *lists diseases against which universal vaccinations are used in childhood,*
- *lists the types of cognitive biases that are used in conspiracy theories about vaccination,*

In terms of skills
Student:
- *develops a questionnaire on vaccinations in their community,*

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– *argues the health benefits for society of widespread immunization programs*
– *assesses the credibility of information sources on vaccination*

In terms of attitudes

- *recognizes the importance of educational campaigns regarding the verification of knowledge sources, cognitive errors and conspiracy theories.*

Methods and forms of work

– *visualization*
– *discussion*
– *social survey,*
– *analysis of the content of articles*

The course of the lesson:

Activity 1
Social research - surveying your community:
Who in the family and against what diseases were vaccinated, and how many times?
Was the immunization schedule different in the parents' day and now? What are the differences? Where do they come from? Are these changes good?
What are vaccinations - for what purpose do we carry them out (protection against severe course and death, not complete protection against infection)?
A problem for social research - what is the perception of vaccination in the immediate area?
What arguments are used by those who are against, and what are those who are for?
Argument types - infographics and https://zpe.gov.pl/a/rozpoznwanie-argumentow/D5X5kOOV0

Activity 2
How to counter conspiracy theories?
Problems in discussions with anti-vaccines:
Why is it so hard to talk to vaccine opponents?

- conspiracy theories - link to the conspiracy theories manual https://www.climatechangecommunication.org/wp-content/uploads/2021/12/ConspiracyTheoryHandbook_Polish.pdf

Activity 3
Review the childhood immunization calendar below and the list of vaccines available
https://www.medicover.pl/o-zdrowiu/szczepienia-dzieci-bezpieczenstwo-i-kalendar-szczepien-2022,3828,n,168
https://szczepienia.pzh.gov.pl/wp-content/uploads/2021/01/szczepienia-covid.png
Justify why there is no vaccination against Japanese encephalitis in the Polish vaccination calendar.
Search the Internet, use your knowledge, and determine when vaccination against Japanese encephalitis would be justified.
(recommended website, e.g., https://medycynatropikalna.pl/choroba/japonskie-zaprzenie-mozgu)
c) Indicate other diseases for which the vaccine exists but it is not in the vaccination calendar.

Activity 4
Searching for an answer to the problems:
Profit and loss balance - virus vs. vaccination - why the disease is more dangerous than possible VAE (Vaccine Adverse Event) or disease after vaccination?
The main issue: what is a VAE, and what does it tell us?

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A VAE is an adverse reaction to a vaccination - a health condition that occurs up to four weeks after vaccination
https://www.pzh.gov.pl/serwisy-tematyczne/niepozadane-odczyny-poszczepienne-covid-19/
Question to Pupils:
What are the consequences of NOP after vaccination that you know?
Compare your answers with the data available on government websites, e.g., https://szczepienia.pzh.gov.pl/wp-content/uploads/2021/12/BEZPIECZEN%CC%81STWO-04.pdf.
Where to report information on VAEs?
https://szczepienia.pzh.gov.pl/wp-content/uploads/2020/10/Info-Gdzie-znalezc-informacje-o-NOP-2.png
https://szczepienia.pzh.gov.pl/wp-content/uploads/2021/12/BEZPIECZEN%CC%81STWO-05.pdf
How often do VAEs occur?
https://szczepienia.pzh.gov.pl/wp-content/uploads/2021/12/BEZPIECZEN%CC%81STWO-06.pdf
Chart analysis
From the EMA COVID-19 vaccines: development, evaluation, approval and monitoring (https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/) treatments-vaccines / vaccines-covid-19 / covid-19-vaccines-development-evaluation-approval-monitoring)
https://szczepienia.pzh.gov.pl/wyniki-bezpieczenstwa-podania-dawki-przypominajacej-szczepionki-prasz-covid-19-u-doroslych/
What was the importance of vaccination in human history? How long since the invention of the vaccine is needed to significantly reduce infection.
variolacja / variolizacja-more information https://pl.wikipedia.org/wiki/Wariolizacja

Activity 5
Task:
Create a timeline of significant historical events in vaccine development.
https://pbs.twimg.com/media/FJeaMC5XEAQWsbg?format=jpg&name=large

Activity 6
Analysis of the term: What is herd immunity, and when can we achieve it?
Who are we vaccinate for?
Infographic, online resources https://www.webmd.com/lung/what-is-herd-immunity#1
https://en.wikipedia.org/wiki/Herd_immunity

Activity 7
Based on the information obtained about herd immunity and the R0 infection rate, analyze the number of tuberculosis infections in Poland and Germany and then answer why we are still vaccinating against tuberculosis in Poland and not in Germany.
https://www.mp.pl/szczepienia/specjalne/190810,programy-szczepien-paniemko-gruzlicy-w-europie
List other European countries where there is also a need for TB vaccination.
http://wwwold.pzh.gov.pl/oldpage/epimeld/2020/Sz_2020.pdf
The graph below shows data on Poland and the number of people - children and adolescents evading vaccination between 2011 and 2020.
http://wwwold.pzh.gov.pl/oldpage/epimeld/2020/Sz_2020.pdf
What conclusion can you draw from this graph?
What dangers are posed by the growing number of people evading mandatory vaccinations?

Activity 8
After analyzing the survey data, create an information leaflet about vaccinations or a video on TikTok.
The leaflet/material will be a response to the problems that arise from the surveys
Rules for creating a leaflet

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https://warwick.ac.uk/fac/soc/cte/pintra/schooldirect/sd-marketing/writing_good_leaflets.pdf
https://www.solopress.com/blog/tutorials/how-to-design-flyers-and-leaflets/
https://www.solopress.com/blog/tutorials/how-to-write-a-leaflet/

The role of understanding probability in conscious decision making.
Discussion about the differences between possibility and probability
Recommended book: Massimo Pigliucci Bujda na resorach. Jak odróżnić naukę od bredni.
In English: Nonsense on Stilts: How to Tell Science

Educational materials
Instruction for social research
What we owe to vaccines – infographic,
Epidemic, Pandemic and Endemic – infographic,
Child vaccination scheme – infographic,
Vaccines and herd immunity – infographic.

Information sources
balance of profits and losses against vaccinations
https://www.youtube.com/watch?v=zBkVCpbNnkU
vaccine wars, vaccinations through the years
https://www.science.org/content/article/here-s-visual-proof-why-vaccines-do-more-good-harm?.
vaccinations and autism, a comic book about Wakefield
https://thenib.com/vaccines-work-here-are-the-facts-5de3d0f9ffd0
metal and salt:
https://twitter.com/qtent2016/status/916764089644453890?lang=de
how much formaldehyde is in the pear:
https://skeptics.stackexchange.com/questions/32562/does-a-pear-contain-600-times-more-formaldehyde-than-a-vaccine
immune amnesia
Are we at risk of measles?
https://www.mp.pl/szczepienia/specjalne/230391,amnezja-immunologiczna
the effectiveness of vaccinations in protection against hospitalization and death
https://pbs.twimg.com/media/FJeaMC5XEAQWsbg?format=jpg&name=large
variolacja / variolizacja-more information https://pl.wikipedia.org/wiki/Wariolizacja
vaccine safety
https://szczepienia.pzh.gov.pl/wyniki-bezpieczenstwa-podania-dawki-przypominajacej-szczepionki-prasz-covid-19-u-doroslych/
From the EMA COVID-19 vaccines: development, evaluation, approval and monitoring (https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/) treatments-vaccines / vaccines-covid-19 / covid-19-vaccines-development-evaluation-approval-monitoring)
conspiracy theories - link to the textbook of conspiracy theories https://www.climatechangecommunication.org/wp-content/uploads/2021/12/ConspiracyTheoryHandbook_Polish.pdf
recognizing arguments
https://zpe.gov.pl/a/rozpoznwanie-argumentow/D5X5kOOV0
tuberculosis vaccination programs
https://www.mp.pl/szczepienia/specjalne/190810,programy-szczepien-paniemko-gruzlicy-w-europie

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Evaluation tasks

Task 1.

The rubella vaccine is highly effective. In the 1960s, there was a global rubella epidemic in the United States, where 12 million people fell ill, and 20,000 newborns were born with Congenital Rubella Syndrome. The greatest number of patients was recorded in 1969. In the same year, the rubella vaccine was approved for use, and in the years that followed, the number of cases of the disease began to decline rapidly. The entire region of the Americas is now recognized as being rubella free. Single cases that happen are usually cases imported from other world areas.

In Poland, compulsory vaccination against rubella was introduced in 1988 - only girls were vaccinated, and one dose of the vaccine was administered at 13 years of age.

In 2004, compulsory vaccination against measles, mumps, and rubella (combined vaccine) was introduced for children of both sexes in the 13–15th months. Since 2005, all children have been given two doses of a combined measles, mumps, and rubella vaccine. The first dose was given in the 13-15th month, the second initially at the age of 12 (2005), and then at 10 (from 2006).

In 2013, 38 thousand jobs were recorded in Poland from January to April. Infections, i.e., 100 cases per 100 thousand residents, and mostly young men were ill. In recent years, the number of cases in Poland has been falling, and there are no cases of congenital rubella at all.

Based on: E. Krawczyk Why do we vaccinate? Viruses, bacteria, and epidemics. Publishing House of Political Critique, Warsaw 2021 and https://www.mp.pl/pacjent/szczepienia/ekspert/82117,kuje-woło-obowiazek-szczepienia-paniem-rozyczce

a) Explain why the rubella epidemic that appeared in Poland in 2013 primarily affected young men.
b) Using the text, show why the number of vaccine cases in Poland has decreased in recent years and there are practically no cases of congenital rubella.
c) On the basis of your own knowledge and information presented in the class, list two goals of vaccinations.

Solution:

a) They were not vaccinated; it was enough to contact sick people who had this disease.

b) All mothers were vaccinated against the disease, and vaccination of both sexes also eliminates the disease from the population.

c) - protecting the vaccinated person against an infectious disease
- ensuring the protection of the population against this disease

Task 2

Precious yeast (Saccharomyces cerevisiae), commonly used in the baking and brewing industry, is also used in the pharmaceutical and biotechnology industries. For example, they are used to produce a recombinant vaccine against hepatitis B (hepatitis B), which is usually administered three times to the vaccinated person.

1. From the following, select and highlight three types of immunity obtained by vaccination against hepatitis.

peculiar non-specific active-passive natural artificial

Solution

peculiar non-specific active-passive natural artificial

2. Explain why the hepatitis B vaccine is repeated three times.

………………………………………………………………………………………………… ......

Sample solutions

This vaccine is repeated three times to obtain a sufficiently high level of serum antibodies in the body and an appropriate number of competent
immune memory cells so that it will be able to fight it immediately in the event of contact with the virus.

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A single administration of the HBV surface antigen (HBsAg) primarily produces antibodies against the virus to combat it. After the (second and third) repetitions of the vaccination, there will be enough memory cells in the body. When it comes into contact with the virus, it will be able to fight it immediately.

Task 3

In Poland, vaccination against tuberculosis (BCG) has been obligatory since 1955, and since 2006, newborns are vaccinated in the first 24 hours of life. The diagram shows the incidence of tuberculosis in several voivodships in Poland in the years 1999, 2003 and 2007, expressed as the number of cases per 100,000. population.

a) Provide the missing description for the vertical axis of the bar chart.

b) Based on the above data, present and justify your opinion on the effectiveness of vaccination against tuberculosis in Poland.

Solution:

a) (0−1) Correct answer:

The number of tuberculosis cases per 100,000 population in thous. population

b) (0−1) Examples of correct answers (one of):

I believe that vaccination is effective because the incidence of tuberculosis decreased in the period 1999-2007 in most of the provinces shown in the chart.

I believe that the effectiveness of vaccinations is not sufficient, as there are voivodships where the incidence of this disease has hardly changed, and has even increased, e.g. in Małopolska.

I believe that TB vaccination is not fully effective because it limits but does not completely eliminate the disease.

Based on the analysis of these data, it cannot be concluded that vaccinations are effective, as other factors may have contributed to the reduction of tuberculosis incidence, e.g. the effectiveness of antibiotics, early detection of cases of disease, compliance with hygiene, and better quality of life.

Task 4

Tuberculosis is an infectious human disease caused by mycobacteria. The main source of infection is a sick person who spreads tuberculosis with coughing or sneezing. They are aerobic bacteria, resistant to many environmental factors, such as: drying, high and low temperature, high and low pH. Mycobacteria attack and develop in various human organs, incl. in the lymph nodes, skin, lungs, bones, brain and kidneys. Name the human organ in which tuberculosis bacilli develop most often. Justify your answer. Organ:

Justification:

Correct answer. Organ: lungs, Rationale: because infection occurs through inhalation of tuberculosis bacilli with air.

Task 5

Tuberculosis is an infectious disease caused by bacteria - Mycobacterium tuberculosis. The most common infection is in the lungs, but Mycobacteria can reach all organs and tissues and, under certain circumstances, cause disease that develops in 5-10% of people infected with Mycobacteria. The BCG vaccine (Bacillus Calmette-Guérin) contains live, weakened bovine bacilli (Mycobacterium bovis). BCG vaccines are considered safe. Vaccination reactions are very rare, and if they do occur, they are painless and have a tendency to heal themselves. However, live bacterial vaccines should not be administered to people with reduced immunity, such as those taking immunosuppressive drugs after organ transplants, due to the possibility of developing infections. BCG vaccination protects infants and children against the most severe form of tuberculosis, tuberculosis meningitis. However, only a fraction of the studies have shown that the vaccine is effective

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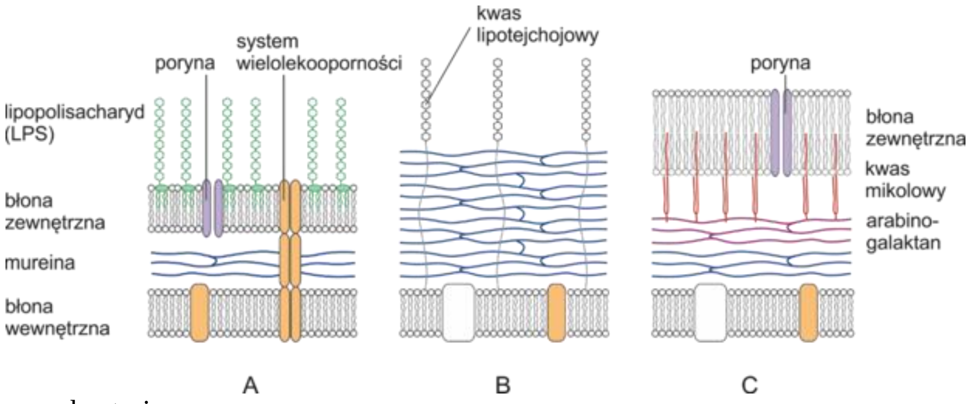

mycobacteria
gram-negative bacteria
gram-positive bacteria
bacteria lacking a cell wall
A .... B .... C ....
Solution A. - 2. B. - 3.C. - 1.

4.2. (0-1) Assess whether the information below on TB and its prevention is accurate. Mark P if the information is true or F if it is false.
1. Infection with Mycobacterium tuberculosis is usually asymptomatic. P F
2. BCG vaccine can be dangerous for immunocompromised people. P F
3. The primary goal of BCG vaccine administration is to prevent pulmonary tuberculosis. P F
Solution: PPF

SUMMARY
Experts (students) review articles from the Internet, catching fake news on social media, etc.
Links:
Q&A on mRNA vaccines
https://www.youtube.com/watch?v=XRW9E5Gq_Ew&t=6s
in a nutshell - about the profit and loss balance
https://www.youtube.com/watch?v=zBkVCpbNnkU

Supplementary learning resources and educational activities

Scenario was consulted with third parties – medical professionals (Piotr Kwaśniewski – paediatrician) and virologists.
Students during the scenario will have opportunities to work with STEM professionals. Also as a follow up students will have visits from third parties in the classroom: paediatrician, virologist, biotechnologist and pharmacists. In this scenario author of a blog – "It is just a theory" Łukasz Sakowski have prepared short article for students about vaccinations.
Students from the school in the project will attend in scientific fairs at Faculty of Biology of Adam Mickiewicz University in Poznań – such as Night of the Scientists, Night of the Biologists or Festival of Science and Art. In all of this events PAFSE will have its own stand but more importantly students from the schools involved in the project will have priority entrance to any workshops and lectures.
Furthermore, students will have opportunity to visit pharmacist company and their Research & Development department and discuss what the process of producing the new vaccine and what precautions are applied to ensure that process is safe and efficient.
They will have also opportunity to be at the lecture with the professor of vaccinology – as there are not a lot of this kind of specialist, lecture will be online which will give the opportunity to participate not only

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for our students but also for whole school community with their families and friends. What's important invited guest will not only talk but vaccines, but more importantly about career path – and explain what students should do if they want to pursue this career in the future.

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17. Specifications for an educational scenario on the topic "Planet of viruses – the variety of genes on the planet in viruses exceeds or is likely to exceed that in all of the rest of life combined."

—E. O. Wilson

Main partner responsible

Adam Mickiewicz University, Poznań, Poland

Overview

Viruses, their pathogenicity, and the prevention of viral diseases are among the obligatory content during the implementation of the core curriculum in biology. The scenario is intended for biology teachers teaching biology in primary and secondary schools. It aims to offer a series of classes dedicated to the issue of viruses and familiarize students with the field of biology, which is virology. It is not required to run all of the proposed scenarios, but they constitute a whole. The idea of the classes offered here is based on the assumption of introducing several concepts into the school reality:
inquiry-based education
project-based education
open school

Viruses are powerful yet microscopic creatures. They are associated with infectious factors that cause viral diseases in animals (including humans), plants, bacteria, and fungi. For this reason, they are referred to as "infectious agents of unimaginably small dimensions." From the point of view of ecosystems, they are essential elements of the environment that transfers DNA between organisms. From the point of view of evolution, they are a vital selection factor. From the perspective of the human economy, they primarily have a negative image - they cause economic losses in animal breeding or plant cultivation. By causing diseases in humans - especially those that occur on a large scale - they cause economic losses resulting from employees' absence in workplaces. It is estimated that during our lifetime, due to a seasonal cold - caused by rhinoviruses, each of us will spend a year in bed with a runny nose and cough).
On the other hand, they are an essential tool used in biotechnology - for example, they are used to treat certain diseases (phage therapy). One can risk a statement that they are one of the oldest known pathogens on Earth that have achieved a kind of "evolutionary cleverness" - they can perfectly manipulate the host cell's metabolism. On the other hand, they are conducted and used by a human (one of their hosts).
Viruses have been accompanying humans for a long time and have made themselves felt in the history of our species many times, causing mass deaths - as in the case of smallpox. The times without viruses on Earth will likely never be known to us. Nevertheless, understanding their nature can help us better prepare for their attacks. We will look at a few "big problems" worth paying attention to when thinking about viruses during the course. Among these big questions, the following can be distinguished:

- What is life?
- What is the nature of viruses?
- How do viruses pursue their own goals - the life strategy of viruses?
- It is now believed that up to 10% of the DNA in human cells is viral DNA. How did it get there? And does it matter?

We can recall the story of the "Frankenstein virus" as if "alive" from its remnants in the human genome. A particularly widespread "trace" of viral infections in our genetic material is the Human Endogenous Retrovirus (HERV). There are dozens of degraded, inactive DNA copies of viruses in our genome that remained after infections at an earlier stage of evolution. In the mid-2000s, a group of French scientists compared them all to guess what their common ancestor might have looked like. They reconstructed the

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genome and obtained an active virus capable of infecting human cells and inserting its DNA into new places on the chromosomes. Some researchers find this experiment very dangerous, but it brought us important information about our evolution, viruses' evolution, and their relationship to cancer (many retroviruses are oncogenic, i.e., carcinogenic).

You can read more about this experiment:
- https://www.nature.com/news/2006/061030/full/news061030-4.html
- https://genome.cshlp.org/content/16/12/1548.full

Scientific content and its relevance to public health education

- Understanding of the decisive importance personal behavior has for the societal good during an epidemic.
- Visualization and active inquiry of epidemiological parameters such as cases, deaths, asymptomatic cases, infectivity, healthcare system capacity and the epidemic curve, which are commonly referred to in the public sphere, during an epidemic.
- Understanding of importance of vaccination and conducting it according to medical professionals' orders.
- Awareness of meaning of antivaccination movements and how public behavior can influence it.

Estimated duration

8 teaching hours, organized in continuous two-hour periods if possible. Proposed lessons should be conducted during biology lessons.

STEM Content

- Fundamental concepts of biomedical sciences (e.g., communicable diseases, infectivity, epidemic).
- Function, use and nature of scientific models.
- Introduction to transdisciplinary issues, such us scientific modelling – Convergence of sciences to handling with complex problems.
- Use of mathematics in natural sciences.
- Scientific work on authentic problems.
- Authentic scientific data driven decision making.
- Importance of scientific work for civic decision making.
- Shows the structure of viruses as cell-free infectious forms;
- Shows the morphological and genetic diversity of viruses;
- Shows the relationship between the structure of viruses and the method of infecting cells;
- Compares virus infection cycles (lytic and lysogenic);
- Explains the mechanism of reverse transcription and its importance in the multiplication of retroviruses;
- Presents the ways of spreading and the principles of prevention of human diseases caused by viruses (rabies, AIDS, Heine-Medina, diseases caused by HPV infection, influenza, measles, smallpox, rubella, mumps, hepatitis A, B and C, some types of cancer);
- Presents the spread of viral diseases in animals (distemper, rabies, foot-and-mouth disease) and plants (tobacco mosaic, potato streak) and their effects;
- Shows the importance of viruses in nature and for humans.

Content glossary

Antibody - is a protein produced by plasma cells (here, stimulated B lymphocytes) in a humoral immune response. It is characterized by the ability to bind antigens specifically.

Antigen - anything capable of triggering an immune response

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Antigenic drift is a genetic variation in viruses arising from the accumulation of mutations in the virus genes that code for virus-surface proteins that host antibodies recognize. This results in a new strain of virus particles that the antibodies that prevented infection by previous strains are not effectively inhibited. This makes it easier for the changed virus to spread throughout a partially immune population. Antigenic drift occurs in both influenza A and influenza B viruses
(Confusion can arise with two very similar terms, antigenic shift and genetic drift. Antigenic shift is a closely related process; it refers to more dramatic changes in the virus's surface proteins. Genetic drift is very different and much more broadly applicable; it refers to the gradual accumulation in any DNA sequence of random mutational changes that do not interfere with the DNA's function and thus are not seen by natural selection.)

Antigenic shift is when two or more different strains of a virus, or strains of two or more different viruses, combine to form a new subtype having a mixture of the surface antigens of the two or more original strains. The term is often applied specifically to influenza, as that is the best-known example, but the process is also known to occur with other viruses, such as visna virus in sheep. Antigenic shift is a specific case of reassortment or viral shift that confers a phenotypic change.

Endemia is a constant incidence of a specific infectious disease in a given area in a number that has remained at a similar level for many years.

Epidemic - (Greek: επιδημία: επι: epi "on," δήμος: demos "people") - occurrence of more cases than expected in a specific time and a particular area.

Genetic material - the genome is a nucleic acid molecule encoding the genetic information of a virus or an organism

Mutation - (Latin mutatio - change) - is a sudden, abrupt change in the genetic material. It is possible to inherit it.

Pandemic (Greek pan = 'all' + Greek demos = 'people') - an infectious disease epidemic in various environments, over a large area, on many continents at the same time

Viruses - (from Latin - poison, venom), Viruses are infectious pathogenic creatures without a cell structure, consisting mainly of nucleic acids and proteins that cannot multiply outside the cell. They contain genetic material in RNA (RNA viruses) or DNA (DNA viruses). Viruses cannot absorb and process energy - they do not have metabolic independence. They can only develop inside living cells, the metabolism of which is subordinated to the virus's genetic information**.** Virion - a particle of a virus. VIRION is the entire infectious viral particle, most often in the form of rest. We talk about VIRUS at every stage of infection.

Pedagogical glossary

Argument - In logic and philosophy, an argument is a series of statements, called the premises, intended to determine the degree of truth of another statement, the conclusion. The logical form in a natural language can be represented in a formal symbolic language. Instead of natural language, formally defined "arguments" can be made in math and computer science. (https://en.wikipedia.org/wiki/Argument). In science education, argumentation is considered a core skill that can empower young people to attain scientific literacy, develop critical thinking, reasoning, communicative and metacognitive skills, and other subsidiary skills. (https://www.sciencedirect.com/science/article/pii/S0883035516300313). Argumentation refers to the process of constructing and negotiating arguments (Osborne et al., 2004), either individually or cooperatively, which can be expressed either verbally or in writing (Driver et al., 2000). In

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its simplest form, an argument typically involves a clearly stated claim about a specific issue, along with supporting evidence and articulated reasoning, connecting the claim with the evidence (Jimenez–Aleixandre et al. 2000).

Claim – Evidence – Reasoning

In Toulmin's Model of argument, we might find:

Claim: Statement of an opinion/position.

Data: Evidence in support of the claim

Warrant: Explicates a connection between the data and the claim. e.g., Assumptions

Backing: Strengthens the warrant.

Rebuttal: Acknowledges (and if possible weakens) possible counter-claims and counter-arguments.

Brainstorming - a technique derived from social psychology that aims to improve group decisions. Brainstorming is also a form of didactic discussion, used as one of the teaching methods. Then it is included in the activating methods, which is a subgroup of problem methods. One of the so-called heuristic methods. Brainstorming is used to generate ideas to solve problems that are generally new problems to which most participants do not know the answers. In one version, it consists of two stages:

- In the first stage, participants are encouraged to freely submit ideas and exchange views, subject to no criticism whatsoever. All ideas are saved or the session is recorded on tape.
- In the second stage, an expert or a group of experts not participating in the first stage reviews the results and tries to filter out ideas that make sense.

In practice, research has shown that while brainstorming can be very effective, its effectiveness can also be easily lost. In particular, factors damaging its effectiveness are, for example, the presence of a very strong dominant personality in the first stage, too high ambition of some participants, preventing others from having a say, little openness to new ideas of experts evaluating ideas, the participant's willingness to change the topic to something unrelated to the task, etc. (see group thinking syndrome).

Case studies are stories that are used as a teaching tool to show the application of a theory or concept to real situations. Dependent on the goal they are meant to fulfill, cases can be fact-driven and deductive where there is a correct answer, or they can be context driven where multiple solutions are possible. Various disciplines have employed case studies, including humanities, social sciences, sciences, engineering, law, business, and medicine. Good cases generally have the following features: they tell a good story, are recent, include dialogue, create empathy with the main characters, are relevant to the reader, serve a teaching function, require a dilemma to be solved, and have generality. Instructors can create their own cases or can find cases that already exist.

Content analysis is, by definition, the study of textual messages, both written (books, newspapers, documents, websites) and oral (broadcast via radio and television). The purpose of the analysis is to reduce the content of the entire text to its most essential meanings: the most frequent words, key threads, dominant grammatical and semantic forms, etc. This method is also used in didactics as a tool that allows you to find answers to a given question by reducing the content of the entire message to key information. It will enable you to search for key terms or concepts important from the point of view of the discussed content.

Discussion - Discussion (this is a term of Latin origin: discutere - to break up, spread out) **-** it is an oral or written exchange of views on a specific topic, aimed at reaching common conclusions. Discussion is an activity carried out in a group of two or more people and aimed at solving a problem. It does not have a structured form like the Oxford debate, but the essence of a good discussion is also well-structured arguments.

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It is a process by which theses are presented, supported by competent arguments, and allows other people to test their theses or present counter-arguments.
Discussion allows you to prevent misunderstandings, solve problems - or at least understand them better.

Exchange of ideas - a method similar to brainstorming, but the ideas generated by students do not have to solve a problem, but be, for example, a proposal to answer a question, for example, about the functions or suggestions for using a solution learned during the classes.

Flipped classroom - The flipped or inverted classroom is a new and popular instructional model in which activities traditionally conducted in the classroom (e.g., content presentation) become home activities. Activities typically constituting homework become classroom activities. The teacher helps the students instead of merely delivering information in the flipped classroom. In contrast, the students become responsible for their learning process and must govern their own learning pace (Lai & Hwang, 2016). It offers more opportunities for a teacher to engage students in the process of learning but also shifts more responsibility for learning from a teacher to the students. At the same time, there is a shift in a perception of a teacher who is not a sage on a stage; now, a teacher is more like a guide from the side. https://www.sciencedirect.com/science/article/pii/S0360131518302045

IBSE – inquiry based sience education, inductive approach in teaching and learning science and technology. inquiry-based learning is based on the recognition that science is essentially a question-driven, open-ended process of constructing coherent conceptual frameworks with predictive capabilities and that students must have personal experience with scientific inquiry and engage in its practices, in order to be enculturated in these fundamental apects of science. inquiry learning, referrs to the active learning processes in which students are inevitably engaged. Inquiry based teaching is a bit more flickering term and less precise in literature. IBST is a proces connected with involving students in inquiry activities with questions that are meaningful to them (e.g. generated from their own experiences) and with the explicit aim to develop coherent knowledge and rigorous understanding of phenomena, as well as understanding of how scientists study the natural world and what ideas they have developed in the process. For achieving that, the teacher needs to prepare an ingenious and planned scaffolding, for assisting the students through modelling and coaching in particular by the use of questioning strategies.

Interview - An interview is generally a qualitative research technique that involves asking open-ended questions to converse with respondents and collect elicit data about a subject.

Learning by doing – it is an approach in which learning takes place in action, by applying knowledge into practice, by internalization of skills and practical exercises a student is supposed to build own knowledge. Teaching and learning by inquiry is described as how teaching and learning is executed, the nature of the classroom interactions and the practice of inquiry skills (Tamir 1990). This notion emphasizes the importance of engaging students in investigative processes that enable them to answer important questions (Chiappetta and Adams 2000). Improved forms of learning by doing now can be supported by information technologies, and there are prospects for extensions to group learning by doing and group learning from examples in the near future.

Microscopy is the technical field of using microscopes to view objects and areas of objects that cannot be seen with the naked eye (objects that are not within the resolution range of the normal eye).[1] There are three well-known branches of microscopy: optical, electron, and scanning probe microscopy, along with the emerging field of X-ray microscopy. Optical microscopy and electron microscopy involve the diffraction, reflection, or refraction of electromagnetic radiation/electron beams interacting with the specimen, and the collection of the scattered radiation or another signal in order to create an image. This process may be carried out by wide-field irradiation of the sample (for example standard light microscopy and transmission electron microscopy) or by scanning a fine beam over the sample (for example confocal laser scanning microscopy and scanning electron microscopy).

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Mind map and concepts maps - are techniques for visualizing information in teaching process. Some of them are: conceptual maps, mind maps, conceptual diagram, visual metaphor, semantic networks, etc. (Eppler, 2006; Parikh, 2015). A concept map is a top-down diagram showing the relationships between concepts, including cross connections and their manifestations (Eppler, 2006). Since concepts are very clearly connected to each other, concept maps represent knowledge structures as a whole (Nousiainen, 2012). According to Usta and Ültay (2016), McClure, Sonak and Suen have emphasized that concept maps can be used as a learning strategy, as a teaching strategy, as a strategy for planning curriculum, and as a means of assessing students' understanding of science concepts (Usta & Ültay, 2016). Mind maps were first constructed by T. Buzan (Buzan & Buzan, 1996). Buzan used Habert's ideas to develop mind mapping as a method of note-taking based on the idea of making notes as brief as possible and as "interesting to the eye" as possible by using visual effects (Abi-El-Mona & Adb-El-Khalick, 2008). Mind mapping is used in order to represent knowledge by organizing it in a form of network or other non-linear diagram (Dhindsa & Anderson, 2011). Mind maps are composed of a central idea, keywords (edges) and nodes (Kedaj, Pavlíček, & Hanzlík, 2014). The central idea can be a physical phenomenon or a concept that is treated during a particular class. The keywords are branching from the central idea to specific details that may be presented in the form of images, formulas or experiment sketches. Images or sketches are most often represented in color. In this way, both brain hemisphere activation is achieved (Buzan & Buzan, 1996; Seyihoglu & Kartal, 2010). Mind maps can be used in all situations involving the need for learning and any form of thinking (Kovačević & Segedinac, 2007). According to them, this can be: planning, organizing, analyzing and solving problems, designing projects, preparing speeches and presentations, writing, making notes, lecturing, and similar.

Models and the process of scientific modeling are core components of human cognition and scientific inquiry. Models as tools are used in classroom for exploration, synthesis, prediction, and knowledge construction. Building models not only has the potential to help students improve their understanding about natural phenomena or complex systems, but it can also facilitate their understanding of the nature of science as an enterprise that is largely concerned with extending and refining models (Gilbert and Rutherford 1998, Linn, 2003). In its simples form model is a representation of an phenomena or object.

Oxford debate - a type of argument exchange to discuss a thesis. The opponents of the thesis and its defenders are debating. They are chaired by the marshal, who is assisted by a secretary who watches over the time and sequence of statements. It comes from the University of Oxford. Its key element is an adequate selection of arguments and counter-arguments. Its course includes:

- Commencement - when the Speaker starts a debate, he informs the parties about its principles and subject.
- Debate between arguing parties - The floor is given alternately to individual parties. The side that defends the thesis begins. Statements are structured as arguments.
- The voice of the audience - in order to be admitted to the debate, one has to attract the marshal's attention, if he or she gives the floor, the person introduces himself (which is written down by the secretary) and only starts to express his opinion.
- Summary - both sides summarize all the speeches. They can provide answers to the counter-arguments of the opposing parties, and support their views with additional arguments.
- Vote - the final part of the debate is voting. Traditionally in Oxford, it is done through an exit through a door. Nowadays, in other cases, the most common vote is by show of hands.

Problem-based learning - Problem-based learning (PBL) is a student-centered approach in which students learn about a subject by working in groups to solve an open-ended problem. This problem is what drives motivation and learning. Rather than teaching relevant material and subsequently having students apply the knowledge to solve problems, the problem is presented first. PBL assignments can be short, or they can be more involved and take a whole semester. PBL is often group-oriented, so it is

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beneficial to set aside classroom time to prepare students to work in groups and to allow them to engage in their PBL project.

Students generally are asked to:
Examine and define the problem.
Explore what they already know about underlying issues related to it.
Determine what they need to learn and where they can acquire the information and tools necessary to solve the problem.
Evaluate possible ways to solve the problem.
Solve the problem.
Report on their findings.

https://teaching.cornell.edu/teaching-resources/engaging-students/problem-based-learning and Nilson, L. B. (2010). *Teaching at its best: A research-based resource for college instructors* (2nd ed.). San Francisco, CA: Jossey-Bass.

Project-based learning - Project-based learning (PBL) or project-based instruction is an instructional approach designed to allow students to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world. Project-based learning is more than just "doing a project," in the way you might remember from your school days. As the Buck Institute for Education (BIE) explains, with PBL, students "investigate and respond to an authentic, engaging, and complex problem or challenge" with deep and sustained attention.1 ArchForKids, an organization that provides STEAM programs for young learners, puts it even more succinctly: PBL is "learning by doing."

https://www.powerschool.com/blog/project-based-learning-benefits-examples-and-resources/

Role-play is a technique that allows students to explore realistic situations by interacting with other people in a managed way in order to develop experience and trial different strategies in a supported environment. Depending on the intention of the activity, participants might be playing a role similar to their own (or their likely one in the future) or could play the opposite part of the conversation or interaction. Both options provide the possibility of significant learning, with the former allowing experience to be gained and the latter encouraging the student to develop an understanding of the situation from the 'opposite' point of view.

Scientific modeling is a process that allows students to use a model in a way that it this model represents, explans the phenomena or onjces and allows for predictions. Scientific modeling seems to be promising in scaffolding learners' understanding of the complex processes of science through building, testing, revising, and applying models. Scientific modeling is conected with:

I Modeling skills, and this involves

• Model formulation

• Identification of model components

• Comparing and contrasting models of the same phenomenon

• Model evaluation and formulating ideas for improvement

• Model validation through comparison with phenomena in the same class

II. Metacognitive knowledge about the modeling process: explicit description and reflection on the major steps of the modeling-based cycle

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III. Meta-modeling knowledge: epistemic knowledge about the

• Nature of models (3 elements – representation, explanation and prediction)

• Purpose or utility of models

SWOT analysis (strengths, weaknesses, opportunities, and threats) is a tool for analyzing the current situation both internally (strengths and weaknesses) and externally (opportunities and threats). It provides helpful baseline information for a group that wants to vision the future or analyze and solve a problem. https://www.educationworld.com/a_admin/greatmeetings/greatmeetings018.shtmlIt is a balanced technique that looks at internal and external factors that could positively and negatively impact whatever it is that's being analyzed (a certain idea, project, or experiment). It helps stakeholders identify what the idea or project could help or hinder both in its development and its outcomes as a final product. https://www.twinkl.pl/teaching-wiki/swot-analysis

The three steps method - Think - pair - share - consists in allowing the students to formulate answers to the questions asked first in their head, then share their thoughts with the neighbor, and then, after joint arrangements, the students share the answer on the forum. This enables students to think about their responses and gives them confidence.

Visualisation - In short *Visualization* is the graphical display of information. The purpose of it is to provide the viewer a visual means of processing the information. It is important to note that for a vizualization to be effective it must draw upon the knowledge base of the viewer. If the viewer does not posess the knowledge to understand the graphical entities and the relations between them the visualization does not achieve its goal. Visualization has many applications. For the most part they can be classified into two categories:

- Data Exploration
- Communicating Information

  Visualization is the creating or recreating of imaginary or real scenes within one's mind. However, the term "visualization" can be misleading, because visualizing involves more than just imagery. In fact, the more senses utilized, such as touch sound and taste, the more powerful the result.

  It is in the visualisation of ideas, and the expression or representation of our ideas, that we can bring something more clearly into consciousness. A drawing might be seen as an externalisation of a concept or idea. drawing, and the related visualisation that results from drawing, helped children to construct meaning for themselves as well as share their ideas with others and across contexts.

  The terms "visual" and "visualisation" are often used in the context of external representations, from depictive ones like photographs, videos, and 3D models, to simplified and abstracted line drawings, and even transient visual referents such as gestures. Formal and relatively well-developed visual codes such as flow charts, networks, and sign languages employ symbols that may be remote from their visual referents, with a vocabulary and grammar of their own.

WANTED - Arrest warrant - a method of describing an object, taking into account its characteristic features, problems caused by a given object, etc. The idea of a wanted poster, known even from literature, is used here.

<u>Competences / Learning Goals</u>

<u>I. Knowledge (Core Concepts)</u>
a) Transdisciplinary concepts: scientific modelling, graphs in science.
b) Specific content concepts: communicable diseases, epidemic, pandemic, disease transmission route, viruses, viruses' cycles, vaccination, viral diseases

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II. Skills
a) General skills: critical thinking, reflective thinking, problem solving, decision making, collaboration and communication within small groups, presentation skills.
b) Specific skills: use of scientific models, scientific data collection, analysis and interpretation, variable distinction and handling, scientific hypotheses testing and question answering, data driven conclusions making, discussing on science topics, scientific conclusions presentation and interpretation, constructing an argument.

III. Attitudes (Affective domain)
a) Attitudes and values: appreciation of biodiversity of viruses', appreciation of their meaning on the level not only diseases but also vectors – positive meaning of viruses for society, appreciation of the vital importance of pharmaceutical interventions (phag therapy), appreciation of the importance of models in scientific research, shaping of positive attitudes towards science during a health crisis, roughly empathizing with scientists in terms of the complex nature of their work and the necessary decision making, upgrading of the position of science in students' personal value systems, comprehension of the role of discussion and disagreements within the scientific community.
b) Behaviors': Constant application of scientific argumentation towards discussion about viruses.

Classroom organization requirements

All special classroom organization requirements are proposed below directly in the lesson's activity.

Prerequisite knowledge and skills

- Microbial nature of contagion by communicable diseases.
- Examples of historical and modern cases of epidemics and pandemics – viral diseases,
- Fundamental hygiene rules as pharmaceutical interventions with use of vaccination or non-pharmaceutical intervention e.g., masks.
- Ability to interpret infographics.
- Ease in making digital presentations.
- Ease in constructing an argument.

School research project

Topics and inquiry processes

M. What is the virus?
N. Viruses - their simple structure and complex relationships.
O. Pathogenicity - virus vs. immune system.

I. Research management and design
Problem question: Why is it worth washing your hands with soap and water?
The task is to build a virus model and check what happens to its envelope when exposed to soap.
https://www.sciencebuddies.org/stem-activities/show-soap-kills-virus

II. Data analysis and reporting
Note: An important aspect of this experiment is to explain what happened and why the viral envelope was damaged.
A more scientific explanation of this phenomenon is available at the link:
https://www.youtube.com/watch?v=miOPtXTeHYE

III. Target audience for recommendations

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The rest of the class, maybe teachers and students of the entire school proving the project is presented at a school event.

III. Public debates and recommendations
Presentation of the project outcomes within a school event.

Teacher professional development actions
Teacher professional development on:

- Inquiry-based teaching and learning in accordance with the learning objective areas involved (content knowledge, inquiry skills, nature of science).
- Issues concerning the use of models in science and STEM education.
- STEM literacy aspects being promoted through the educational scenario (use of scientific models, authentic problem solving, inquiry-based teaching and learning, attitudes towards science, science within the societal contexts) and the issues of scientific and health numeracy.
- Project-based teaching and learning and principles and techniques of collaborative learning.
- Argumentation – structure and use of it in debates and discussions.
- The utilisation of Digital Learning Objects in the learning process.
- Main ideas of introducing scenario into the school – presenting to the teachers' possibility of doing only the chosen activities from the scenario which answer to the needs of their group.

Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)

DLOs created especially for the needs of the PAFSE project

I. Principles of the Oxford debate - infographic
II. Argument structure - infographic
III. Features of dead and living matter of viruses - infographic
IV. What is life - infographic
V. Features of animate matter - infographic
VI. Structure of viruses - infographic
VII. Various virus shapes - infographic
VIII. Lytic and lysogenic cycle - infographic
IX. Features of dead and living matter of viruses - infographics
X. Argument structure - infographic
XI. Principles of a SWOT analysis - infographics
XII. Virus wanted poster rules - infographic
XIII. Sample wanted poster - infographic
XIV. Definitions and types of health – infographics

Available resources (link) :
https://www.dropbox.com/sh/itl5i7j96vi90nt/AABj_v06cOmwJCWeFZ33COisa?dl=0

Supplementary Educational Resources (SERs)

Lesson 1-2

1. What is life – a long version (up to 1h)

Extended version – what is life:
https://www.youtube.com/watch?v=_z-SUo2wP4I
What is life?
https://youtu.be/QOCaacO8wus
Definition of life:

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https://plato.stanford.edu/entries/life/
Article –its only theory:
https://www.totylkoteoria.pl/czym-jest-zycie/
Khan Academy article:
https://www.khanacademy.org/science/biology/intro-to-biology/what-is-biology/a/what-is-life
Other sources:
https://www.biologyonline.com/dictionary/life
https://www.degruyter.com/document/doi/10.1515/bmc-2020-0001/html
Tsokolov, S. A. (2009). Why is the definition of life so elusive? Epistemological considerations. *Astrobiology*, *9*(4), 401-412.
https://www.liebertpub.com/doi/pdfplus/10.1089/ast.2007.0201?casa_token=VlG-uK1fOcsAAAAA:nnUffKjr8y0Jajx8yWGrqmgBl4mRXks7AjHUi_L5-9MJVze30x9zhMysPis9i-CuPPS8CQhwSUHBriq6
What are the viruses, according to virologists?:
https://www.youtube.com/watch?v=Tryg5UCp6fI
Are viruses alive? Carl Zimmer
What is a virus https://www.youtube.com/watch?v=jX3MhWWi6n4
Viruses (Updated)

Lesson 3-4

Variety of viruses
https://viralzone.expasy.org/
https://www.rcsb.org/search?q=struct_keywords.pdbx_keywords:VIRUS (modele 3d)
Soap and viruses
https://www.sciencebuddies.org/stem-activities/show-soap-kills-virus
Note: An important aspect of this experiment is to explain what happened and why the viral envelope was damaged.
A more scientific explanation of this phenomenon is available at the link:
https://www.youtube.com/watch?v=miOPtXTeHYE
Scale of the universe
https://scaleofuniverse.com/
Size of the viruses in comparison to human cells
https://www.youtube.com/watch?v=slUUu5tO0o4
Films – building a virion
Influenza virus and antigenic drift
https://www.youtube.com/watch?v=ug-M1nIhfIA&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=21
HIV and reverese transcriptaze
https://www.youtube.com/watch?v=PlSvywlLuNw&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=18
Bakteriophage vs E. coli
https://www.youtube.com/watch?v=YAy4MxRnPYY&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=27
ingress of the virus
https://www.youtube.com/watch?v=jkNxmTrrZSk&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=2v
Bacteriophage as the most lethal factor on Earth
https://www.youtube.com/watch?v=YI3tsmFsrOg
Virus size comparison vs. other microorganisms

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Virus Size Comparison with Viruses and Microorganisms
Lityc and lysogenic cycle
https://zpe.gov.pl/b/cykle-lityczny-i-lizogeniczny/PjbM0mNOA
Video about the bacteriophage attack on the bacterium:
https://www.youtube.com/watch?v=YAy4MxRnPYY&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=27
https://www.youtube.com/watch?v=V73nEGXUeBY&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=26
Recommended secondary resource - Bacteriophages, Khan Academy:
https://pl.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages

Lesson 5-6

We distinguish between physical, mental, emotional, social, and spiritual health. For a fuller reading: https://pl.wikipedia.org/wiki/Zdrowie
Masks: https://www.youtube.com/watch?v=DNeYfUTA11s
Coronavirus video - spread, penetration mechanism, etc. https://www.youtube.com/watch?v=I-Yd-_XIWJg&list=PLRuLO8d3L-MA5ieaZnVbGs6XIGzTlgiOX
Hepatitis A and B https://www.youtube.com/watch?v=Q9L7ZQPc8EA&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=11 attacking hepatocytes
avian / swine flu, antigenic jump https://www.youtube.com/watch?v=tMTl3gU0mFc&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=4
Antiviral drugs and interferons: https://bioinfo.imdik.pan.pl/coronavirus-service/mesmerize/leki-prawywirusowe/
Plant and animal viruses:
Global pandemics and epidemics of plant viruses: https://pubmed.ncbi.nlm.nih.gov/33504044/
Plant viruses overview and disease management:
https://www.frontiersin.org/articles/10.3389/fpls.2020.01092/full
Foot-and-mouth disease: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3989032/
Plant viruses: https://www.totylkoteoria.pl/roslinne-wirusy-bakulowirusy/

Teaching - learning activities

Lesson 1-2 - What is the virus?

Teaching phase according to the inquiry & project based instructional model: Engagement – Externalisation of students' initial conceptions – Initiation of reconstruction/completion of students' initial conceptions

Objectives
In terms of knowledge:
Student:

- *defines what life is,*
- *lists the features of living matter,*
- *gives the features of viruses that indicate belonging to the living world,*
- *gives the features of viruses that indicate belonging to the inanimate world.*

In terms of skills
Student:

- *argues that viruses belong to the living world,*
- *argues that viruses belong to the inanimate world,*
- *plans the sequence of arguments used during the debate,*
- *designs the course of the debate on the belonging of viruses to the animate or inanimate world.*

In terms of attitudes
Student:
- *recognizes the complexity and variety of infectious agents that are viruses.*

Methods
- *Elements of the reversed class*
- *Visual methods - film*
- *Content analysis*
- *Group work - negotiating meanings*
- *Discussion*
- *Oxford debate*

The course of the lesson:
The main dilemma - are viruses alive or not?

Activity 1
Presentation of fragments of films about what life is
https://www.youtube.com/watch?v=_z-SUo2wP4I
https://youtu.be/QOCaacO8wus - what is life?
Analysis of the content of articles:
Then analyze an article from the blog "It's just a theory" or other sources of information.
Students compare their definitions with the definitions they receive from scientific sources - they create one synthetic definition of life.
A problem to consider in the discussion - why define life?
4) definition of life
https://plato.stanford.edu/entries/life/
5) article – its only theory – in Polish
https://www.totylkoteoria.pl/czym-jest-zycie/
6) Khan Academy article
https://www.khanacademy.org/science/biology/intro-to-biology/what-is-biology/a/what-is-life
Other sources:
https://www.biologyonline.com/dictionary/life
https://www.degruyter.com/document/doi/10.1515/bmc-2020-0001/html
Tsokolov, S. A. (2009). Why is the definition of life so elusive? Epistemological considerations. *Astrobiology*, *9*(4), 401-412.
https://www.liebertpub.com/doi/pdfplus/10.1089/ast.2007.0201?casa_token=VlG-uK1fOcsAAAAA:nnUffKjr8y0Jajx8yWGrqmgBl4mRXks7AjHUi_L5-9MJVze30x9zhMysPis9i-CuPPS8CQhwSUHBriq6

Activity 2
Negotiating the meaning of the term "life" together
Contrasting definition of life with examples of borderline cases.

Activity 3
Compare the definitions given by the students with those given by the scholars, provided in scenario.

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Living organisms are, without exception, composed of three interrelated subsystems:

- metabolic system - ensuring energy autonomy
- information system - providing regulation and control
- compartmentalization system - ensuring separation from the outside world.

Activity 4
Distinguishing features of living and inanimate matter;
Discussion with students with the question: What are the manifestations of life in general - and why is one indication not sufficient to consider a creature alive?
What does it mean to live? What features do all living organisms have in common?
Evaluation task:
Separating living and non-living things – activity for students with Question for students: when can we know that something is alive.

Activity 5.
Presentation of the structure and nature of viruses
Screening of a video introducing the issue of Viruses (Updated)
https://pl.wikipedia.org/wiki/Wirusy#/media/Plik:Virion.png
presenting the basic structure of the virus
Question - can you see viruses?
Harvard sees viruses in a new light

Activity 6.
The Oxford debate - do viruses belong to the animate and inanimate world.
Preparation of arguments for and against when analyzing the received materials.
Conducting the Oxford debate. RULES OF THE OXFORD DEBATE (infographic)
ARGUMENT STRUCTURE (infographic)
What are viruses, according to virologists?
2) https://www.youtube.com/watch?v=Tryg5UCp6fI
Are viruses alive? Carl Zimmer
3) What is a virus https://www.youtube.com/watch?v=jX3MhWWi6n4
• Summary – what do you think about it, Nobel award winners? ("Viruses are Viruses") André Lwoff. The concept of virus. J. Gen. Microbiol. 17: 239-253 1957

Evaluation tasks

Task 1, CKE 2019
One of the experimental forms of antibacterial therapy is phage therapy. The phage preparations contain bacterial viruses (bacteriophages) that act on specific bacterial strains. The bacteriophage produces adhesin proteins that recognize the receptors on the cells of specific bacterial strains and produces enzymes that degrade elements of the bacterial cell wall or envelope. Phage preparations are prepared individually for each patient: a bacteriophage strain is selected that effectively multiplies and destroys pathogenic bacteria isolated from the patient's body. Phage preparations are used, among other things, orally, and antacids are also administered to the patient to limit phage inactivation. Based on: https://www.iitd.pan.wroc.pl/pl/OTF/ZasadyTerapiiFagowej.html; P. Kowalczyk et al., Phage therapy - hopes and fears, "Nowa Medycyna", 2/2013.
1.1.
Determine which bacteriophages - primarily carrying out the lytic or lysogenic cycles - are used in the described phage therapy. Justify your answer.
Sample solutions
• Phage therapy uses bacteriophages that carry out a lytic cycle as this cycle destroys the bacterial cells.

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• Performing a lytic cycle - phage therapy destroys bacterial cells, not just multiplying the phage nucleic acid in them.
• Lytic cycle - bacteriophages damage the cell wall from the inside with enzymes.
• Lytic - such bacteriophages trigger processes leading to the lysis of bacterial cells.
1.2.
Explain how a low gastric pH can inactivate phage preparations. In response, consider the structure of the bacteriophages.
Sample solutions
• Low pH of gastric juice can denature the proteins that make up the virus envelope and damage it and thus inactivate phages.
• There is hydrochloric acid in the stomach, which destroys the structure of the proteins that make up the viral capsid.
• There is hydrochloric acid in the stomach, which causes the denaturation of the structural proteins of the virus.
• Low pH of gastric juice can denature proteins that recognize receptors on bacterial cells, and phages will not be able to infect them.
• There is hydrochloric acid in gastric juice, which destroys the DNA contained in the bacteriophage molecule.
• Low pH of gastric juice activates secreted proteolytic enzymes that can digest phage proteins.
• Low pH of gastric juice activates protein-digesting enzymes that can degrade viral proteins.
1.3.
Please evaluate whether the following statements regarding problems with phage therapy are true. Mark P if the statement is true or F if it is false.

1. Human cells can be infected by viruses used in phage therapy. P. F.

2. Strains of pathogenic bacteria may acquire phage resistance. P. F.
3. Finding a bacteriophage that acts specifically on the patient's bacterial strains in phage therapy is crucial. P. F.
Solution 1.- F, 2.- P, 3.- P

Lesson 3-4 Viruses - their simple structure and complex relationships..
Teaching phase according to the inquiry & project based instructional model: Continue of the inquiry phase

<u>*Objectives*</u>
In terms of knowledge:
Student:
- lists the structural elements of viruses (glycoproteins, capsomers, capsid, virion, tail, virion, genetic material - RNA or DNA, sheath),
- classifies viruses in terms of virion symmetry,
- gives examples of different viruses,
- determines the size of viruses,
- defines the terms: parasitism, parasitoid, and predation.

In terms of skills
Student:
- constructs a mind map of the places where viruses occur,
- designs a virus model,
- analyzes the importance of washing hands with soap in the context of the structure of the virus and its lipid coat,
- shows a relationship between the structure of the virus and its way of entering the cell,

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- analyzes the lytic and lysogenic cycle of viruses,
- compares the lytic and lysogenic cycles of the virus, pointing to their importance for virus survival.

In terms of attitudes
- recognizes the complexity and variety of virus forms.

<u>*Methods*</u>

Visual methods - film
Content analysis
Group work - negotiating meanings
Discussion
Brainstorming - and its record in the form of a mind map according to the method: think-pair-share (think and draw - share your map with a neighbor and verify the map - discuss on the forum)
Building a virus model

The course of the lesson:

Activity 1
Students draw the virus and the infectious cycle to the best of their knowledge and without additional support material.

Activity 2
Brainstorming - Where can we find viruses? And where do we usually meet them?
Where are most of them? Are there virus-free places on Earth?
Command: Application of the idea: think - pair - share
Construct a mind map that will answer the above questions.
Discuss your map with your neighbor. Verify your maps.
Present the effects of your work on the forum.

Activity 3
Problem question: What do the different types of viruses look like?
Task:
Design a virus model
Supporting materials
- Variety of virus structure (infographic)
material: https://viralzone.expasy.org/ (construction)
material: https://www.rcsb.org/search?q=struct_keywords.pdbx_keywords:VIRUS (3d models)

Activity 4
Problem question: Why is it worth washing your hands with soap and water?
The task is to build a virus model and check what happens to its envelope when exposed to soap.
https://www.sciencebuddies.org/stem-activities/show-soap-kills-virus
A more scientific explanation of this phenomenon is available at the link:
https://www.youtube.com/watch?v=miOPtXTeHYE

Activity 5
Main problem: How big are the viruses?
The task for the student: Order the items below from smallest to largest.
Liver, atom, Indian Ocean, ovum, spermatozoid, coliform bacteria, coronavirus, the cell nucleus, Białowieża Primeval Forest

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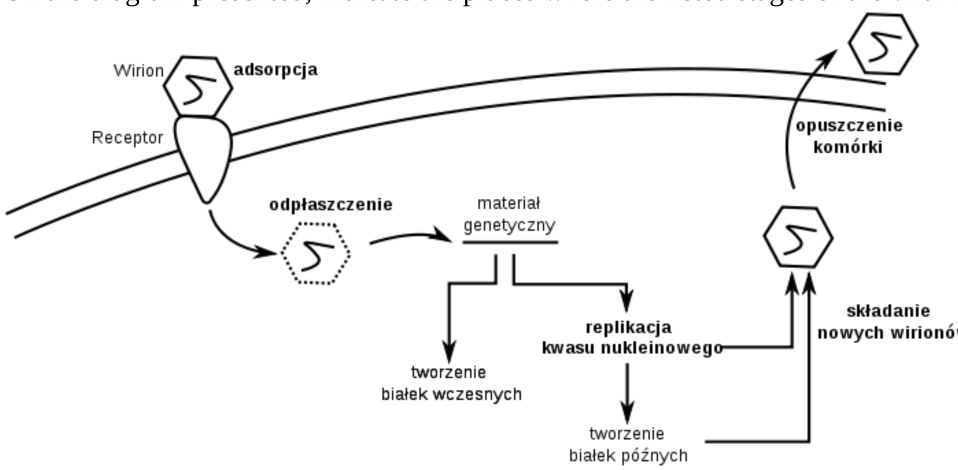
Now compare your answers with the scale of the universe
https://scaleofuniverse.com/
The size of viruses relative to bacteria or human cells
https://www.youtube.com/watch?v=slUUu5tO0o4

Activity 6

The main problem: How do viruses enter cells? Demonstrate the relationship between the structure of the virus and how it penetrates the cell.
Analysis of selected educational films and educational materials shows the relationship between the structure of the virus and the way it enters the cell. https://pl.wikipedia.org/wiki/Wirusy
The basic scheme of virus entry into cells, duplication of components, assembly and release of viral particles (infographics)

Evaluation task

On the diagram presented, indicate the places where the listed stages of the viral life cycle take place:



entry of the virus into the cell (1),
duplicating virus components (2),
assembling virus components (3),
viral particle release (4).
Helpful videos:

1. Videos - virion assembly:

https://www.youtube.com/watch?v=ugM1nIhfIA&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=21 - influenza virus and antigenic drift (new virus mutations)
b) HIV and Reverse Transcriptase:
https://www.youtube.com/watch?v=PlSvywlLuNw&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=18
c) bacteriophage vs. E. coli
https://www.youtube.com/watch?v=YAy4MxRnPYY&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=27
d) ingress of the virus
https://www.youtube.com/watch?v=jkNxmTrrZSk&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=2v
e) bacteriophage as the most lethal agent on Earth
https://www.youtube.com/watch?v=YI3tsmFsrOg

Activity 7

The main problem: How do viruses survive in cells? Life cycle

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Analysis of infographics and content analysis of the life cycle of viruses (additionally, students can be instructed to analyze information from the ZPE - lytic and lysogenic cycle of viruses).
The student's task is to analyze information and select the elements that allow viruses to survive in cells and guarantee their success on Earth for billions of years.
https://pl. A movie about the bacteria attack:
https://www.youtube.com/watch?v=YAy4MxRnPYY&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=27
https://www.youtube.com/watch?v=V73nEGXUeBY&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=26
How scientists investigate bacteriophages:
https://www.youtube.com/watch?v=sWM8vRLSRtg&t=133s
Hershey's and Chase's experiments:
https://pl.khanacademy.org/science/biology/dna-as-the-genetic-material/dna-discovery-and-structure/a/classic-experiments-dna-as-the-genetic-material
Additional information sources:
Lityc and lysogenic cycle:
https://zpe.gov.pl/b/cykle-lityczny-i-lizogeniczny/PjbM0mNOA
Khan Academy:
khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages

Activity 8
The main problem: Are viruses parasites, parasitoids, or predators? Use of infographic with definition of these terms
Task:
In the light of the presented definitions, determine which ecological group the viruses belong to and construct an argument supporting your position.

Evaluation task

Task 1
Please evaluate whether the following virus information is correct. Mark P if the information is true or F if it is false.
1. Viruses are obligatory intracellular parasites - they can reproduce only in the host's cells.
P F
2. Each virus is made of nucleic acid, a protein capsid, and a lipid envelope, facilitating the penetration only. **P F**
3. The genome of animal viruses is made up of DNA, and in plant viruses, it is made of either DNA or RNA. **P F**
1. (0–1)
Resolution
1. – **P**, 2. – **F**, 3. – **F**
Zadanie 2. 6.3. / NF, June2016
Wymienione poniżej etapy infekcji wirusowej uporządkuj we właściwej kolejności – wpisz w tabel numery 2–5.
Viral infection stages
Order
Connecting viral proteins with the genetic material of the virus.
Recognition by virus particles of the appropriate receptors on the surface of the attacked cell.
1.
Releasing new virions.

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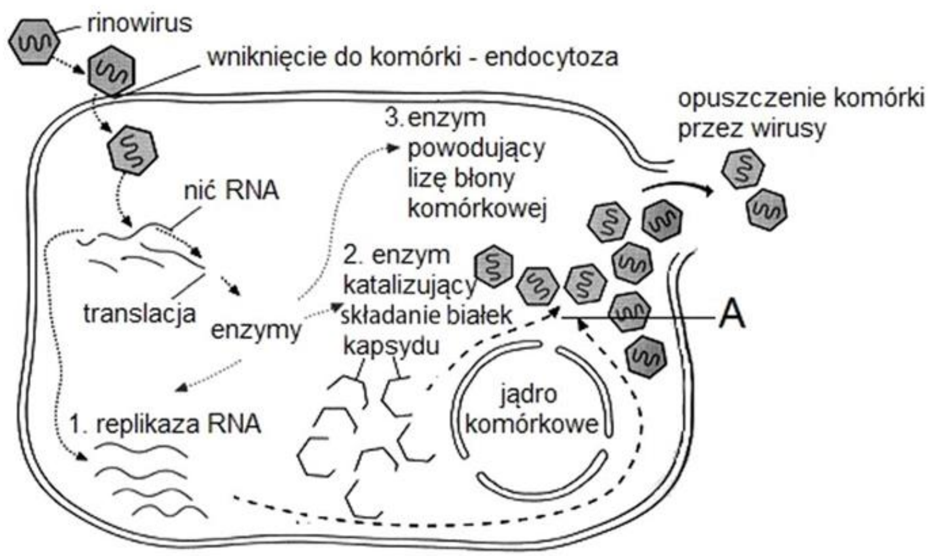
Replication of the genetic material of the virus.
Penetration of the virion inside the cell and decay of the capsid.
2. (0–1)
Resolution
Viral infection stages
Order
Connecting viral proteins with the genetic material of the virus. **4**
Recognition by virus particles of the appropriate receptors on the surface of the attacked cell.
1
Releasing new virions. **5**
Replication of the genetic material of the virus. **3**
Penetration of the virion inside the cell and decay of the capsid. **2**
Task 3. 8. / SF-R, July 2020
The figure shows the life cycle of the rhinovirus (which causes the common cold).



Adapted from: C. J. Clegg, D. G. Mackean, Advanced Biology, London 2012.
3.1. Using the figure, present three processes in the host cell catalyzed by enzymes encoded by the genetic material of the rhinovirus - marked with numbers 1–3.
enzyme 1. …………………………………………………………………
enzyme 2. ………………………………..…. ………………………………… ..
enzyme 3. ……………………………… .. ………………………………… ..
3.1. (0-1)
Solution
enzyme 1.- virus RNA replication,
2nd enzyme - folding the capsid from proteins,
enzyme 3. - digestion of the cell membrane/disruption of the cell membrane
3.2. Identify the stage in which the virus multiplies in the host cell, marked with the letter A. in the figure.
3.2. (0-1)
Sample solution
Step A of rhinovirus multiplication in the host cell consists in assembling the viral RNA and the capsid/building the capsid around each viral RNA particle / viral RNA strand.

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Lesson 5-6 Pathogenicity - virus vs. immune system

Objectives

In terms of knowledge:
Student:

- *gives the routes of transmission of viral diseases,*
- *lists the factors that weaken the immune system,*
- *lists viral diseases: rabies, AIDS, Heine-Medina, diseases caused by HPV infection, influenza, measles, smallpox, rubella, mumps, hepatitis A, B, and C,*
- *characterizes the symptoms of a viral infection,*

In terms of skills,

- *proposes a definition of health and disease,*
- *designs an experiment examining the effectiveness of masks in preventing the spread of pathogens.*
- *evaluates the economic importance of plant and animal viruses.*

In terms of attitudes
- shapes pro-health and prophylactic attitudes that protect against viral infections.

Methods

- *Negotiating meanings, working in groups*
- *Wanted poster*
- *Case study*
- *Role-play*
- *Interview*
- *SWOT analysis*

The course of the lesson:

Activity 1
The main issue to be debated: When are we sick and when are we healthy? Which means that someone is healthy, and what means that someone is sick?
The definition of disease and the definition of health - the relationship between the two terms.
Principles of work: Students (first individually) create definition cards of two concepts - health and disease, and stick their definitions on two sheets of paper. In the next step, they look for common elements and discuss those that are only in individual cases. Ultimately, each group presents its own mutually agreed definition.

Activity 2
The main issue to be debated: What determines the health problems caused by viruses? What factors contribute to viral infections?
Students are asked to prepare a guide for other students informing them about risk factors and preventing viral diseases.

Activity 3.
Problem: Do the masks give us something?
Dividing the class into two groups - those who think they are helpful and skeptical about the effectiveness of face masks. Then both groups are asked to provide arguments justifying the selected positions.
After listening to the arguments, the film is shown - masks:
https://www.youtube.com/watch?v=DNeYfUTA11s High-speed camera captures how different types of face masks work

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Problem questions for classroom discussion: How does the infamous virus that paralyzed the world work? What can we do to prevent the development of the coronavirus pandemic in the future? What factors are contributing to the spread of this virus?
Film Screening: Coronavirus Film - Spread, Penetration Mechanism, etc.
https://www.youtube.com/watch?v=I-Yd-_XIWJg&list=PLRuLO8d3L-MA5ieaZnVbGs6XIGzTlgiOX

Activity 4
How do the viruses spread?
Activity with using fluorescent material and UV lamp.

Activity 5
It is a task to be performed in a computer lab or as homework, as it requires Internet access.
Instruction for the student: Using the prepared infographics - presenting the idea of the arrest warrant and the example of this letter, prepare arrest warrants for the viruses that have hit your desk. You can use the information available on the Internet.
Some sources of information:
https://www.youtube.com/watch?v=tMTl3gU0mFc&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=4 - bird and swine flu/ antigenic shift
https://www.youtube.com/watch?v=Q9L7ZQPc8EA&list=PLDtejNiUATM82I70CAGoLVgvjXr09DnQP&index=11 - hepatitis A and B, attacking hepatocytes.

Activity 6
Main problem: Do plants, and other animals than human also get viral diseases?
Should we focus on protecting against epidemics that threaten plants and not humans?
https://thebiologist.rsb.org.uk/biologist-opinion/the-threat-of-a-plant-disease-epidemic
Students take on the role of members of a food defense association. Their task is to prevent another pandemic that will cause losses to growers and growers.
They receive information packages on:
swine foot-and-mouth disease,
cucumber green mosaic virus

The student's task is to prepare a 3-minute press conference recording. They will summarize - how the virus works, what costs we incur in connection with infections, and what actions we plan to take to reduce financial losses.
Additional materials:

1. Global pandemics and epidemics of plant viruses:

https://pubmed.ncbi.nlm.nih.gov/33504044/
B) Plant viruses overview and disease management:
https://www.frontiersin.org/articles/10.3389/fpls.2020.01092/full
C) Mouth and hooves disease: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3989032/
D) Plant viruses: https://www.totylkoteoria.pl/roslinne-wirusy-bakulowirusy/

Activity 7
The game - is a puzzle
Student activity - choose the name of the disease with the name of the virus and the description.

Activity 8
Main problem: Are we alone in the fight against the virus?
In addition to our immune system, some drugs can support the work of our system.
Analysis of the content of the article:
Antiviral drugs and interferons:
https://bioinfo.imdik.pan.pl/coronavirus-service/mesmerize/leki-prawywirusowe/

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Activity 9
Is it worth making the flu vaccine a problem for students to investigate?
checking statistics, risk and benefit analysis - swot (strengths, weaknesses, opportunities, threats)

Evaluation tasks

Task 1.
Even though it happens several times a year, the rhinovirus infection is relatively harmless. Could there be any benefit to a human being from having a rhinovirus infection?
Proposed answer
Thanks to rhinovirus infections, our immune system is constantly active, stimulated, and working to produce antibodies.

Task 2
2.1. Explain why RNA viruses are generally more of a challenge to our health than DNA viruses?
The reason is the inaccuracy of reverse transcriptase, which transcribes viral RNA into DNA for incorporation into cellular material, hence the genetic material of new viruses leaving the cell differs from those that accustom it, often posing a challenge to the immune system, which may no longer recognize new virus components.
2.2. What are two possible sources of variation in the genetic material of viruses?
inaccuracy of the polymerase when duplicating the genetic material of the virus
Reverse transcriptase inaccuracy
Antigenic shift: A genetic variation that involves the exchange of one or more single-stranded RNA fragments of the influenza virus. It occurs when the host cell is simultaneously infected with two different viruses.
Antigenically distinct virus subtypes are formed, with significant antigenic changes, mainly in the molecules that build the envelopes.
H (haemagglutinin) and N (neuraminidase). Against these "new" subtypes of influenza viruses, the body does not have previously built-up immunity and hence is often the cause of an epidemic or pandemic.
Antigenic drift: The phenomenon of genetic variation consisting in point, spontaneous mutations Slight changes, "new" strains of the virus will be similar to the "old" strains, and part of the society will be resistant to them

Task 3
Antigenic drift: The phenomenon of genetic variation consisting in point, spontaneous mutations Slight changes, "new" strains of the virus will be similar to the "old" strains, and part of society will be resistant to them. e.g., influenza will penetrate a cell that is already infected with a different type of virus; their genetic materials may be mixed - there is an antigenic jump) mutations (Antigenic shift - a phenomenon of genetic variation consisting in point, spontaneous mutations occurring in the course of virus replication)
Analysis of the text from Planet of the Viruses (pp. 43-44) about the influenza virus and the 2009 epidemic - swine flu - look for a diagram
https://en.wikipedia.org/wiki/Antigenic_shift#/media/File:AntigenicShift_HiRes.svg
3.1. Regarding the phenomenon of the antigenic jump, explain why a new strain of influenza (swine flu) posed a risk to people who came into contact with this virus.
3.2. Show what the 1918 flu epidemic had in common with that of 2009.
3.3. Explain why scientists cannot predict whether new emerging viruses will be "mild" or "virulent."
3.4. Suggest actions that each of us can and should take to help reduce the spread of flu.
Proposed answers:
washing hands, avoiding contact with the sick (patients should stay home), vaccination campaigns

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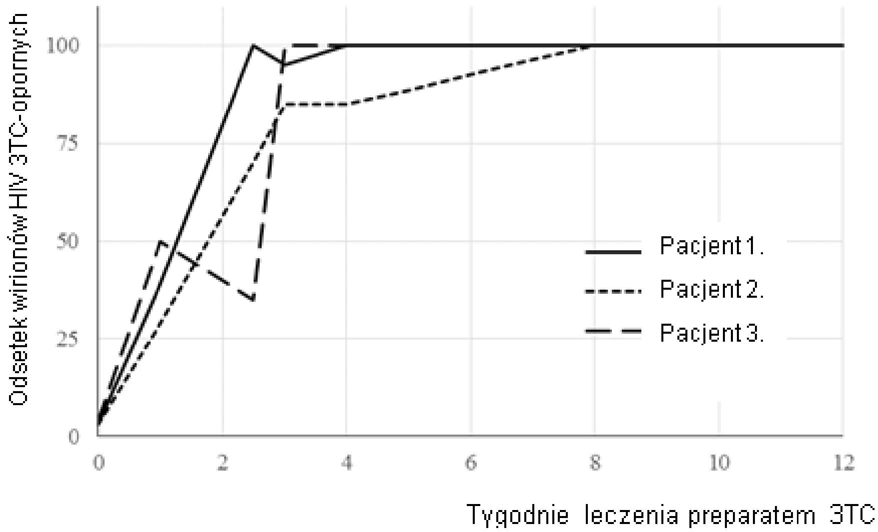
Task 4. 23. / SF-R, June 2018
3TC blocks the action of reverse transcriptase, an enzyme that HIV uses to make DNA molecules from its genome. The 3TC molecule is structurally related to a cytosine nucleotide, and therefore viral reverse transcriptase integrates into the nascent DNA of the 3TC molecule instead of the cytosine nucleotide. Due to this error, extending the DNA strand any further becomes impossible. There are strains of HIV that have reverse transcriptases that distinguish 3TC molecules from the cytosine nucleotide and are insensitive to 3TC.
The figure shows HIV resistance to the drug 3TC in three patients.



Based on: N.A. Campbell et al., Biologia, Poznań 2012.
4.1. Explain why the 3TC preparation prevents the integration of the viral genetic material into the host genome. Consider reverse transcriptase's mechanism of action as an answer.
4.1. (0-1)
Sample solutions
Blockade of the action of HIV reverse transcriptase by 3TC will prevent the virus from transcribing the genetic information from RNA into DNA, thus preventing the integration of the viral genetic material into the host genome's DNA.
Reverse transcriptase blockade will prevent the virus from making the reverse transcription, the product of which could be incorporated into the host's DNA.
4.2. Use the graph to explain the mechanism of acquiring HIV resistance to 3TC in patients treated with this drug.
4.2. (0-1)
Sample solutions
The administration of the 3TC preparation resulted in the elimination of virions sensitive to the 3TC preparation. HIV 3TC virions - resistant remained and were able to multiply. As a result, the proportion of resistant 3TC viruses in the population increased until they accounted for 100% of the population.
With the preparation administration, more and more 3TC virions sensitive to the preparation decreased, with the simultaneous multiplication of the resistant virions, whereby the proportion of resistant virions increased until finally, only these remained.
By administering 3TC, the susceptible virions were eliminated, and the resistant virions remained and multiplied.

Supplementary learning resources and educational activities

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Scenario was consulted with third parties – medical professionals (Piotr Kwaśniewski – pediatrician) and virologists.
Also parents of the students and will be invited to actively participate in the debate and summary meetings and university to observe, reflect and discuss on the results presented by students. Schools will be also invited to participate in specially organised project for them at the University.
Additionally to that University professor – Robert Nawrot serves as a consultant on the meetings with students. In this scenario author of a blog - journalist – "It is just a theory" Łukasz Sakowski have prepared short article for students about life. Students from the school in the project will attend in scientific fairs at Faculty of Biology of Adam Mickiewicz University in Poznań – such as Night of the Scientists, Night of the Biologists or Festival of Science and Art. In all of this events PAFSE will have its own stand but more importantly students from the schools involved in the project will have priority entrance to any workshops and lectures.
Beside of this part included in scenarios students will be also invited to the Institute of Protecting plants to observe and experience projects which treat about plant viruses and how they might be threat to food industry. Moreover students will be visited by physician from infectious diseases ward who will bring students closer to the reality of fighting the epidemic and will answer students questions and doubts. In the end students will have also opportunity to meet with mathematician and IT specialist at the University, who will do with the students model of spreading viral disease and visualise it in graphic programme.

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18. Specifications for an educational scenario on the topic "The different shades of bacteria - Humanity is just a tiny crumb in a largely bacterial world"

(Martin J. Blaser, microbiologist)

Main partner responsible

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Overview

Bacteria are a group of unicellular, prokaryotic organisms that make up their kingdom. They are the first organisms that appeared on Earth about 3.5 billion years ago. Before eukaryotic cells evolved, bacteria flourished without competition. They are ubiquitous, and apart from places that are sterile by nature (e.g., inside of our organs), bacteria can be found in all biotopes. They are also found in radioactive areas and even ... in space - where they probably got along with spacecraft. There are roughly five quintillions ($5x10^{30}$) bacteria on Earth, making up a large proportion of the planet's biomass. So far, their biodiversity has not been fully known.

Among the bacteria, we have commensal, mutualistic, predatory, and parasitic organisms. They have unique abilities to survive unfavourable environmental conditions, and their adaptability is almost exemplary. Such a wide range of ecological influences and evolutionary abilities mean that from the anthropocentric perspective, they can be perceived both as friends and enemies, causing several dangerous bacterial diseases, influencing the world's fate, and making our life possible. Their role is difficult to overestimate; they contribute to the circulation of elements in nature. They take part in all biogeochemical cycles and the processes of fermentation and rotting. As symbiotic organisms, they enable the digestion of food or facilitate its digestion and subsequent excretion; they produce vitamins and affect the general well-being. More and more studies indicate the role of the microbiome in the functioning of organisms in human functioning and the relationship of diseases such as Parkinson's and Alzheimer's syndrome or depression with the microbiota.

Scientific content and its relevance to public health education

- Understanding of the decisive importance personal behavior has for the societal good during an epidemic.
- Visualization and active inquiry of epidemiological parameters such as cases, deaths, asymptomatic cases, infectivity, healthcare system capacity and the epidemic curve, which are commonly referred to in the public sphere, during an epidemic.
- Understanding of importance of antibiotic therapy and conducting it according to medical professionals' orders.
- Awareness of meaning of antibiotic resistance bacteria and how public behavior can influence it (e.g., limiting consumption of meat as antibiotics are used in animal feed

Estimated duration

8 teaching hours, organized in continuous two-hour periods if possible. Proposed lessons should be conducted during biology lessons.

STEM Content

- Fundamental concepts of biomedical sciences (e.g., communicable diseases, infectivity, epidemic).
- Function, use and nature of scientific models.

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- Introduction to transdisciplinary issues, such us scientific modelling – Convergence of sciences to handling with complex problems.
- Use of mathematics in natural sciences.
- Scientific work on authentic problems.
- Authentic scientific data driven decision making.
- Importance of scientific work for civic decision making.
- Shows the structure of a prokaryotic cell, taking into account the differences in the structure of the cell wall of Gram-positive and Gram-negative bacteria;
- Explains the differences between archaea and bacteria; shows the importance of archaea; shows the variety of morphological forms of bacteria;
- Presents the vital functions of bacteria: nutrition (chemoautotrophy, photoautotrophy, heterotrophy); anaerobic (denitrification, fermentation) and aerobic respiration; multiplication;
- Shows the importance of sexual processes in the genetic variability of bacteria;
- Presents the importance of bacteria in nature and for humans, including those causing human diseases (tuberculosis, tetanus, Lyme disease, salmonellosis, syphilis, gonorrhea).

Content glossary

A microbiome (from Ancient Greek μικρός (mikrós) 'small', and βίος (bíos) 'life') is the community of microorganisms that can usually be found living together in any given habitat. It was defined more precisely in 1988 by Whipps et al. as "a characteristic microbial community occupying a reasonably well-defined habitat which has distinct physio-chemical properties. The term thus not only refers to the microorganisms involved but also encompasses their theatre of activity". In 2020, an international panel of experts published the outcome of their discussions on the definition of the microbiome.

A biofilm comprises any syntrophic consortium of microorganisms in which cells stick to each other and often also to a surface. These adherent cells become embedded within a slimy extracellular matrix that is composed of extracellular polymeric substances (EPSs). The cells within the biofilm produce the EPS components, which are typically a polymeric conglomeration of extracellular polysaccharides, proteins, lipids and DNA. Because they have three-dimensional structure and represent a community lifestyle for microorganisms, they have been metaphorically described as "cities for microbes".

A plasmid is a small, extrachromosomal DNA molecule within a cell that is physically separated from chromosomal DNA and can replicate independently. They are most commonly found as small circular, double-stranded DNA molecules in bacteria; however, plasmids are sometimes present in archaea and eukaryotic organisms. In nature, plasmids often carry genes that benefit the survival of the organism and confer selective advantage such as antibiotic resistance.

Adhesion is the tendency of dissimilar particles or surfaces to cling to one another (cohesion refers to the tendency of similar or identical particles/surfaces to cling to one another). The forces that cause adhesion and cohesion can be divided into several types. The intermolecular forces responsible for the function of various kinds of stickers and sticky tape fall into the categories of chemical adhesion, dispersive adhesion, and diffusive adhesion. In addition to the cumulative magnitudes of these intermolecular forces, there are also certain emergent mechanical effects.

An antibiotic is a type of antimicrobial substance active against bacteria. It is the most important type of antibacterial agent for fighting bacterial infections, and antibiotic medications are widely used in the treatment and prevention of such infections. They may either kill or inhibit the growth of bacteria. A limited number of antibiotics also possess antiprotozoal activity. Antibiotics are not effective against viruses such as the common cold or influenza; drugs which inhibit viruses are termed antiviral drugs or antivirals rather than antibiotics.

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Antimicrobial resistance (AMR) occurs when microbes evolve mechanisms that protect them from the effects of antimicrobials. Antibiotic resistance is a subset of AMR, that applies specifically to bacteria that become resistant to antibiotics.

Archaea (/ɑːrˈkiːə/ (listen) ar-KEE-ə; singular archaeon /ɑːrˈkiːən/) constitute a domain of single-celled organisms. These microorganisms lack cell nuclei and are therefore prokaryotes. Archaea were initially classified as bacteria, receiving the name archaebacteria (in the Archaebacteria kingdom), but this term has fallen out of use. Archaeal cells have unique properties separating them from the other two domains, Bacteria and Eukaryota. Archaea are further divided into multiple recognized phyla. Classification is difficult because most have not been isolated in a laboratory and have been detected only by their gene sequences in environmental samples.

Bacteria (/bækˈtɪəriə/ (listen); common noun bacteria, singular bacterium) are ubiquitous, mostly free-living organisms often consisting of one biological cell. They constitute a large domain of prokaryotic microorganisms. Typically, a few micrometres in length, bacteria were among the first life forms to appear on Earth and are present in most of its habitats. Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep biosphere of Earth's crust. Bacteria are vital in many stages of the nutrient cycle by recycling nutrients such as the fixation of nitrogen from the atmosphere. The nutrient cycle includes the decomposition of dead bodies; bacteria are responsible for the putrefaction stage in this process. In the biological communities surrounding hydrothermal vents and cold seeps, extremophile bacteria provide the nutrients needed to sustain life by converting dissolved compounds, such as hydrogen sulphide and methane, to energy. Bacteria also live in symbiotic and parasitic relationships with plants and animals. Most bacteria have not been characterised and there are many species that cannot be grown in the laboratory. The study of bacteria is known as bacteriology, a branch of microbiology.

Bacterial conjugation is the transfer of genetic material between bacterial cells by direct cell-to-cell contact or by a bridge-like connection between two cells. This takes place through a pilus. It is a parasexual mode of reproduction in bacteria. It is a mechanism of horizontal gene transfer as are transformation and transduction although these two other mechanisms do not involve cell-to-cell contact.

Gram stain or Gram staining, also called Gram's method, is a method of staining used to classify bacterial species into two large groups: Gram-positive bacteria and Gram-negative bacteria. The name comes from the Danish bacteriologist Hans Christian Gram, who developed the technique in 1884. Gram staining differentiates bacteria by the chemical and physical properties of their cell walls. **Gram-positive cells** have a thick layer of peptidoglycan in the cell wall that retains the primary stain, crystal violet. **Gram-negative cells** have a thinner peptidoglycan layer that allows the crystal violet to wash out on addition of ethanol. They are stained pink or red by the counterstain,[2] commonly safranin or fuchsine. Lugol's iodine solution is always added after addition of crystal violet to strengthen the bonds of the stain with the cell membrane.

Peptidoglycan or murein is a polymer consisting of sugars and amino acids that forms a mesh-like peptidoglycan layer outside the plasma membrane of most bacteria, forming the cell wall. The sugar component consists of alternating residues of β-(1,4) linked N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM). Attached to the N-acetylmuramic acid is a peptide chain of three to five amino acids. The peptide chain can be cross-linked to the peptide chain of another strand forming the 3D mesh-like layer. Peptidoglycan serves a structural role in the bacterial cell wall, giving structural strength, as well as counteracting the osmotic pressure of the cytoplasm. Peptidoglycan is also involved in binary fission during bacterial cell reproduction.

Prebiotics are compounds in food that induce the growth or activity of beneficial microorganisms such as bacteria and fungi. The most common example is in the gastrointestinal tract, where prebiotics can alter the composition of organisms in the gut microbiome .

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Resident and transient bacteria - the resident microbiota consists of microorganisms that constantly live in or on our bodies. The term transient microbiota refers to microorganisms that are only temporarily found in the human body, and these may include pathogenic microorganisms. Hygiene and diet can alter both the resident and transient microbiota.

Symbiosis (from Greek συμβίωσις, symbíōsis, "living together", from σύν, sýn, "together", and βίωσις, bíōsis, "living")[2] is any type of a close and long-term biological interaction between two different biological organisms, be it mutualistic, commensalistic, or parasitic. The organisms, each termed a symbiont, must be of different species. In 1879, Heinrich Anton de Bary defined it as "the living together of unlike organisms". The term was subject to a century-long debate about whether it should specifically denote mutualism, as in lichens. Biologists have now abandoned that restriction

<u>**Pedagogical glossary**</u>

Brainstorming - a technique derived from social psychology that aims to improve group decisions. Brainstorming is also a form of didactic discussion, used as one of the teaching methods. Then it is included in the activating methods, which is a subgroup of problem methods. One of the so-called heuristic methods. Brainstorming is used to generate ideas to solve problems that are generally new problems to which most participants do not know the answers. In one version, it consists of two stages:

- In the first stage, participants are encouraged to freely submit ideas and exchange views, subject to no criticism whatsoever. All ideas are saved or the session is recorded on tape.
- In the second stage, an expert or a group of experts not participating in the first stage reviews the results and tries to filter out ideas that make sense.

In practice, research has shown that while brainstorming can be very effective, its effectiveness can also be easily lost. In particular, factors damaging its effectiveness are, for example, the presence of a very strong dominant personality in the first stage, too high ambition of some participants, preventing others from having a say, little openness to new ideas of experts evaluating ideas, the participant's willingness to change the topic to something unrelated to the task, etc. (see group thinking syndrome).

Case studies are stories that are used as a teaching tool to show the application of a theory or concept to real situations. Dependent on the goal they are meant to fulfill, cases can be fact-driven and deductive where there is a correct answer, or they can be context driven where multiple solutions are possible. Various disciplines have employed case studies, including humanities, social sciences, sciences, engineering, law, business, and medicine. Good cases generally have the following features: they tell a good story, are recent, include dialogue, create empathy with the main characters, are relevant to the reader, serve a teaching function, require a dilemma to be solved, and have generality. Instructors can create their own cases or can find cases that already exist.

Content analysis is, by definition, the study of textual messages, both written (books, newspapers, documents, websites) and oral (broadcast via radio and television). The purpose of the analysis is to reduce the content of the entire text to its most important meanings: the most frequent words, key threads, prevailing grammatical and semantic forms, etc. This method is also used in didactics as a tool that allows you to find answers to a given question by reducing the content of the entire message to key information. It also allows you to search for key terms or concepts important from the point of view of the discussed content.

Discussion - Discussion (this is a term of Latin origin: discutere - to break up, spread out) - it is an oral or written exchange of views on a specific topic, aimed at reaching common conclusions. Discussion is an activity carried out in a group of two or more people and aimed at solving a problem. It does not have a

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structured form like the Oxford debate, but the essence of a good discussion is also well-structured arguments.

It is a process by which theses are presented, supported by competent arguments, and allows other people to test their theses or present counter-arguments.

Discussion allows you to prevent misunderstandings, solve problems - or at least understand them better.

IBSE – inquiry based sience education, inductive approach in teaching and learning science and technology. inquiry-based learning is based on the recognition that science is essentially a question-driven, open-ended process of constructing coherent conceptual frameworks with predictive capabilities and that students must have personal experience with scientific inquiry and engage in its practices, in order to be enculturated in these fundamental apects of science. inquiry learning, referrs to the active learning processes in which students are inevitably engaged. Inquiry based teaching is a bit more flickering term and less precise in literature. IBST is a proces connected with involving students in inquiry activities with questions that are meaningful to them (e.g. generated from their own experiences) and with the explicit aim to develop coherent knowledge and rigorous understanding of phenomena, as well as understanding of how scientists study the natural world and what ideas they have developed in the process. For achieving that, the teacher needs to prepare an ingenious and planned scaffolding, for assisting the students through modelling and coaching in particular by the use of questioning strategies.

Learning by doing – it is an approach in which learning takes place in action, by applying knowledge into practice, by internalization of skills and practical exercises a student is supposed to build own knowledge. Teaching and learning by inquiry is described as how teaching and learning is executed, the nature of the classroom interactions and the practice of inquiry skills (Tamir 1990). This notion emphasizes the importance of engaging students in investigative processes that enable them to answer important questions (Chiappetta and Adams 2000). Improved forms of learning by doing now can be supported by information technologies, and there are prospects for extensions to group learning by doing and group learning from examples in the near future.

Models and the process of scientific modeling are core components of human cognition and scientific inquiry. Models as tools are used in classroom for exploration, synthesis, prediction, and knowledge construction. Building models not only has the potential to help students improve their understanding about natural phenomena or complex systems, but it can also facilitate their understanding of the nature of science as an enterprise that is largely concerned with extending and refining models (Gilbert and Rutherford 1998, Linn, 2003). In its simples form model is a representation of an phenomena or object.

Mind map and concepts maps - are techniques for visualizing information in teaching process. Some of them are: conceptual maps, mind maps, conceptual diagram, visual metaphor, semantic networks, etc. (Eppler, 2006; Parikh, 2015). A concept map is a top-down diagram showing the relationships between concepts, including cross connections and their manifestations (Eppler, 2006). Since concepts are very clearly connected to each other, concept maps represent knowledge structures as a whole (Nousiainen, 2012). According to Usta and Ültay (2016), McClure, Sonak and Suen have emphasized that concept maps can be used as a learning strategy, as a teaching strategy, as a strategy for planning curriculum, and as a means of assessing students' understanding of science concepts (Usta & Ültay, 2016). Mind maps were first constructed by T. Buzan (Buzan & Buzan, 1996). Buzan used Habert's ideas to develop mind mapping as a method of note-taking based on the idea of making notes as brief as possible and as "interesting to the eye" as possible by using visual effects (Abi-El-Mona & Adb-El-Khalick, 2008). Mind mapping is used in order to represent knowledge by organizing it in a form of network or other non-linear diagram (Dhindsa & Anderson, 2011). Mind maps are composed of a central idea, keywords (edges) and nodes (Kedaj, Pavlíček, & Hanzlík, 2014). The central idea can be a physical phenomenon or a concept that is treated during a particular class. The keywords are branching from the central idea to specific details that may be presented in the form of images, formulas or experiment sketches. Images or sketches are most often represented in color. In this way, both brain hemisphere activation is achieved (Buzan & Buzan, 1996;

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Seyihoglu & Kartal, 2010). Mind maps can be used in all situations involving the need for learning and any form of thinking (Kovačević & Segedinac, 2007). According to them, this can be: planning, organizing, analyzing and solving problems, designing projects, preparing speeches and presentations, writing, making notes, lecturing, and similar

Microscopy is the technical field of using microscopes to view objects and areas of objects that cannot be seen with the naked eye (objects that are not within the resolution range of the normal eye).[1] There are three well-known branches of microscopy: optical, electron, and scanning probe microscopy, along with the emerging field of X-ray microscopy. Optical microscopy and electron microscopy involve the diffraction, reflection, or refraction of electromagnetic radiation/electron beams interacting with the specimen, and the collection of the scattered radiation or another signal in order to create an image. This process may be carried out by wide-field irradiation of the sample (for example standard light microscopy and transmission electron microscopy) or by scanning a fine beam over the sample (for example confocal laser scanning microscopy and scanning electron microscopy).

Oxford debate - a type of argument exchange to discuss a thesis. The opponents of the thesis and its defenders are debating. They are chaired by the marshal, who is assisted by a secretary who watches over the time and sequence of statements. It comes from the University of Oxford. Its key element is an adequate selection of arguments and counter-arguments. Its course includes:

- Commencement - when the Speaker starts a debate, he informs the parties about its principles and subject.
- Debate between arguing parties - The floor is given alternately to individual parties. The side that defends the thesis begins. Statements are structured as arguments.
- The voice of the audience - in order to be admitted to the debate, one has to attract the marshal's attention, if he or she gives the floor, the person introduces himself (which is written down by the secretary) and only starts to express his opinion.
- Summary - both sides summarize all the speeches. They can provide answers to the counter-arguments of the opposing parties, and support their views with additional arguments.
- Vote - the final part of the debate is voting. Traditionally in Oxford, it is done through an exit through a door. Nowadays, in other cases, the most common vote is by show of hands.

Project - based learning - Project-based learning (PBL) or project-based instruction is an instructional approach designed to give students the opportunity to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world. Project-based learning is more than just "doing a project," in the way you might remember from your own school days. As the Buck Institute for Education (BIE) explains, with PBL, students "investigate and respond to an authentic, engaging, and complex problem or challenge" with deep and sustained attention.[1] ArchForKids, an organization that provides STEAM programs for young learners, puts it even more succinctly: PBL is "learning by doing."

Problem-based learning - Problem-based learning (PBL) is a student-centered approach in which students learn about a subject by working in groups to solve an open-ended problem. This problem is what drives the motivation and the learning. Rather than teaching relevant material and subsequently having students apply the knowledge to solve problems, the problem is presented first. PBL assignments can be short, or they can be more involved and take a whole semester. PBL is often group-oriented, so it is beneficial to set aside classroom time to prepare students to work in groups and to allow them to engage in their PBL project.

Role-play is a technique that allows students to explore realistic situations by interacting with other people in a managed way in order to develop experience and trial different strategies in a supported environment. Depending on the intention of the activity, participants might be playing a role similar to their own (or their

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likely one in the future) or could play the opposite part of the conversation or interaction. Both options provide the possibility of significant learning, with the former allowing experience to be gained and the latter encouraging the student to develop an understanding of the situation from the ‘opposite’ point of view.

Scientific modeling is a process that allows students to use a model in a way that it this model represents, explans the phenomena or onjces and allows for predictions. Scientific modeling seems to be promising in scaffolding learners’ understanding of the complex processes of science through building, testing, revising, and applying models. Scientific modeling is conected with:

I Modeling skills, and this involves
• Model formulation
• Identification of model components
• Comparing and contrasting models of the same phenomenon
• Model evaluation and formulating ideas for improvement
• Model validation through comparison with phenomena in the same class
II. Metacognitive knowledge about the modeling process: explicit description and reflection on the major steps of the modeling-based cycle
III. Meta-modeling knowledge: epistemic knowledge about the
• Nature of models (3 elements – representation, explanation and prediction)
• Purpose or utility of models

Visualisation - In short *Visualization* is the graphical display of information. The purpose of it is to provide the viewer a visual means of processing the information. It is important to note that for a vizualization to be effective it must draw upon the knowledge base of the viewer. If the viewer does not posess the knowledge to understand the graphical entities and the relations between them the visualization does not achieve its goal. Visualization has many applications. For the most part they can be classified into two categories:

- Data Exploration
- Communicating Information

Visualization is the creating or recreating of imaginary or real scenes within one’s mind. However, the term “visualization” can be misleading, because visualizing involves more than just imagery. In fact, the more senses utilized, such as touch sound and taste, the more powerful the result.
It is in the visualisation of ideas, and the expression or representation of our ideas, that we can bring something more clearly into consciousness. A drawing might be seen as an externalisation of a concept or idea. drawing, and the related visualisation that results from drawing, helped children to construct meaning for themselves as well as share their ideas with others and across contexts.
The terms “visual” and “visualisation” are often used in the context of external representations, from depictive ones like photographs, videos, and 3D models, to simplified and abstracted line drawings, and even transient visual referents such as gestures. Formal and relatively well-developed visual codes such as flow charts, networks, and sign languages employ symbols that may be remote from their visual referents, with a vocabulary and grammar of their own.

Competences / Learning Goals

I. Knowledge (Core Concepts)
a) Transdisciplinary concepts: scientific modelling, graphs in science.
b) Specific content concepts: communicable diseases, epidemic, pandemic, disease transmission route, bacteria, bacteria communication, antibiotics, antibiotic resistance, bacterial diseases

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II. Skills
a) General skills: critical thinking, reflective thinking, problem solving, decision making, collaboration and communication within small groups, presentation skills.
b) Specific skills: use of scientific models, scientific data collection, analysis and interpretation, variable distinction and handling, scientific hypotheses testing and question answering, data driven conclusions making, discussing on science topics, scientific conclusions presentation and interpretation, constructing an argument.

III. Attitudes (Affective domain)
a) Attitudes and values: appreciation of biodiversity of bacteria, appreciation of their meaning on the level not only diseases but also symbionts – positive meaning of bacteria for society, appreciation of the vital importance of pharmaceutical and non-pharmaceutical interventions for the limitation of disease spreading, appreciation of the importance of models in scientific research, shaping of positive attitudes towards science during a health crisis, roughly empathizing with scientists in terms of the complex nature of their work and the necessary decision making, upgrading of the position of science in students' personal value systems, comprehension of the role of discussion and disagreements within the scientific community.
b) Behaviours: Constant application of scientific argumentation towards discussion about bacteria.

Classroom organization requirements
All special classroom organization requirements are proposed below directly in the lesson's activity.

Prerequisite knowledge and skills

- Microbial nature of contagion by communicable diseases.
- Examples of historical and modern cases of epidemics and pandemics – bacterial diseases,
- Fundamental hygiene rules as pharmaceutical interventions with use of antibiotics for preventing antibiotic resistance bacteria
- Ability to interpret infographics.
- Ease in making digital presentations.
- Ease in constructing an argument.

School research project

Topics and inquiry process:

P. What is bacteria? Do perfect bacteria exist?
Q. Incredibly small, incredibly numerous, but as clever as parasites - About bacteria that cause disease.
R. Life of bacteria under a magnifying glass - What is it like to be a bacterium?
S. Microbiome - how many humans and how many bacteria are in you?
T. Bacteria - enemy or friend?
U. Bacteria in court.

I. Research management and design

Pickling cucumbers/yogurt production
Recipe for pickling cucumbers, for making yogurt:
http://pracowniaaserow.pl/domowy-jogurt-naturalny/
Research question: what conditions must exist for lactate fermentation to occur?
Students can pickle pickles or make yogurt. Their task is to find the ideal conditions for this process (including temperature, amount of salt, etc.). Various unexpected effects may appear during the fermentation process, e.g., yogurt may turn bitter, which will indicate the presence of other bacteria - mainly

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anaerobic. Making microscopic slides from bacterial cultures' prepared cultures and comparing them is recommended.
After a week:
The smear is prepared on a degreased, cooled down glass slide by applying and spreading drops of the microorganism suspension (e.g., drops of water from cucumbers)
Then fix the specimen by pulling the slide 3x over the burner (thermal fixation method).
Dye the preparation with methylene blue

II. Data analysis and reporting
Observe the bacteria under the microscope - it is worth comparing the preparations quantitatively (where there are more and fewer bacteria)

III. Target audience for recommendations
The rest of the class, maybe teachers and students of the entire school proving the project is presented at a school event.

IV. Public debates and recommendations
Presentation of the project outcomes within a school event.

Teacher professional development actions

Teacher professional development on:

- Inquiry-based teaching and learning in accordance with the learning objective areas involved (content knowledge, inquiry skills, nature of science).
- Issues concerning the use of models in science and STEM education.
- STEM literacy aspects being promoted through the educational scenario (use of scientific models, authentic problem solving, inquiry-based teaching and learning, attitudes towards science, science within the societal contexts) and the issues of scientific and health numeracy.
- Project-based teaching and learning and principles and techniques of collaborative learning.
- Argumentation – structure and use of it in debates and discussions.
- The utilisation of Digital Learning Objects in the learning process.
- Main ideas of introducing scenario into the school – presenting to the teachers possibility of doing only the chosen activities from the scenario which answer to the needs of their group.

Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)

DERs created especially for the needs of the PAFSE project

I. Gram bacterial cell staining method - infographic
II. A computer game - drag and drop to build a bacterial cell
III. Bacterial cell structure - infographics
IV. Comparison of bacteria and archaeobacteria – infographic
V. Disease cards for case studies - infographic, case studies for diseases: tuberculosis, tetanus, Lyme disease, salmonellosis, syphilis, gonorrhea
VI. A blank disease card to be filled in by a group of students who are "doctors."
VII. Recipe for pickling cucumbers / making yogurt - infographic
VIII. The course of chemosynthesis in bacteria - infographic
IX. Stress in the life of bacteria - infographic
X. Bacteria coping strategies with antibiotics - infographic
XI. Argument structure – infographic
XII. Microbiome – infographic

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XIII. Argument structure – infographic
XIV. Prebiotics and probiotics – infographic
XV. Human map - the possibility of an interactive page with the marking of the places of occurrence of bacteria
XVI. Interesting facts about human microbiota - infographics under the slogan: "did you know that ...
XVII. The distribution of bacteria in your home - infographic
XVIII. Principles of creating a concept map - infographic
XIX. Ways of using E. coli by humans – infographic
XX. Rules of court work – infographic

Available resources (link) :

https://www.dropbox.com/sh/68datnzs9hn2xhj/AAC25IvEVW8tZZt95fBGVMHqa?dl=0

Supplementary Educational Resources (SERs)

Lesson 1
Examples of bacteria cells:
https://microbewiki.kenyon.edu/index.php/Microbial_Biorealm
Structure of the bacterial cell:
https://www.e-biotechnologia.pl/Artykuly/Budowa-bakterii
https://szkolnictwo.pl/test,4,3794,15,Bakterie-pierwsze_organizmy_na_Ziemi-Bakterie_gramujemne
https://szkolnictwo.pl/test,4,3794,13,Bakterie-pierwsze_organizmy_na_Ziemi-Mechanizm_barwienia
https://szkolnictwo.pl/test,4,3794,18,Bakterie-pierwsze_organizmy_na_Ziemi-Fimbrie
Bacteria communication:
https://www.ted.com/talks/bonnie_bassler_how_bacteria_talk

Lesson 2
https://www.mp.pl/pacjent/choroby-zakazne/choroby/zakazenia-bakteryjne
https://pl.wikipedia.org/wiki/Gru%C5%BAlica_cz%C5%82owieka
https://pl.wikipedia.org/wiki/T%C4%99%C5%BCec
https://pl.wikipedia.org/wiki/Salmonelloza
https://pl.wikipedia.org/wiki/Borelioza
https://pl.wikipedia.org/wiki/Ki%C5%82a
https://pl.wikipedia.org/wiki/Rze%C5%BC%C4%85czka

Lesson 3-4
For efflux pumps - https://przystaneknauka.us.edu.pl/artykul/czy-pompy-efflux-najlepsza-strategia-opornosci-bakterii
https://www.youtube.com/watch?time_continue=2&v=1q0z9lBJfRU&feature=emb_logo
Bacterial evolution and antibiotic resistance:
https://www.youtube.com/watch?v=plVk4NVIUh8
Antibiotic resistance:
https://www.totylkoteoria.pl/opornosc-na-antybiotyki-antybiotykoopornosc/
Bacteria vs Viruses - The Eternal War - CAS9 and CRISPR protein - (3: 51-5: 55) https://www.youtube.com/watch?v=jAhjPd4uNFY
Bacterial chemosynthesis
https://zpe.gov.pl/a/przeczytaj/DbGhwjCPA
Autotrophs and Heterotrophs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

Autotrophs and Heterotrophs

Lesson 5
https://pl.wikipedia.org/wiki/Mikrobiom
How the gut microbiome can affect our brain.
https://kosmos.ptpk.org/index.php/Kosmos/article/view/2634/2575
https://www.youtube.com/watch?v=VzPD009qTN4
Diet and the gut microbiome bacteria that degrade mucus in the intestine or fiber
https://www.uofmhealth.org/sites/default/files/Martens%20gut%20fiber%20diagramsm.jpg
Enzymes produced by the microbiome and the breakdown of testosterone leading to depression
https://www.cell.com/cell-host-microbe/fulltext/S1931-3128(22)00037-3
https://www.cell.com/cell-host-microbe/fulltext/S1931-3128(22)00038-5?fbclid=IwAR0KU2gbbbFrQV9ti52pcpAKTO9yislK_0stWOOxFZkgrHYvjM2g9QKVWEo

Lesson 6
https://www.youtube.com/watch?v=9R8fHo6WfzY - if you could see bacteria without a microscope? (gloves and hand hygiene)
https://www.youtube.com/watch?v=nEzJ_QKjT14 - experience with proper handwashing
https://www.youtube.com/watch?v=Pxujitlv8wc - comparison of eukaryotic and prokaryotic cells
https://www.youtube.com/watch?v=vAR47-g6tlA - archaea, bacteria, and protists
https://www.youtube.com/watch?v=ORB866QSGv8 - bacteria
https://www.amnh.org/explore/ology/microbiology/bacteria-in-the-cafeteria-game - an internet game about the importance of bacteria, but it's rather for primary school
E. coli - friend or foe
https://www.crazynauka.pl/bolesny-dowod-na-ewolucje-gdy-nasze-mile-bakterie-pokazuja-pazury/
General Visualisation
https://web.cs.wpi.edu/~matt/courses/cs563/talks/education/IEindex.html
https://minds-in-bloom.com/teaching-visualization-can-improve/

Teaching - Learning activities

Lesson 1 - What is bacteria? Do perfect bacteria exist?

Teaching phase according to the inquiry & project based instructional model: Engagement – Externalisation of students' initial conceptions – Initiation of reconstruction/completion of students' initial conceptions

Objectives
In terms of knowledge:
Student:

- *lists the elements of the structure of the bacterial cell,*
- *shows the features that allowed the distinction between the bacteria proper and the archaebacteria,*
- *lists the elements of the structure and physiology of bacteria included in its pathogenic mechanisms,*
- *describes the Gram staining method.*

In terms of skills
Student:

- *recognizes the elements of the structure of the bacterial cell in the drawing,*
- *compares different bacterial cells,*
- *shows the relationship between the structure of the bacterial cell and pathogenic mechanisms,*

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- *designs a bacterial cell that might be an ideal pathogen.*

In terms of attitudes
Student:

- *recognizes the complexity and diversity of the life forms of bacterial cells.*

Teaching methods

- *visualization of the bacterial cell as an ideal pathogen with use of computer programme*
- *group work*
- *discussion*
- *model building - creating a model from the salt mass*
- *computer game*

Course of the lesson:

Activity 1
Students are designing an ideal bacteria that can be a pathogen - a perfect bacterial cell that attacks the host cell/organism. Students are asked to make a drawing or a poster describing the mechanisms of operation of individual elements.

Activity 2
Working in pairs: Presenting examples of different bacterial cells that develop under different conditions (for example, in certain places of the human body - and must have specific fimbriae or saw blades, thanks to which they stick to, e.g., only the kidneys and not the urinary bladder).
Students are asked to compare the general structure of a bacterial cell provided during the lesson by the teacher with the construction of specific and different bacterial cells and their design.

https://pl.wikipedia.org/wiki/Bakterie
https://www.e-biotechnologia.pl/Artykuly/Budowa-bakterii
Discussion: When did the first bacteria arise? Are all bacteria an evolutionarily uniform group? What is LUCA? (Last universal common ancestor) - the last universal common ancestor and relative of all living creatures on Earth.

Activity 3
Objective: To learn about the structure of the bacterial cell
Key question: Which of the presented features of the structure and physiology of a bacterial cell are important as mechanisms of pathogenicity,
While discussing the individual elements of the bacterial cell structure, students wonder which of them may be of importance as a mechanism of pathogenicity. - discussion.
Key information: Elements of the structure and physiology of the bacterial cell, with particular emphasis on those crucial as mechanisms of pathogenicity,

a) Equipment of the cell necessary for adhesion https://szkolnictwo.pl/test,4,3794,18,Bakterie-pierwsze_organizmy_na_Ziemi-Fimbrie
b) Communication among bacteria
c) layer of mucus
d) genetic material and ribosomes
e) the possibility of improving your weapons - conjugation - recombining genetic material - also for fimbria and pili

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f) typical features of a bacterial cell - such as cell wall, cytoplasm, etc.

https://www.e-biotechnologia.pl/Artykuly/Budowa-bakterii
https://szkolnictwo.pl/test,4,3794,15,Bakterie-pierwsze_organizmy_na_Ziemi-Bakterie_gramujemne
https://szkolnictwo.pl/test,4,3794,13,Bakterie-pierwsze_organizmy_na_Ziemi-Mechanizm_barwienia
https://youtu.be/ORB866QSGv8

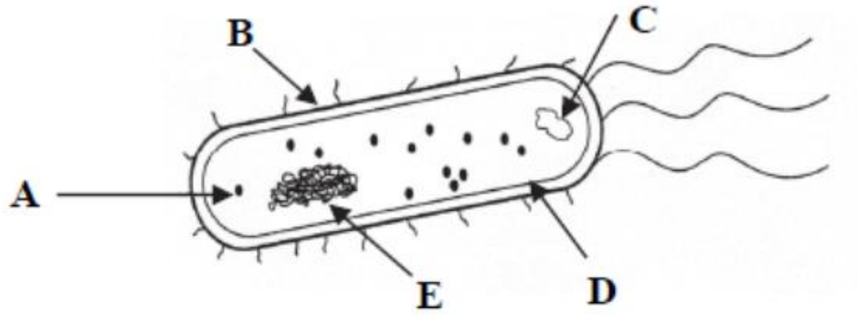
* Recommended small research project: check on which surfaces are the most batteries? The research question belongs to the students

Activity 4
Students are asked to build bacterial cell from the salt mass, foam poles or other available materials. You might want to search for different shapes on the Internet.

Activity 5
Computer game - programming a simple application with the selection of appropriate bacterial characteristics and designing the ideal bacterial pathogen.

Evaluation tasks

Task 1. NF, June 2016
The diagram shows the structure of a typical bacterial cell.



Based on: P.C. Turner, A.G. McLennan, A.D. Bates, M.R.H. White, Short Lectures. Molecular biology, Warsaw 2005.
1.1. Use the diagram to assign the appropriate letter designations (A – E) to the given bacterial structures.
plasmid ………..… cell membrane ………..… nucleoid ………..…
Answer
1.1. (0-1)
plasmid - C, cell membrane - D, nucleoid - E
1.2. Determine the location of DNA in the bacterial cell and in the assimilating crumb cell. If the DNA is located in different cell compartments, list them all.
Bacterial cell: ……………………………………………………………. ……………….
Assimilation crumb cell: ………………………………………………………… ..
1.2. (0-1)
Example of an answer
bacterial cell: cytoplasm / cytosol / nucleoid,
assimilation crumb cell: cell nucleus, mitochondria, chloroplasts / plastids
1.3. Choose below two diseases of the digestive system (A – E), in which the most common source of infection is food and which are caused by the action of pathogenic bacteria.

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A. cholera B. syphilis C. typhoid D. tetanus E. borreliosis
Example of an answer:
1.3. (0-1)
A./ cholera C./ typhoid

Task 2
Provide an example of the function of fimbriae/pile in bacteria.

Example of an answer: (0-1)

- Fimbriae facilitate the adherence of bacterial cells to various surfaces.
- Fimbriae facilitate a bacterial cell's adherence to an infected host cell/organ.
- These outgrowths allow the bacterial cells to adhere to each other.
- They can be involved in transferring DNA (e.g., plasmids) between bacterial cells.

Task 3
Quorum sensing * is how bacteria "communicate" with each other through molecules of chemical compounds. Signal molecules released into the environment are used in various physiological processes, including forming a biofilm (biological membrane). There are many indications that this phenomenon seems to be a key factor in the emergence and development of infections or the pathogenesis of chronic diseases. Microbes send communication signals within one species and between different species.
Microorganisms that occur in various environments have developed subsidence mechanisms on the surfaces on which they are located (both organisms and abiotic elements of the environment). This form of microorganisms gives them the possibility of more accessible access to nutrients and protects cells against the negative influence of harmful environmental factors. Then a biological membrane is formed - a biofilm. Bacterial biofilms are universal structures - those found in the natural environment usually consist of many species of microorganisms and remain in relations of commensalism and symbiosis with each other. On the other hand, pathogenic biofilms are created by one species of bacteria, which leads to the formation of symbiotic relationships or competition. As a result, tends to the succession of a given micronise. Biofilms come in many forms, such as dental plaque, a slippery coating on the surface of a rock in a stream, or a sediment covering the inside walls of a flower vase after two or three days.
3.1 Assess the truthfulness of the following sentences. Mark T if the statement is true or F if the statement is false.

1	Gram-positive and gram-negative bacteria have different signaling systems for quorum sensing.	T	F
2	Receptor proteins recognize the signaling molecule and ultimately lead to the activation of gene expression mechanisms that control vital processes for microorganisms.	T	F
3	Different species of bacteria do not precisely know the signaling molecule's chemical nature, only its concentration.	T	F
4	Bacterial biofilms are essential for human life and many organisms found in the natural environment.	T	F

Answers: 1 T, 2 T, 3 F, 4 T

3.2 Explain how the phenomenon of "quorum sensing" contributes to the formation of bacterial biofilms. In response, consider the role of biofilm in bacterial function

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Example of an answer:
Bacteria, thanks to the possibility of transmitting chemical signals as part of "quorum sensing" communication between cells, lead to the expression of genetic information, as a result of which they create biofilms, contributing, for example, to the breakdown of toxic compounds present in the environment of their occurrence.

Lesson 2 Incredibly small, incredibly numerous, but as clever as parasites - About bacteria that cause disease.
Teaching phase according to the inquiry & project based instructional model: Continue of the inquiry phase

Objectives
In terms of knowledge
Student:
– *defines pathogenic bacteria,*
– *lists the most common routes of infection with bacteria that cause bacterial diseases,*
– *lists pathogenic bacteria,*
– *Lists the symptoms characteristic of such diseases as: tuberculosis, diphtheria, tetanus, gonorrhea syphilis and salmonellosis.*

In terms of skills
Student:
– *compares the symptoms of various bacterial diseases,*
– *determines the difference in the treatment of bacterial and viral infections,*
– *argues the selected diagnosis of bacterial disease.*

In terms of attitudes
– *shaping a pro-health and prophylactic attitude towards bacterial diseases.*
– *Shaping attitudes to prevent the phenomenon of antibiotic resistance.*

Methods and forms of work
- *case study and role play*
- *work in groups*
- *visualization - creating posters/information leaflets / designing social campaigns on the prevention of bacterial diseases.*
- *a biological taboo game about bacteria*

The course of the lesson:

Activity 1
Analysis of patient cards
Template of the patient card for the doctor.
Symptoms:
Recommended diagnostic tests:
Choose from:
lung X-ray,
bacterial culture with an antibiogram (without an antibiogram),
PCR test of a material sample,
bronchoscopy,
tuberculin test,
serological ELISA tests (to monitor immunity and antibody levels),
patient interview,

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blood test,
serological tests - the presence of specific anti-Borrelia antibodies in the class of Lyme disease IgM and Lyme disease IgG
Cause:
Diagnosis:
Recommendations:
administration of an antibiotic
administration of serum
hospitalization
monitoring of the level of antibodies - ELISA tests
Information from the patient
Activity 4
Problem question: how was DNA discovered to be the carrier of genetic information?
https: //pl.khanacademy.org/science/biology/dna-as-the-genetic-material/dna-discovery-and-structure/a/classic-experiments-dna-as-the-genetic-material \
It is worth discussing with students the experiments of Frederick Griffith: Bacterial Transformation and Avery, McCarty and MacLeod: Identification of the transforming particle - as those in which bacteria contributed to the development of scientific thought, but also an introduction to further sections - in genetic engineering.

Evaluation tasks

Task 1
Up to 421,000 different species of bacteria can live on the soles of shoes, while in the shoe's interior, only 2280. After just two weeks of using the boots, the soles are already inhabited in such a large number. They found bacteria such as *E. coli* that live in our intestines, urinary tract infections, and *Serratia ficaria*, which often leads to respiratory tract infections. However, our immune systems can deal with these bacteria as a rule. However, among the bacteria found on the soles of shoes, there were also species such as *Clostridium difficile*, a bacterium resistant to numerous antibiotics, and bacteria of the genus *Listeria*.

1.1. Explain why children up to two years of age are particularly vulnerable to infections from bacteria transmitted to our shoes.

Example of an answer:
Children up to two years of age spend most of their activity on the floor, and very often (about 80 times an hour), they put their hands in their mouths - this way, germs can get into them.

1.2. List two activities that can reduce the risk of spreading pathogenic bacteria brought home on your shoes.

Example of an answer:
- walking around the house in slippers / taking off shoes right at the front door
- frequent shoe cleaning/shoe washing / thorough shoe wiping before entering the house

Task 2
Bacteria can attach to various surfaces and create a biofilm on them. The smoother and wetter the surface is, the faster biofilm is formed.
2.1. Explain why coins contain significantly fewer bacteria than banknotes, although money moves under the same conditions.
Example of an answer:

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Coins have a smoother surface than banknotes, and the smooth surface of the coins gives the bacteria fewer catch points. If the coins are additionally copper, the copper has a slight antibacterial effect. Banknotes are rougher - in addition, the longer a banknote is in use, the rougher it becomes, so more bacteria attach to it.

Task 3

Salmonella - is a type of gram-negative bacteria that are rod-shaped relative anaerobes. These bacteria are medium-sized, usually with cilia. They belong to relatively intracellular bacteria - they reside in the cells of the infected organism. They can form a mucilaginous coat around their cell (and, in effect, create a biofilm) that practically surrounds the bacteria. Salmonella sticks feel great on poultry, raw meat, ice cream, eggs, and mayonnaise. They cause two forms of the disease. The first is a gastrointestinal disease, which can cause severe diarrhea accompanied by vomiting, high fever, and headache.

One of the bacteria belonging to this genus is Salmonella Typhi, which causes the other type of disease - typhoid fever. Typhoid fever has similar symptoms, including high fever, headache, lethargy, and rashes. It often leads to the death of the sick.

All bacteria from the salmonella group die after several minutes at a temperature of 60 ° C. The source of infection can be dirty water, unwashed fruit, and waste containing Salmonella Typhi sticks. However, cases of cross-contamination, i.e., the transfer of bacteria or other microorganisms, as well as allergens, chemicals, or toxins from one product to another, and the coexistence of many of these species on one surface, can potentially threaten our health, are particularly dangerous.

3.1. Determine the meaning of the mucous shell - the mantle produced by the bacteria cells.
Example of an answer:
Protective significance
3.2. Give the name of the process that ensures ATP supply for the bacterial cell of the genus Salmonella and indicate the substrate for this process.
Example of an answer:
Fermentation, glucose
3.3. Explain why cross-contamination is especially dangerous with Salmonella contamination.
Example of an answer:
Bacteria of the genus Salmonella are a large group of species that cause various disease symptoms. Infection with several species simultaneously due to cross-contamination may lead to increased inflammatory response and difficulties in an adequate reaction from the immune system.

3.4. Taking into account the places of occurrence of Salmonella, give two examples of preventive measures reducing the risk of infection with these bacteria.
Example of an answer:
- use separate boards for processing fish and meat, and always wash them with hot water and detergent after use
- wash your hands after touching the eggshell,

3.5. Explain why hardwood boards are preferable to plastic boards for cutting poultry.
Example of an answer:
Hardwood planks are less porous, so it is more difficult for Salmonella to attach to the surface.

Educational materials

Disease cards for case studies - infographic, case studies for diseases: tuberculosis, tetanus, Lyme disease, salmonellosis, syphilis, gonorrhea
A blank disease card to be filled in by a group of students who are "doctors."
Bacterial disease prevention cards
Internet sources

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Escape room (genially) to solve the patient's puzzle - disease

Lesson 3-4 Life of bacteria under a magnifying glass - What is it like to be a bacterium?

Objectives

In terms of knowledge

Student:

- *defines the lactate fermentation process,*
- *classifies bacteria into anaerobic and aerobic,*
- *characterizes aerobic and anaerobic bacteria,*
- *determines the optimal conditions for the metabolic activity of bacteria,*
- *lists structures produced by bacteria to adapt to environmental conditions (e.g., fimbriae, attractants, efflux pump),*

In terms of skills

Student:

- *designs the experience of pickling cucumbers / making yogurt,*
- *compares the processes of photosynthesis and chemosynthesis,*
- *performs a microscopic preparation,*
- *characterizes the features of bacteria, adapting them to adultery and self-nutrition.*

In terms of attitudes

Student:

- *sees the practical use of bacteria in the dairy and food industries (e.g., pickled vegetables).*

Methods of teaching

- *hands-on - Manual work / scientific project*
- *mind map*
- *using microscopy*
- *scientific modelling*
- *brainstorming*
- *discussion*

The course of the lesson:

Activity 1

Pickling cucumbers/yogurt production

Recipe for pickling cucumbers, for making yogurt:

http://pracowniaaserow.pl/domowy-jogurt-naturalny/

Research question: what conditions must exist for lactate fermentation to occur?

Observe the bacteria under the microscope - it is worth comparing the preparations quantitatively (where there are more and fewer bacteria).

Activity 2

Students make a mind map to answer the questions about the bacteria's activities in life? What could be stressful for them?

Then students are becoming familiar with bacterial activities some source of information is here: https://www.youtube.com/watch?v=gMK6qme9qFY&t=148s

After this part of the lesson, students are asked to supplement mind maps (after discussing the critical life processes of bacteria).

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Activity 3
Brainstorming your search for an answer to the question of what bacteria can do when an antibiotic appears.
Bacterial evolution and antibiotic resistance:
https://www.youtube.com/watch?v=plVk4NVIUh8
Antibiotic resistance:
https://www.totylkoteoria.pl/opornosc-na-antybiotyki-antybiotykoopornosc/
Bacteria vs. Viruses - The Eternal War - CAS9 and CRISPR protein - (3: 51-5: 55) Genetic Engineering Will Change Everything Forever – CRISPR
https://www.youtube.com/supported_browsers?next_url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DjAhjPd4uNFY

Activity 4
The debate about whether antibiotic resistance is a problem in the modern world? Use of arguments. Infographic
Additionally - for partner schools - a visit to the Faculty of Biology - preparation - live observations of bacteria - from ideas that come to students' minds (e.g., nasal swab, purse and fixation, and observation where there is more)

Activity 5
Scientific modelling - simulation of the growth process of bacteria on the medium under various conditions. Students choose factors such as the temperature and concentration of two antibacterial substances as well as the duration of the experiment. Depending on the selected variables, they observe different results of the experiment.
https://biomanbio.com/HTML5GamesandLabs/SciMethodGames/bacterialabpage.html

Evaluation tasks

Task 1. NF, July 2020
The transfer of genetic material (DNA) between bacterial cells takes place by conjugation, transduction, or transformation:

- conjugation - consists in a one-way transfer of plasmid DNA from one bacterial cell to another;
- transduction - occurs with the participation of viruses;
- transformation - bacteria take up genetic material from the environment.

Based on: U. Kasprzykowska, M. Sobieszczańska, Plasticity of bacterial genomes - intercellular transfer of genetic information, "Postępy microbiologii", 53 (2) 2014.
1.1. Arrange the bacterial conjugation steps (A – E) shown below in the order that illustrates the process.

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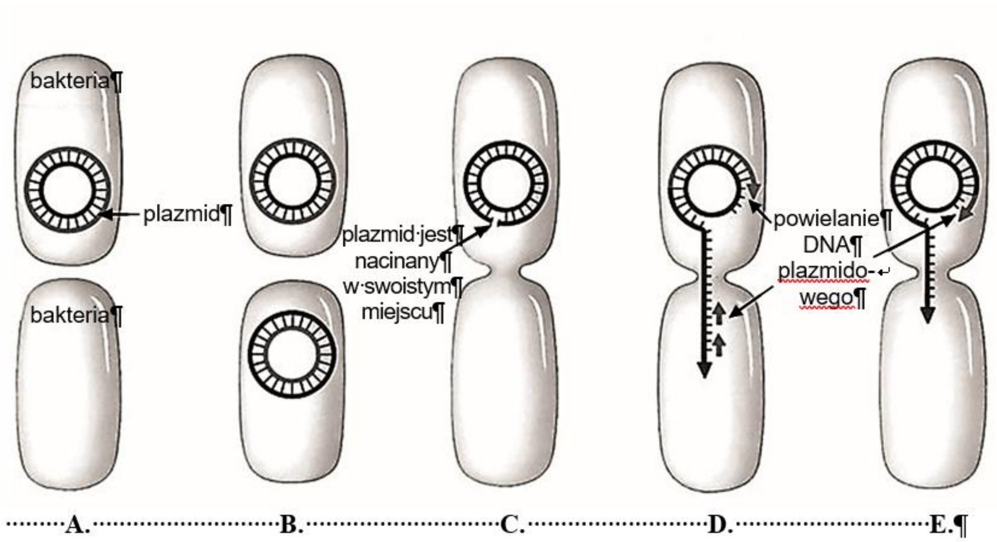

Chosen order:
1.2. Justify that it is enough to transfer only one strand of plasmid DNA to the recipient cell to transfer the genetic information stored in the plasmid by conjugation.
1.3. Justify that a bacterium that is a recipient of plasmid DNA in the conjugation process may benefit from the conjugation process. Include an example of this benefit in your response.
1.4. Justify that bacteriophages can be vectors that transfer DNA between bacterial cells.
1.5. Explain why the intense intercellular exchange of genetic information in the bacterial population provides these microorganisms with a fast rate of adaptive evolution.

Answers:
1.1. (0-1)
order: A, C, E, D, B
1.2. (0-1)
Sample solutions:
Due to the fact that the DNA forms two complementary strands, the second strand can be synthesized on the matrix of one strand transferred to the recipient cell.
Because the second strand is created based on the rule of complementarity of nitrogen bases on the plasmid DNA strand transferring just one strand is enough.
It is enough to transfer only one strand of plasmid DNA to the recipient cell because it can be added (thanks to complementary nitrogen bases).
Since the strands of DNA are complementary, bacteria can build up the other with one strand of plasmid DNA.
1.3. (0-1)
Sample solutions
In this way, bacteria gain new features, e.g., resistance to antibiotics.
Thanks to conjugation, the bacterium obtains new genes that code for proteins that give bacteria unique characteristics, such as the ability to produce certain amino acids.
Thanks to conjugation, the bacterium receives genetic material, thanks to which the bacterium acquires new properties, e.g., the ability to break down specific organic compounds.
1.4. (0-1)
Sample solution
Bacteriophages can be DNA transfer vectors between bacterial cells because, during virus assembly, a fragment of the bacterial DNA can enter the virus and be transferred by the phage to a new cell.

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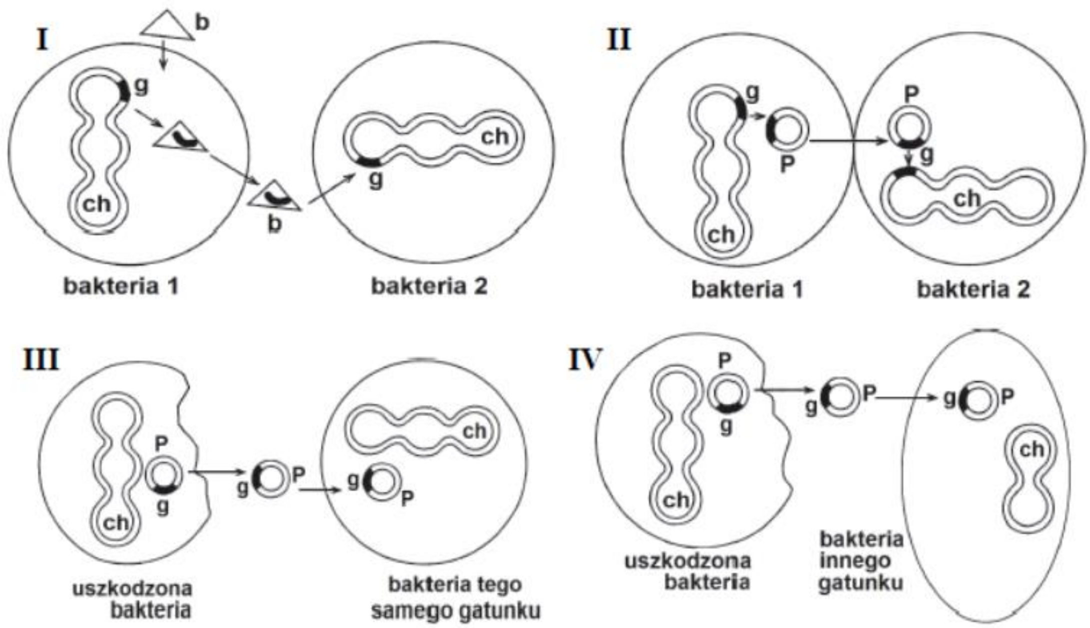
1.5. (0-1)
Sample solutions
The intensive transfer of genetic information leads to the large genetic variability of these organisms within one species/population. Thus, the probability of individuals who are better adapted to the environmental conditions increases.
The transfer of genetic information causes bacteria to differ from one another in terms of genetic information, and therefore also in terms of their ability to survive under certain environmental conditions.
It ensures the exchange of genetic material and, consequently, an increase in genetic variability. Genetic variability causes the emergence of bacteria that will be adapted to changing environmental conditions.

Task 2 NF, June 2017
The genetic information determining microbial resistance to drugs can be stored in their chromosomes or plasmids. Figures 1- IV show four different ways in which bacteria that belong to the same species (I-III) or belong to different species (IV) acquire drug resistance.
Symbols used: g - drug resistance gene, b - bacteriophage, ch - bacterial chromosome,
P - plasmid.



Based on: Ecology. Its connections with various fields of medical knowledge, edited by A. Kurnatowska, Warsaw 2001.
2.1. Enter the designation of the picture: I, II, III or IV, which shows the conjugation of the bacteria and why conjugation is not a method of reproduction.
Answer:
2.1. (0-1)
Sample solutions:
II - it is not a method of reproduction, because as a result of this process the number of daughter cells does not increase.
II - because it is a phenomenon of the exchange of part of the genetic material between participating cells, as a result of which the number of cells does not change.
2.2. Use the flow chart to evaluate whether the following statements about how bacteria develop drug resistance are true. Mark P if the statement is true, or F if the statement is false.

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1.	Conjugation in bacteria can contribute to the transfer of the drug resistance gene only between different species of bacteria.	**P**	**F**
2.	Bacteria can become drug-resistant if they acquire the gene or plasmid with the gene only from other live bacteria.	**P**	**F**
3.	Viruses that attack bacterial cells can contribute to the transfer of the drug resistance gene between them.	**P**	**F**

Answer:
2.2. (0-1)
1 - F, 2 - F, 3 – P
Task 3 NF, June 2016
Three summary reactions describing carbon dioxide assimilation by various groups of autotrophic organisms are presented below.

$$\text{I. } 6H_2O + 6CO_2 \xrightarrow{\text{energia z utleniania } NH_4^+ \text{ do } NO_2^-} C_6H_{12}O_6 + 6O_2$$

$$\text{II. } 6H_2O + 6CO_2 \xrightarrow{\text{światło}} C_6H_{12}O_6 + 6O_2$$

$$\text{III. } 12H_2S + 6CO_2 \xrightarrow{\text{światło}} C_6H_{12}O_6 + 12S + 6H_2O$$

3.1. Indicate which of the above reactions represents chemosynthesis and which - photosynthesis carried out by some sulfur bacteria, eg, purple bacteria. Justify your choice in any case.
Chemosynthesis ………………, because …………………………………………………….
Photosynthesis in some sulfur bacteria ………………… because ……………… ..…

Answer:
3.1. (0-2)
Sample solutions
Chemosynthesis: And because:
- the source of energy for CO2 assimilation is the oxidation of the inorganic compound.
- it takes place without light, and the energy source for CO2 assimilation is ammonia oxidation.

Photosynthesis in some sulfur bacteria: III because:
The energy source for CO2 assimilation is light, and no oxygen is released (anoxygenic photosynthesis).
- the source of energy for CO2 assimilation is light, and sulfur is released due to the decomposition of hydrogen sulfide (H2S).

Materials
Recipe for pickling cucumbers / making yogurt - infographic
The course of chemosynthesis in bacteria - infographic
Stress in the life of bacteria - infographic
Bacteria coping strategies with antibiotics - infographic
Argument structure - infographic

Lesson 5. Microbiome - how many humans and how many bacteria are in you?

Objectives
In terms of knowledge
Student:
- *defines the importance of bacteria for human health (e.g., vitamin synthesis, supporting the digestion of complex sugars),*
- *characterizes the resident and transient bacterial flora,*

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- *explains the importance of using probiotics in antibiotic therapy,*

In terms of skills
Student:

- *designs a human map taking into account the richness of human bacterial microflora,*
- *compares the effects of probiotics and antibiotics,*
- *analyzes the influence of human gut microbiota on the brain,*
- *constructs arguments regarding the impact of human gut microbiota on the brain,*

In terms of attitudes
Shaping a pro-health attitude regarding the sustainable use of antibiotics and taking care of your intestinal microbiota and the use of probiotics.

<u>*Methods and forms of work*</u>

- *visualization*
- *discussion*
- *analysis of the content of articles*

The course of the lesson:

Activity 1
Draw a silhouette of a person. Ask students to mark where the bacteria are - where they are most quantitatively and most diverse, ask for sterile sites.
Discussion of the concepts of resident bacteria and transitional in the context of the drawn map - discussion of the significance of the resident flora and the transitional flora

Activity 2
Analysis of articles on the microbiome
Problem question - are bacteria crucial to our mental and physical health - a second brain in the gut?
Problem question: is it correct to say that the gut microbiota rules the brain? Do we rule bacteria?
The student's task is to write down arguments enabling them to provide a complete answer to the questions posed.

Activity 3
Discussion on: Prebiotics and probiotics - fashion or support for your health? Use of an argument

Activity 4
Redraw the map the second map of humans and their microbiota and compare it with the first map.
Compare with infographic provided to this scenario.

<u>*Evaluation tasks*</u>

Task 1
The term microbiome, microbiota - is the total of microorganisms present in a given habitat. It includes bacteria, fungi, archaea and viruses. One of the environments inhabited by microorganisms is the human body and its digestive tract or respiratory tract lumen. Specific microbiomes can be distinguished, among other things, for mouth, nasal cavity, ears, vagina, intestines, lungs, hair, and skin. According to estimates, the microbiome of a healthy adult may reach a mass of 2-3 kg. It is estimated that the human body has 39 trillion bacterial cells for 30 trillion human cells

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1.1. Explain why, since there are 1.3 microbes per human cell, the total estimated weight of the human microbiome is only 2-3 kg.
1.2. Bacteria are our most faithful companions. Some biologists even believe that the evolution unit is not Homo sapiens, but Homo sapiens plus its microbiome. Assess the truthfulness of the above statement with justification.
Answers:
1.1
Bacterial cells are much smaller than human cells and have a much lower mass, hence the disproportion between the number of cells and the mass.
1.2
The human body is a complex ecological system. The gut itself is an ecosystem for the gut microbiota. Our body is a network of relationships between the organisms that inhabit us and our bodies; we need them so much that we could not function without them, so this is true.
Task 2
The bacterium *Helicobacter pylori* are present in the human stomach. In the 1980s, Australian doctors Barry Marshall and Robin Warren determined that it was an important cause of stomach ulcers. The World Health Organization in 2006 estimated that about 70% of people in developing countries and about 30% in developed countries were infected with this bacterium. Its presence increases the risk of diseases such as type B gastritis (which can lead to cancer) and peptic ulcers. A different genome of this bacterium may explain discrepancies in the incidence of cancer in different geographic regions in different regions; not all strains are equally virulent (depending on the presence of *vacA* and *cagA* genes). In turn, Martin Blaser discovered that Helicobacter also has a different face. Its presence helps regulate the degree of acidity in the stomach - if the stomach produces too much acid, these bacteria create the *cagA* protein so that the stomach reduces the production of HCl. However, in sensitive individuals, this protein can have adverse side effects that lead to the development of peptic ulcer disease. Another function of *Helicobacter* is to control the host's appetite. If the bacteria is present, the level of ghrelin (the hormone that signals our body's hunger) drops after a meal. However, if these bacteria have been eliminated (e.g., due to antibiotic therapy), this effect disappears. When this bacterium enters the liver, the risk of hepatocellular carcinoma is increased.
2.1. Give the interspecies relationships that occur between humans and the *Helicobacter pylori* bacterium.
2.2. Explain what probably depends on whether the battery present in our digestive tract contributes to cancer development.
Answers:
2.1
On the one hand, Helicobacter pylori is a pathogenic bacterium (a parasite), but it can also be a harmless commensal.
2.2
It depends on two factors **-** the genetic variant of the bacteria and the human sensitivity to proteins produced by bacteria. Variants capable of producing *cagA* protein are more virulent, but only in people who are sensitive to this protein.

<u>*Educational materials*</u>
- Microbiome – infographic
- Argument structure – infographic
- Prebiotics and probiotics – infographic
- Human map - the possibility of an interactive page with the marking of the places of occurrence of bacteria
- Interesting facts about human microbiota - infographics under the slogan: "did you know that ..."

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Lesson 6. Bacteria - enemy or friend?

<u>Objectives</u>
In terms of knowledge:
Student:

- *lists the factors indicating/adapting to the pathogenic nature of bacteria (e.g., adhesion, efflux pump)*
- *defines the concepts of symbiotic and enterotoxic bacteria,*
- *points to the example of E. coli as a bacterium with symbiotic and enterotoxic strains,*
- *justifies the use of E. coli as bacteria used by humans in biotechnology, e.g., for the production of insulin or a species indicating the cleanliness of water reservoirs (coli)*

In terms of skills:
Student:

- *analyzes articles on the use of bacteria by humans,*
- *constructs a conceptual map regarding the use of bacteria by humans,*
- *proves the critical importance of bacteria in the circulation of elements in nature,*

In terms of attitudes:
Shaping a reflective attitude regarding the diverse nature of bacteria in their positive role and pathogenicity.

<u>Methods and forms of work</u>

- *discussion*
- *exchange of ideas*
- *concept map*
- *content analysis*

The course of the lesson:

Activity 1
Discussion about:
What does enemy mean and friend mean in life, and what can it mean in biology?

Activity 2
Working in groups - an exchange of ideas: what do people use *E. coli* for.
Comparison of the results of the students' group work in the classroom. Summary of work by the teacher.

Activity 3
Creating a concept map based on articles/textbook showing the role of bacteria in nature and the human economy.

<u>Evaluation tasks</u>

Task 1 SF-R, May 2016
The colon rod (*Escherichia coli*) is part of the physiological bacterial flora of the human large intestine (and - in small amounts - of the small intestine). It is involved in the breakdown of food and contributes to the production of B and K vitamins. However, some strains of *E. coli*, as a result of acquiring new features, are pathogenic for humans. For example the enterotoxic strain of *E. coli* (ETEC) is the most common cause of travelers' diarrhea. After entering the small intestine, these bacteria adhere to epithelial cells and release toxic proteins into the intestine, disrupting the functioning of ion pumps in epithelial cells and the loss of

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water by these cells. Another eneteropathogenic strain of *E. coli* (EPEC), also causing diarrhea, binds to the intestinal epithelial cells and injects protein toxins into the epithelial cells through a specially created channel. EPEC strain toxins cause poor water absorption.
Based on: A. Salyers, D. Whitt, Mikrobiologia, Warsaw 2012.

1.1. Based on the text analysis, complete the table in which you will compare the place and effects of the toxins produced by E. coli ETEC and E. coli EPEC strains in the intestine.

Strain ***Escherichia coli***	**The site of action of toxins produced by bacteria**	**The influence of toxins on human water management**
ETEC		
EPEC		

* 1.2. Give the names of the interspecies relationships that exist between humans and E. coli bacteria
1.components of the physiological flora of the intestine: ………………………… ..… ..
2. belonging to strains ETEC and EPEC: ……………………………………….
Answers:
1.1

Strain ***Escherichia coli***	**The site of action of toxins produced by bacteria**	**The influence of toxins on human water management**
ETEC	**inside the gut/surface of the epithelial cells/outside of the epithelial cells**	**The disruption of the ion pumps of the intestinal epithelial cells by toxins causes these cells to lose water**
EPEC	**inside intestinal epithelial cells / epithelial cells**	**cause poor water absorption by intestinal epithelial cells and, as a result, water deficiency in the body**

* 1.2. (0-1)
Answer:
mutualism / protocooperation
parasitism

<u>*Educational materials*</u>
The distribution of bacteria in your home - infographic
Principles of creating a concept map - infographic
Ways of using E. coli by humans – infographic

Lesson 7. Bacteria in court

<u>*Objectives*</u>
In terms of knowledge
Student:
- *mentions the positive importance of bacteria for human health and the economy,*
- *lists the negative effects of bacteria on human health and the economy,*

In terms of skills
Student:
- *constructs arguments for and against the perception of bacteria as negative organisms,*
- *compares information on the impact of bacteria on human health and the economy,*

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- *designs a social study on the perception of bacteria.*

In terms of attitudes:
Noticing the influence of bacteria on the historical fate of the world (pandemics and premature deaths of rulers).
Noticing the importance of bacteria in civilization changes, e.g., the discovery of the first antibiotics, the plague epidemic, and the transition from the Middle Ages to the Renaissance.

Materials and methods

- *discussion*
- *role play*
- *student project - a study of the social perception of bacteria*

The course of the lesson:

Activity before class
Social research on the perception of bacteria
Students can conduct research on the perception of bacteria in their local community, pose research problems and consider how to change the perception of bacteria in society - where are the main issues?

Activity 1
The course is like a court hearing.
Students prepare stories of witnesses and questions for witnesses.
* This part of the role-playing can be prepared in cooperation with the history teacher. It is worth paying attention to the influence of bacteria on the historical fate of the world - or the importance of bacteria in civilization changes, e.g., the discovery of the first antibiotics, the plague epidemic and the transition from the Middle Ages to the Renaissance.
List of questions that may help us make a decision:
Do we have enemies among bacteria? Does their presence bring us any losses?
Are our friends among the bacteria? Does their presence bring us any benefits?
Do bacteria benefit us more or do more harm?
Do we have a chance to protect ourselves against those bacteria whose activity is harmful to us?
Can we protect ourselves from those bacteria whose activities are harmful to us?
Can we acquit the bacteria?
Should we erect a monument to bacteria?

Supplementary learning resources and educational activities

Scenario was consulted with microbiologists.
Students during the scenario will have opportunities to work with STEM professionals. Also as a follow up students will have visits from third parties in the classroom: microbiologists, biotechnologist and specialist from food industry. Also as an additional activity students will have possibility to construct campaign about antibiotic resistance with pharmacists.
Students from the school in the project will attend in scientific fairs at Faculty of Biology of Adam Mickiewicz University in Poznań – such as Night of the Scientists, Night of the Biologists or Festival of Science and Art. In all of this events PAFSE will have its own stand but more importantly students from the schools involved in the project will have priority entrance to any workshops and lectures.
Moreover students will be invited to local Sanitary and epidemiological station – observe the work of specialists, and actively participate in lecture prepared for them. Also they will have visit in the classroom

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by food quality engineer who will introduce our students to idea of bacteria which reduce food quality and how engineering and proper quality control can be helpful.

Indicative literature

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19. Specifications for an educational scenario on the topic of "Droplets & the physics of viruses transmission"

Main Partner responsible: ISEL

Context and relevance of the scenario for public health education

The scenario prepares students and school community to reduce the risk of airborne diseases and epidemics in a phase of the COVID-19 pandemic that remains uncertain how Sars-Cov-2 virus mutates and spreads in high vaccinated populations. Nevertheless, there is strong scientific evidence that the virus is transmitted essentially by air. So is important to engage students in discourse on the measures that limit the spread of the virus droplets to prevent the fast growing of airborne diseases within the school community. The strategy to combat Sars-Cov-2 pandemic worldwide had a strong focus on the confinement of populations at home, on restricting contacts between people, on promoting the rule of "2m-social distance" and on the recommended or mandatory use of masks. With the technological advances achieved today, it is possible and relevant to explore with students a Computational Fluid Dynamics (CFD) tool that simulates and predicts the propagation of respiratory particles when changing the configuration of spaces and other conditions (e.g., area, furniture, number of inhabitants, distance between them, use/no use of mask) and so estimate the risk of disease transmission between individuals. The learning scenario increases students understanding on how airborne transmission works and how STEM may contribute to anticipate, mitigate and solve public health threats, by exploring simulations from a CFD tool.

Estimated duration

6 classes of 40-45 minutes (lesson 1 – lesson 6).
6 sessions of 40-45 minutes for school project (session 7 – session 12)

Classroom organization requirements

From lesson 1 to lesson 5 students work alone or occasionally in groups.
From lesson 6 to lesson 12 students form four- or five-member groups which carry out the school project. The use of computer is required.

Prerequisite knowledge and skills

Basic knowledge of software and browsers

Content Glossary

Air flow – It refers to the amount of moving air around a given space or area. It is created by the natural means of wind and circulation, or it can be created artificially by the mechanical means of a fan or blower unit.

Airborne disease - any disease that is caused by a microorganism that is transmitted through the air. There are many airborne diseases that are of clinical importance and include bacteria, viruses, and fungi. These organisms may be spread through sneezing, coughing, spraying of liquids, the spread of dust, or any activity that results in the generation of aerosolized particles. The microorganisms transmitted airborne may be spread via a fine mist, dust, aerosols, or liquids.

Airborne Transmission - The droplet nuclei remain airborne for long periods, may disseminate widely in an environment such as a hospital ward or an operating room, and can be acquired by (and infect) patients directly, or indirectly through contaminated medical devices. Housekeeping activity such as sweeping,

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using dry dust mops or cloths, or shaking out linen, can aerosolize particles that may contain microorganisms.

Computational Fluid Dynamics (CFD) – It is the process of mathematically modelling a physical phenomenon involving fluid flow and solving it numerically using the computational power. Computational fluid dynamics is based on the Navier-Stokes equations. These equations describe how the velocity, pressure, temperature, and density of a moving fluid are related.

Droplet Nuclei - A type of particle implicated in the spread of airborne infection. Droplet nuclei are tiny particles (1–10 μm diameter) that represent the dried residue of droplets. They may be formed by evaporation of droplets coughed or sneezed into the air or aerosolization of infective materials.

Droplets Transmission – The disease-causing bacteria and viruses are carried in the mouth, nose, throat, and respiratory tree. They can spread by coming into direct contact with droplets when an infected person coughs or sneezes, or through saliva or mucus on unwashed hands.

Fluid Dynamics - Fluid dynamics refers to a sub-discipline of fluid mechanics that revolves around fluid flow in motion. Furthermore, fluid dynamics comprises of some branches like aerodynamics and hydrodynamics. Fluid dynamics involves the calculation of various fluid properties, such as flow velocity, pressure, density, and temperature, as functions of space and time.

Incompressible Fluids - A fluid in which the density remains constant for isothermal pressure changes.

Natural Air Ventilation – It is a method of supplying fresh air to a building or room by means of passive forces, typically by wind speed or differences in pressure internally and externally.

Navier-Stokes Equations - In fluid mechanics, it is a partial differential equation that describes the flow of incompressible fluids.

Respiratory Droplets – It is a small aqueous droplet produced by exhalation, consisting of saliva or mucus and other matter derived from respiratory tract surfaces. Respiratory droplets are produced naturally because of breathing, speaking, sneezing, coughing, or vomiting.

Respiratory Disease – It´s a type of disease that affects the lungs and other parts of the respiratory system. Respiratory diseases may be caused by infection, by smoking tobacco, or by breathing in second-hand tobacco smoke, radon, asbestos, or other forms of air pollution. Respiratory diseases include asthma, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, pneumonia, and lung cancer. Also called lung disorder and pulmonary disease.

Thermodynamics – It´s the science of the relationship between heat, work, temperature, and energy. In broad terms, thermodynamics deals with the transfer of energy from one place to another and from one form to another. The key concept is that heat is a form of energy corresponding to a definite amount of mechanical work.

Ventilation System - It´s a mechanical system in a building that provides fresh air.

Viscosity – It is the resistance of a fluid (liquid or gas) to a change in shape, or movement of neighbouring portions relative to one another. Viscosity denotes opposition to flow.

Pedagogical glossary

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Active Learning. A teaching and learning approach that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.".

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills.

Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Sources: https://www.britannica.com/; Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

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Competences / Learning Goals

Key Competences

STEM/ personal, social, citizenship

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Knowledge

Physics concepts:

- air flow
- ventilation system
- fluid dynamics

Epidemiology concepts:

- transmissibility
- sociability
- infectiousness
- epidemic spreading

Medical science concepts:

- droplets
- social distancing
- EPIs (individual protective equipment)
- Airborne disease

Knowledge - outcome assessment:

1. Explains how airborne transmission works.
2. Identifies factors that influence the propagation of droplets.
3. Identifies sources of risk in the environment.
4. Identifies measures and proposes general action to fight diseases that spread by air.
5. Understands how ventilation systems inhibit airborne transmission.

Skills (abilities/competences)

General: curiosity; collaboration; critical thinking; self-awareness, citizenship, problem definition, problem solving, analysis and discussion of evidence, argumentation, public speaking and presentation, brainstorming participation, debate, hypothetical-deductive reasoning, inductive reasoning, problem based learning, understand scientific principles and models, planning and carrying out a research-based project, critical thinking, teamwork, reading and understanding a simulation motion, understanding the applications of mathematical models, assess risks and take decisions.

Specific:

- ✓ Finding, analysing and interpreting scientific data, texts and dynamic graphical representations to understand the burden of diseases that spread by air.
- ✓ Understanding the difference between facts and opinions, understanding how to find fake claims, evaluate the reliability of health-related information, based on multiple factors influencing the reliability of information.
- ✓ Understanding the relevance of scientific evidence to explain phenomena related to health and illness and produce argumentation.
- ✓ Assessing personal and community risks and patterns of risky and protective behaviour.
- ✓ Pointing appropriate strategies that reduce personal and community risk of airborne diseases.
- ✓ Understanding the importance of using a computational tool to assess risks on the configuration of spaces.

Skills – outcome assessment:

1. Obtains, assesses, and communicates evidence related to viruses’ transmission by air.

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2. Can anticipate the consequences of risky behaviour (e.g.: not putting the arm in front of the mouth when one´s about to sneeze or cough).
3. Rejects risky behaviours in front of one's peers (e.g.: no use of masks in closed spaces if it is mandatory or recommended).
4. Feels able to influence the adoption of protective behaviour by others (e.g., family, peers, friends).

Affective /Attitudes/Behaviour

- Adopting general risk perception attitudes.
- Adopting attitudes towards minimizing the risk of diseases transmitted by air (e.g., awareness to maintain shared spaces well sanitized).
- Engaging public speaking and debating of measures to reduce risks, with a particular focus on public policy that impacts school and community health.
- Use of computation tools to resolve complex mathematical problems connected with citizens health.

Affective, Attitudes and behavior - outcome assessment:

7. Believes that a civic and conscient behaviour is fundamental to prevent the disproportionated growth of airborne diseases in the school and in the community.
8. Believes that individual behaviour influences the incidence of airborne diseases.
9. Reproves patterns of risky behaviour in his/her living environment.
10. Believes that the usage of computational tools benefits the resolution of STEM- related problems connected with public health.

Learning goals and outcomes

- ✓ Uses computational tools to plot tables, graphs, and other data that boosts understanding the physical process behind droplets spread.
- ✓ Obtains, evaluates, and communicates data and scientific information about diseases that spread by air.
- ✓ Uses evidence to build argumentation on viruses' transmission by the air.
- ✓ Gives examples of issues influencing the prevalence of viruses' transmission in the community.
- ✓ Describes different approaches to protect, develop and positively influence public health.

<u>Assessment methods</u>

- ✓ Outcome assessment
  - Quantitative – questionnaire in paper.
  - Qualitative – students project.
- ✓ Process assessment - assessment of the teaching-learning sequence – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

<u>Content</u> (relevant to learning goals & research topics)

STEM content

- Fluid Dynamics.
- Computational Thermodynamic Calculus.
- Computational Fluid Dynamics.
- Navier-Stokes Equations.
- Momentum Equation.
- Numerical Investigation About Droplets Distribution in Closed Spaces.
- The spreading of diseases by air.

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Non-STEM content
- Civic and conscient lifestyle to avoid and mitigate risks.

Digital learning objects (LOs) and Digital Educational Resources (DERs)

New:

- Computational Fluid Dynamics (CFD) tool **(LO1)**
- Repository of simulation results obtained with the CFD tool. (*images, videos)* **(DER1)**
- Droplets transmission in closed spaces. **(DER2)**
- Different breathing regimes and their influence on droplets transmission (e.g., Coughs, Sneezes, Common Talking, etc.). **(DER3)**
- Worksheets **(DER4)**
- Elements inherent to the spaces and their influence on droplets transmission**. (DER5)**
- Strategies to mitigate the dissemination of airborne diseases (*images, maps, infographics, graphics*) **(DER6)**

Available resources (link):
https://www.dropbox.com/sh/i75wvwywvn2igdm/AABE2Nq-TfryAOvpQWwBReY4a?dl=0
From other sources/high-quality platforms:

Airborne Transmission Process
- https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf (Page 1-4). **(DER7)**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/ (Table II). **(DER8)**
- https://aip.scitation.org/doi/pdf/10.1063/5.0063475 **(DER9)**
- https://www.healthline.com/health/disease-transmission#indirect-contact **(DER10)**
- https://www.medicalnewstoday.com/articles/317632#common-airborne-diseases **(DER11)**
- https://www.webmd.com/lung/what-are-airborne-diseases **(DER12)**

Size and Duration of Airborne Respiratory Droplets
- https://www.cambridge.org/core/services/aop-cambridge-core/content/view/219325B967EEBDB76464532AB3357F6C/S0022172400019288a.pdf/size_and_the_duration_of_aircarriage_of_respiratory_droplets_and_dropletnuclei.pdf **(DER13)**

CFD simulations results regarding airborne transmission
- *https://www.youtube.com/watch?v=aDLs3vbzZag* **(DER14)**
- https://reader.elsevier.com/ **(DER15)**
- https://re.public.polimi.it/ **(DER16)**
- *https://www.buffalo.edu/ccr/services/research-highlights.host.html/content/shared/www/ccr/research-highlights/simulations-of-indoor-space-with-the-sterispacetm-air-sterilizat.* **(DER17)**

Airborne diseases
- *https://www.healthline.com/health/airborne-diseases* **(DER18)**
- *https://www.medicoverhospitals.in/articles/air-borne-diseases* **(DER19)**

Preventing the spread of Airborne Diseases with ventilation systems
- *https://www.daikinapplied.uk/news-center/preventing-the-spread-of-coronavirus-with-ventilation-systems/* **(DER20)**

CFD Tool:
- https://www.britannica.com/science/Navier-Stokes-equation **(DER21)**

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Teaching -learning activities (lesson plan/ learning trajectory)

Principal target:
Physics classes, science clubs
9th grade (+/- 15 years old students)
About 6 lessons of 40-45 minutes
Physics teachers integrate other colleagues in the enactment of the scenario (e.g., ICT, Science, Mathematics, English teachers), as scenario enactment aims to be interdisciplinary.

Topics of each lesson:
Lesson 1: Explore the CVD tool
Lesson 2: Define environment
Lesson 3: Define baseline case study
Lesson 4: More Complex case studies
Lesson 5: Compare case studies of lesson 4 with baseline case of lesson 3
Lesson 6: Identifying risk factors and proposing general action for better Public Health

Lesson 1: Explore the CFD tool
The main goals to achieve in this class, in a student's perspective, are:
- Recognizes and characterizes the general physical process of droplets dissemination.
- Understands how a CFD simulator can support the prediction, prevention and dissemination of diseases transmitted by air.
- Can identify variables that have an effect on respiratory particles dissemination.

➢ **Activity 1**
In the begging of lesson 1, the Computational Fluid Dynamics (CFD) tool **[LO1]** is presented to students. The teacher discusses with students the goals and planification of next classes, which are directly related to a project. The teacher explains the major goals and scope of the work:

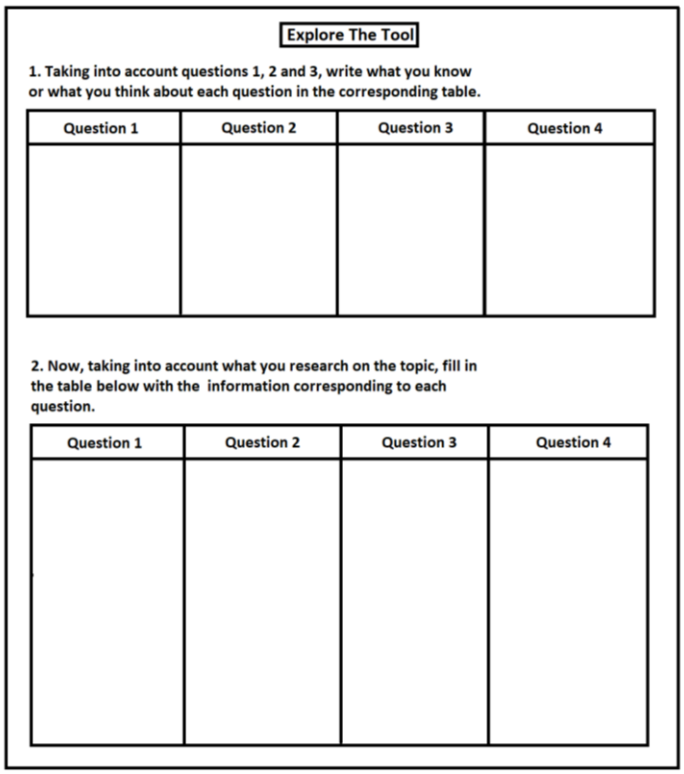
1. Students study problems related with droplets' dissemination by air and humans' infection, in a certain room, and under pre-defined conditions.
2. Students explore and explain the problem by understanding how airborne transmission works.
3. Students search for scientific information about respiratory particles spreading through guided research on trustful sources and sharing of ideas with the teacher and colleagues.
4. Students explore a computational tool that simulates the particles flow inside closed spaces.
5. Students understand the process complexity but then with the support of a computational tool **[LO1]** the phenomena is easier to predict, characterize and analyse; students understand that simulators are relevant computational tools for real-life problem solving.
6. Students understand the physics principles and mathematic equations that explain particles spread and the functioning of a computational tool.
7. Students analyse and study simulation cases, are asked to explain the behaviour of particles inside the room and explain the differences between simulations.
8. Students understand how particles flow in different scenarios and so propose measures and recommendations to prevent or mitigate the spread of airborne particles.
9. Students propose measures and recommendations to prevent or mitigate the spread of airborne particles.at school and community spaces.
9. Based on the evidence coming from simulations generated by the CFD tool, proposals and recommendations are prepared by students and presented to the community, in the open schooling event.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

➢ **Activity 2**

The teacher starts scenario implementation by proposing an activity to the classroom that aims to map their previous knowledge on how respiratory droplets spread by air. The initial questions may be:
1. "Do you have any idea on how respiratory droplets spread by air?",
2. "Do respiratory droplets expelled from coughing, or in the normal respiratory process, e.g., during eating or sleeping, have the same characteristics?"
3. "Do you know the mean average diameter of respiratory droplets?"
4. "Do you know what is an airborne disease? Can you give some examples?"

First, and to facilitate the organization of students' ideas and their subsequent research, a worksheet **[DER4]** is distributed where students indicate their initial responses. These answers will then be explored by the teacher as students' preconceptions and misconceptions on how airborne diseases transmission works. The worksheet also contains other fields where the students fill the information they found in the inquiry-based process. An example of worksheet template to be distributed to the students/groups so they can efficiently organize their ideas and reasoning can be observed in the image below.


Explore The Tool

1. Taking into account questions 1, 2 and 3, write what you know or what you think about each question in the corresponding table.

Question 1	Question 2	Question 3	Question 4

2. Now, taking into account what you research on the topic, fill in the table below with the information corresponding to each question.

Question 1	Question 2	Question 3	Question 4

Students write their initial ideas, and the teacher asks them to look up for this information themselves, by searching for reliable sources, and later discuss their reasoning in groups (3/4). Then the teacher expresses that they should always check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

The teacher encourages students to look for information in trustful databases (e.g.: WHO database, CDC webpage) and scientific articles, so that these two conditions are guaranteed. During the activity the teacher moves around the classroom, supervises and supports students work, while

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making reflective and supportive questions and providing feedback when needed. The teacher organizes and structures information on the topic, which may be gattered from the following resources:

- https ://engineering.purdue.edu/~yanchen/paper/2006-3.pdf (Page 1-4). **(DER7)**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/ (Table II). **(DER8)**
- https://aip.scitation.org/doi/pdf/10.1063/5.0063475 **(DER9)**
- https://www.cambridge.org/core/services/aop-cambridge-core/content/view/219325B967EEBDB76464532AB3357F6C/S0022172400019288a.pdf/size_and_the_duration_of_aircarriage_of_respiratory_droplets_and_dropletnuclei.pdf **(DER13)**

- **Activity 3**

After managing an internal discussion between the students/groups about their reasoning (teacher defines a time limit for the students to complete the worksheet and discuss their reasoning with the formed groups), the teacher provides credible and organized information about the ideas and concepts under study by exploring the resources mentioned above. Then the teacher summarizes the process of droplets dissemination and airborne diseases transmission. In case of fluids, it can be explained through physical and mathematical equations, the Navier-Stokes Equations (general information can be found in https://www.britannica.com/science/Navier-Stokes-equation **(DER21)**. Due to the complexity of their resolution, there are computational systems that can easily solve these equations, therefore is possible to predict the spread of respiratory particles under pre-defined conditions. Finally, the teacher points that depending on environmental conditions, droplets are disseminated in multiple ways. The primary variables/parameters to be manipulated at the simulator are:

- The breathing regime (whether is speaking, coughing or a sneezing regime).
- Whether exists or not natural ventilation or a ventilation system inside the space.
- The elements/physical infrastructure of the space (windows, doors, chairs, tables, etc..).

- **Activity 4**

The teacher explains that is possible to predict how respiratory droplets spread by using a Computational Fluid Dynamics (CFD) simulator, whereby introducing the referred parameters, students can see how droplets are distributed in the space. The teacher then demonstrates a couple of examples to students, on how a simulator usually operates, through videos visualisations, retrieved from the following links:

- "CFD simulation of airborne droplets implementing droplet interaction": *https://www.youtube.com/watch?v=aDLs3vbzZag* **(DER14)**
- *"Simulations of indoor space with the SteriSpaceTM Air Sterilization System": https://www.buffalo.edu/ccr/services/research-highlights.host.html/* **(DER17)**
- *https://www.medicoverhospitals.in/articles/air-borne-diseases* **(DER19)**

Note: Since students will use the simulator and analyse simulations during scenario implementation, this activity introduces to the dynamics of subsequent classes.

A couple images obtained from simulations similar to the ones that students will explore (from the CFD tool) are seen bellow:**(DER1)**

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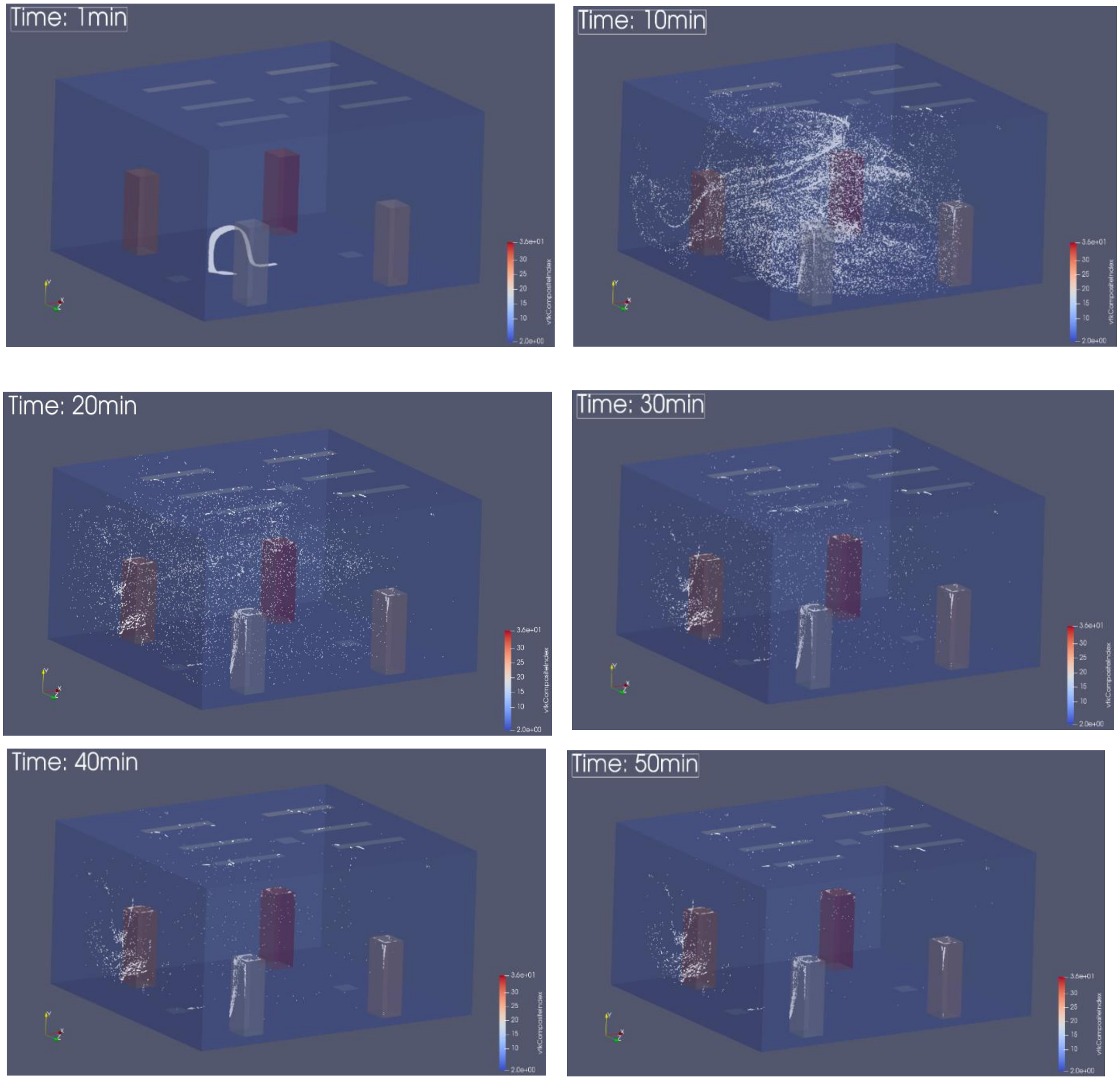

- **General Interpretation of the Simulation:**

These are typical graphical outputs from a CFD simulator that students will explore. This simulation was run to evaluate the behaviour of the particles (for 50 minutes), and successive images demonstrate the spread of such particles. The room is composed by 6 lamps, which are represented on the ceiling by rectangles, and it also includes 4 human simulators, an air extractor located on the ceiling and the air suppliers located on the floor. In the subsequent classes, students analyse the behaviour of the particles when changing the variables/ parameters that simulate environmental conditions. For example, identifying who was most infected, or furniture where particles where most deposited, e.g., tables, chairs, walls, etc. (more information about the interpretation of the simulation can be seen in the “General information regarding the stated questions” topic in lesson 3). **(DER2)**

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- **Activity 5**

The teacher proposes a basic inquiry activity to students. First, they indicate the main parameters that influence the dissemination of droplets. Then, other questions will drive the activity:
"1. The size of the droplets influences their spreading through the air. A) true. B) False."
"2. Please identify the option that contains 3 factors that influence droplets transmission. A) Different respiration regimes (either sneezing, coughing or common talking), ventilation systems, and elements inherent to the spaces where the droplets are spread; B) Radiation, temperature of the walls, different respiration regimes (sneezing, coughing or in common talking); C) Ventilation system, number of people inside a room, radiation." "3. The Navier-Stokes equations can explain the physical process behind droplets transmission. A) True. B) False." "4. The velocity and the dimension of the respiratory particles influences their dissemination. A) True. B) False. "5. Which of the following statements about droplets dissemination is NOT true? A) Droplets tend to follow the airflow in the room. B) Drag and Buoyancy forces are the most significant external forces that influence the droplets trajectories. C) External forces applied on the airflow don´t influence the trajectory of droplets."
Answers:

1. A)
2. A)
3. A)
4. A)
5. C)

Students search to answer the questions in group work within the groups previously formed. The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback when needed. The teacher understands if students resorted to reliable sources of information and the difficulties they faced to obtain the answers. To obtain more information about this last issue, the teacher can also launch the question "What were the main difficulties you face in collecting reliable information and answering the questions?".

- **Learning objects of this lesson:**
  - Computational Fluid Dynamics (CFD) tool **(LO1)**
  - Repository of simulation results obtained with the CFD tool. **(DER1)**
  - Droplets transmission in closed spaces. **(DER2)**
  - Worksheets **(DER4)**
  - https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf (Page 1-4). **(DER7)**
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/ (Table II). **(DER8)**
  - https://aip.scitation.org/doi/pdf/10.1063/5.0063475 **(DER9)**
  - https://www.cambridge.org/core/services/aop-cambridge-core/content/view/219325B967EEBDB76464532AB3357F6C/S0022172400019288a.pdf/size_and_the_duration_of_aircarriage_of_respiratory_droplets_and_dropletnuclei.pdf **(DER13)**
  - "CFD simulation of airborne droplets implementing droplet interaction": *https://www.youtube.com/watch?v=aDLs3vbzZag* **(DER14)**
  - *"Simulations of indoor space with the SteriSpaceTM Air Sterilization System": https://www.buffalo.edu/ccr/services/research-highlights.host.html/* **(DER17)**
  - *https://www.medicoverhospitals.in/articles/air-borne-diseases* **(DER19)**
  - https://www.britannica.com/science/Navier-Stokes-equation **(DER21).**

Lesson 2: Define the environment

The main goals to achieve in this class, in a student's perspective, are:

- Identifies factors that influence the propagation of droplets.
- Identifies sources of risk in environments.
- Adopts attitudes towards minimizing the risk of airborne diseases.

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➢ **Lesson Summary:**

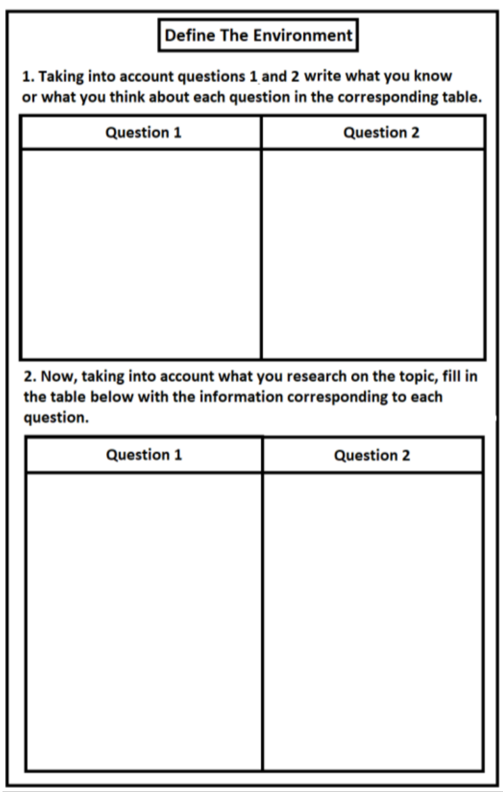
In lesson 2 is taken a discussion on the settings where is mostly important to study and predict the fast spreading of airborne diseases. The factors associated to increased risk are discussed and such settings can be an hospital or a nursing home. This lesson also intends to create awareness on students about the importance of using CFD simulators in particularly risky environments (e.g., healthcare environments) and in places where most vulnerable groups live, study and work (e.g., children, elderly ones, people with chronic conditions).

➢ **Activity 1**

The teacher proposes an activity to capture students' general perceptions on the issue of predicting and preventing the incidence of airborne diseases, especially in places where most vulnerable groups live, study and work. This may be driven by two questions:

1. "Where is most relevant to predict the air flow and anticipate droplets dissemination? Which settings? Which environments? Why?"
2. "By predicting the air flow in those spaces, the risk of droplets spreading may be decreased? Why? "Which groups may particularly benefit from the use of technology that predicts the risk of contamination? Who are the most vulnerable groups for diseases that spread by air? Who is mostly at risk of disease and death from airborne diseases, such as COVID-19?

First, and to facilitate the organization of students' reasoning and their subsequent research, a worksheet **(DER4)** is distributed, and students write their initial preconceptions in the first table. Then students are asked to search for reliable information on the topic and fill a second table with scientific information they found in the inquiry process. An example of a worksheet template to be distributed to the students/groups so that they can efficiently organize the information, reasoning, and arguments, can be observed in the image below.



Define The Environment

1. Taking into account questions 1 and 2 write what you know or what you think about each question in the corresponding table.

Question 1	Question 2

2. Now, taking into account what you research on the topic, fill in the table below with the information corresponding to each question.

Question 1	Question 2

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Students look up for this information themselves and later discuss their reasoning in groups (3/4). Additionally, the teacher explains that they should always check the following, before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older the document, data or information is, greater the chances are of being outdated.

Then the teacher encourages students to look for information in scientific articles because those two mentioned conditions are almost always guaranteed.

The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback when needed. The teacher has organized and structured information on the topic, which can be retrieved from the following sources:

- What are airborne diseases": *https://www.healthline.com/health/airborne-diseases* **(DER18)**
- "Airborne Disease": *https://www.medicoverhospitals.in/articles/air-borne-diseases* **(DER19)**
- "Preventing the spread of Coronavirus with ventilation systems":

https://www.daikinapplied.uk/news-center/preventing-the-spread-of-coronavirus-with-ventilation-systems/ **(DER20)**

- **Activity 2**

After conducting the first inquiry-based activity and the internal discussion between the groups about their reasoning (teacher defines a time limit for the students to complete the worksheet of activity 1 and discuss their reasoning with the formed groups), the teacher provides students with credible, organized, and systematized information on the topics students were asked to investigate (for this, the teacher prepares a presentation on the topic based on sources mentioned above, **DER18-DER20**). The aim of this presentation is increasing students' understanding on how to prevent and mitigate viruses' spreading through air by predicting the dissemination of respiratory droplets in multiple spaces.

- **Activity 3**

To capture if students retained the essential learnings of activity 1 and 2, the teacher proposes to the classroom another inquiry activity. Students indicate environmental conditions that might elevate the risk of respiratory droplets dissemination and identify simple actions to prevent or mitigate it.

"1. Please identify a source of risk regarding droplets transmission. A) Leaving the windows open. B) No proper maintenance of ventilation systems. C) Having ventilation systems working for a long period of time."

"2. Analysing the air flow in different locations will have no impact in preventing or mitigating viruses' transmission in such places. A) False. B) True."

"3. Ventilation systems may contribute to prevent viruses' transmission by air: A) Yes, ventilation systems provide comfort on closed spaces, by making the air continuously circulating around the room, and may prevent the accumulation and stagnation of droplets, which influences diseases transmission between humans. B) No, ventilation systems just provide thermal comfort in closed spaces, don't influence diseases transmission between humans. C) No, because droplets accumulation is inevitable, and nothing can be done to mitigate such phenomena."

Answers:

1. B)
2. A)
3. A)

Students search to answer the questions in group work (within the groups previously formed).

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The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback when needed. The teacher understands if students resort to reliable sources of information and the difficulties they face to obtain the answers. To obtain more information about this last issue, the teacher launches the question "What were the main difficulties you face in the process?".

➢ **Learning objects of this lesson:**
- Worksheets **(DER4)**
- What are airborne diseases": *https://www.healthline.com/health/airborne-diseases* **(DER18)**
- "Airborne Disease": *https://www.medicoverhospitals.in/articles/air-borne-diseases* **(DER19)**
- "Preventing the spread of Coronavirus with ventilation systems": *https://www.daikinapplied.uk/news-center/preventing-the-spread-of-coronavirus-with-ventilation-systems/* **(DER20)**

Lesson 3: Define Baseline Case

The main goals to achieve in this class, in a student's perspective, are:
- Uses concepts of physics science to explain the process of droplets dissemination in closed spaces.
- Can find, analyse, and interpret scientific data, texts, and dynamic graphical representations to understand the burden of diseases that spread by air.
- Understands the relevance of scientific evidence to explain phenomena related to health and illness and produce argumentation.
- Uses computational tools to increase understanding on the process of virus spreading through air.
- Understands how ventilation systems may prevent or mitigate the dissemination of diseases transmitted by air.

➢ **Lesson Summary:**
In lesson 3 the teacher starts the school STEM project. During the two previous classes, the process of respiratory particles dissemination in closed spaces was explained by exploring concepts of physics science. At this phase the teacher defines an initial baseline case study, where students manipulate basic parameters and understand the behaviour that respiratory particles perform under certain conditions.

➢ **Activity 1**
The initial baseline case is a simple room, without windows, or doors, just with some humans, where only one of them will spread a certain number of particles, with different sizes, and in different breathing regimes (speaking, coughing, and sneezing), in a certain period of time. This initial room will also be simulated with and without the functioning of a ventilation system. The *modus operandi* of the simulations which the students will observe and analyse will be very similar of the ones of lesson 1 (activity 4).
Students are asked to form groups of 3/4 students and analyse the results/outputs of the different simulations. The following questions are answered: **(DER2, DER3, DER5)**
1. Who was most infected?
2. In which situations (with and without a ventilation system) the particles were removed in a greater number?
3. What influences particles dissemination in this situation?
4. What is the dimension of the particles in the room and which ones were easily removed?
5. Are there any differences in terms of respiratory virus transmission and infection risk?
6. The removal of particles from the room is influenced by humans' behaviour, such as speaking or coughing?

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- **Information regarding the stated questions:**

Students will conclude that in the baseline case, respiratory particles follow the direction of the air flow inside the room due to their reduced size. Every circumstance that leads to airflow disturbances, such as increasing complexity of geometries in the room, or functioning of a ventilation system, will directly influence the droplets' flow. In this initial case (very similar to the images of lesson 1) we have human simulators inside the room, represented with very simple geometries, in rectangular shapes; the particles are mostly removed by the extractor located in the ceiling, as the airflow is greatly influenced by the ventilation system performance.

On the other hand, what is also observed, is that the largest particles are those inhaled by humans or deposited on walls. The smaller ones mostly follow the air flow, and with the ventilation system working, they end up being removed from the room, through the extractor.

Regarding the differences in simulations with and without a ventilation system working, what is observed, is that without appropriate ventilation, the particles stand at the room, just a few of them are removed, and the level of infectiousness in the room is high.

In relation to particles spread in the different breathing regimes, students will observe that in sneezing or coughing situations, compared to situations in which people are speaking, particles are much more uniform, a greater number of droplets are deposited in furniture and not removed from the room, since there are more particles of larger dimension in sneezing and coughing circumstances. (**DER2, DER3, DER5).**

Bearing the stated questions in mind, students produce, in groupwork, a report **(DER2, DER3, DER 5)** that explains droplets release in the different time periods of the simulation. In addition to what was shown in lessons 1 and 2 about the physics of respiratory droplets dissemination, students will also be invited to search for trustful information in additional sources. These educational resources can be retrieved from the following links:

- https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf ; **(DER7**)
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234804/pdf/jhyg00188-0053.pdf **(DER8)**
- https://reader.elsevier.com/ **(DER15)**
- https://re.public.polimi.it/ **(DER16)**

As these scientific outputs are essentially used in university environments to set up research, and can be complex to interpretate, is suggested that students consult the abstract and conclusions of the articles, which assure that they can get the essential information for executing their work. The report is initiated in class, completed outside the classroom, and preferentially produced in the original groups of 3-4 students. The report is kept for later discussion in lessons 5 and 6.

To facilitate students' reasoning and organization of ideas, a worksheet **(DER4)** is provided, where they point out, for each case, dimensions, elements, furniture, configuration of the room (windows, doors, HVAC, etc…) and the type of breathing regime. This worksheet also contains a field where students might write their ideas and reasoning, as well as a space for final remarks. An example of worksheet template to be distributed to the students/groups in order that they can efficiently organize their thinking and reasoning, is observed in the image below.

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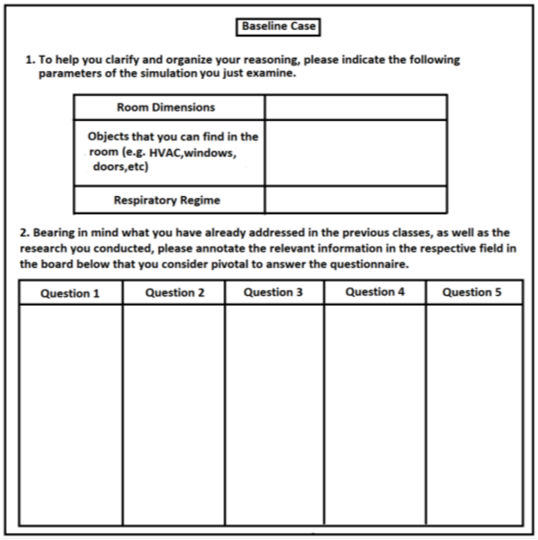


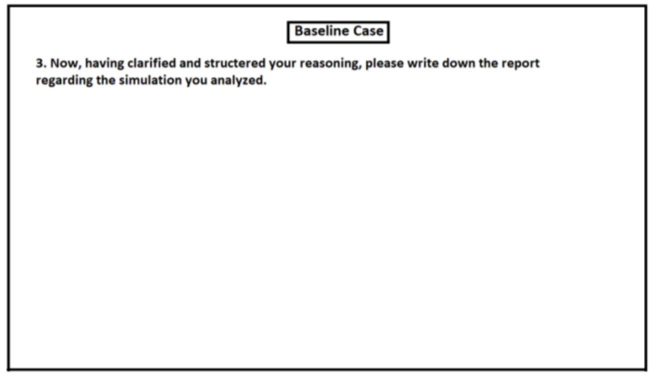
Baseline Case

1. To help you clarify and organize your reasoning, please indicate the following parameters of the simulation you just examine.

Room Dimensions	
Objects that you can find in the room (e.g. HVAC,windows, doors,etc)	
Respiratory Regime	

2. Bearing in mind what you have already addressed in the previous classes, as well as the research you conducted, please annotate the relevant information in the respective field in the board below that you consider pivotal to answer the questionnaire.

Question 1	Question 2	Question 3	Question 4	Question 5



Baseline Case

3. Now, having clarified and structered your reasoning, please write down the report regarding the simulation you analyzed.

- **Learning Objects of this lesson:**

- Repository of simulation results obtained with the CFD tool. **(DER1)**
- Droplet distribution in closed spaces. **(DER2)**
- Different breathing regimes and their influence on droplets transmission (e.g., Coughs, Sneezes, Common Talking, etc.). **(DER3)**
- Worksheets **(DER4)**
- Elements inherent to the spaces and their influence on droplets transmission. **(DER5)**
- https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf . **(DER7)**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234804/pdf/jhyg00188-0053.pdf **(DER8)**
- https://reader.elsevier.com/ **(DER15)**
- https://re.public.polimi.it/ **(DER16)**

Lesson 4: More Complex Case Studies

The main goals to achieve in this class, in a student's perspective, are:

- Uses concepts of physics science to explain the process of droplets dissemination in closed spaces.
- Can find, analyse, and interpret scientific data, texts, and dynamic graphical representations to understand the burden of diseases that spread by air.
- Understands the relevance of scientific evidence to explain phenomena related to health and illness and produce argumentation.
- Uses computational tools to increase understanding on the physical process behind virus spreading.
- Understands how ventilation systems may prevent or mitigate the dissemination of diseases transmitted by air.

- **Lesson Summary:**

In lesson 4, and using the same *modus operandi* of lesson 3, students will qualitatively analyse the results of more complex simulations, in comparison with the baseline case study (lesson 3).

- **Activity 1**

The simulations to be analysed in lesson 4: **(DER1)**

1. Room with more complex human simulators (instead of being represented by simple rectangular shapes, they assume a more realistic structure), sitting on chairs, and with a ventilation system.

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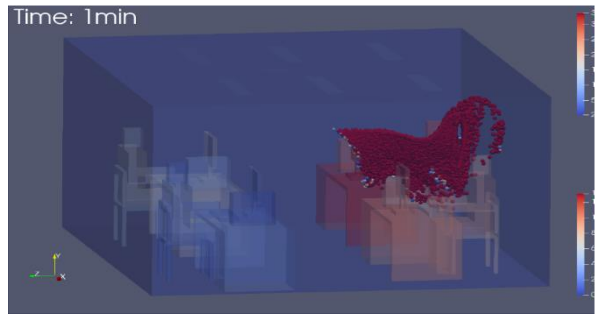
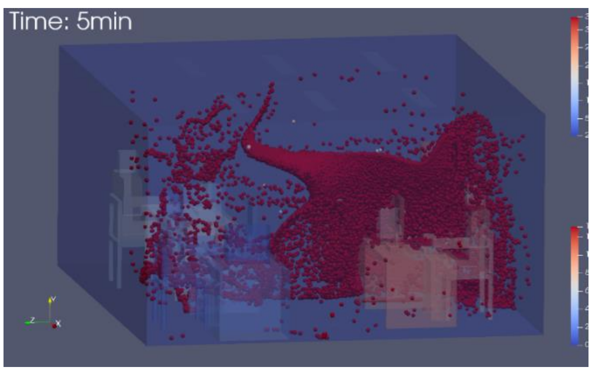
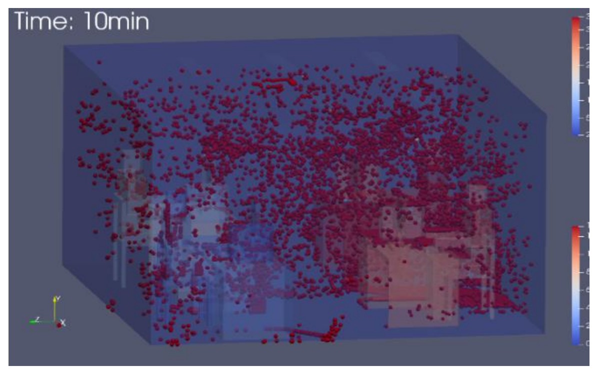
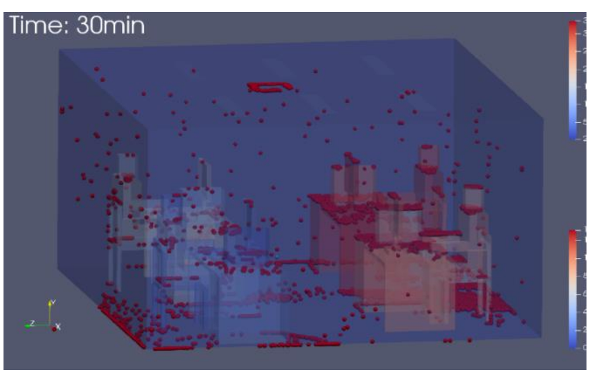
2. Room with more complex human simulators sitting on chairs, and with more furniture (tables, 1 monitor, 1 keyboard and 1 tower), and with a ventilation system.
3. Room similar to the mentioned above, with the introduction of windows and doors, without a ventilation system.
4. Room similar to the mentioned above and with a ventilation system on the celling.

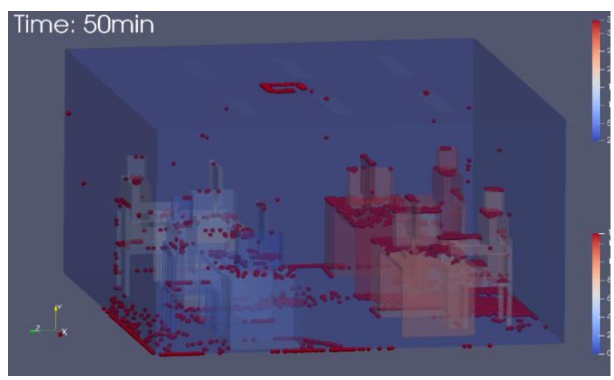
A couple images of simulations similar to the ones that students will explore are seen bellow:**(DER1)**











In this task students are asked to describe their observations regarding the above simulations and compare to the ones of lesson 3 (baseline simulation). Students qualitatively evaluate the differences by answering the following questions:

1. In which simulation was a greater number of particles observed, at the end?
2. Did the presence of more furniture inside the room, in simulations of lesson 4, greater influence the circulation of particles, compared to what was observed in the baseline case (lesson 3)?
3. What are the differences observed in simulations of lessons 3 and 4 when a person: 1. sneezes, 2. coughs, 3. speaks.?

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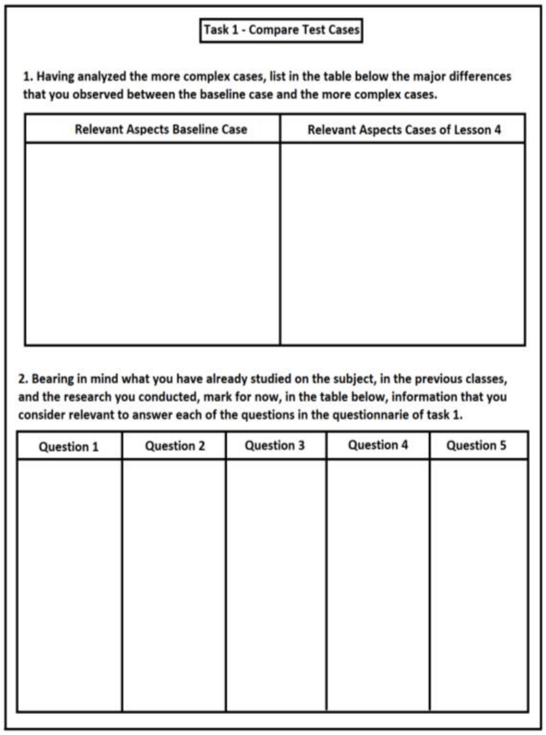
4. In the baseline case study (lesson 3), and in simulations of lesson 4, what are the differences observed in the region near the extractor?
5. If humans keep "2m-social distance" or wear a mask in both cases (baseline simulation and simulations of lesson 4) does the infection risk changes?

To facilitate students' reasoning and organization, a worksheet **(DER4)** is provided to the students/groups, where they write their answers and then elaborate a final report to be concluded outside the classroom and discussed later (in lessons 5/6). An example of a similar worksheet template to be distributed to students so that they can efficiently organize their ideas and reasoning, can be observed in the image below.

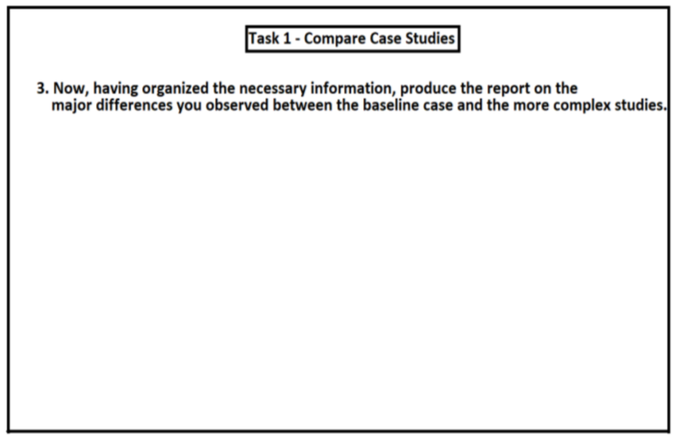

Task 1 - Compare Test Cases

1. Having analyzed the more complex cases, list in the table below the major differences that you observed between the baseline case and the more complex cases.

Relevant Aspects Baseline Case	Relevant Aspects Cases of Lesson 4

2. Bearing in mind what you have already studied on the subject, in the previous classes, and the research you conducted, mark for now, in the table below, information that you consider relevant to answer each of the questions in the questionnarie of task 1.

Question 1	Question 2	Question 3	Question 4	Question 5


Task 1 - Compare Case Studies

3. Now, having organized the necessary information, produce the report on the major differences you observed between the baseline case and the more complex studies.

The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and provides feedback when needed. The teacher has organized and structured information on the topic to consolidate students' learnings of lesson 4 **(DER2, DER3, DER4)**.

➢ **Information regarding the simulation/stated questions:**

Simulations of lesson 4, when compared to the baseline case, are very similar in the process of droplets dissemination inside the room. The particles will continue to follow the airflow created inside the room, which is strongly influenced by the ventilation system in operation. The difference between those two case studies is: as there are more furniture in the room, the airflow generated by the ventilation system has more disturbances, and in certain spaces this system won´t be able to influence the airflow as much, and so particles stuck in those areas, and in geometries, such as the monitor, the table, or the chair, etc. and the risk of virus transmission between human increases. In both cases, keeping social distance and wearing a mask decreases the risk of virus transmission between humans. At the end of the simulation, the presence of a greater number of particles will be observed in the room, in comparison with the baseline case.

➢ **Learning objects of in this lesson:**

- Droplets transmission in closed spaces. **(DER2)**

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- Different breathing regimes and their influence on droplets transmission (e.g., coughs, sneezes, common talking, etc.). **(DER3)**
- Worksheets **(DER4)**
- Elements inherent to the spaces and their influence on droplets transmission. **(DER5)**

Lesson 5: Compare case studies of lesson 4 with baseline case of lesson 3

The main goals to achieve in this class, in a student's perspective, are:

- Can use evidence to build argumentation on viruses' transmission.
- Can evaluate and communicate data and scientific information about airborne diseases.
- Can understand the relevance of scientific evidence to explain phenomena related to health and illness and produce argumentation.

➢ **Lesson Summary:**

In lesson 5 the reports produced by the students are discussed (relative to simulations results analysed in lessons 3 and 4) and a debate is organized.

➢ **Activity 1**

The teacher proposes a classroom debate on the topic "How can we change the risk of virus transmission by planning or changing the configuration of a space or influencing humans' behaviour?". The driven question for the debate may be focused on a specific space (e.g., classroom, lunch room). In order to conduct an effective debate, the teacher agrees with students on the nature of the debate and assures compliance with the described below:

▪ **The main focus of the Debate:**

The main focus of the debate is use scientific argumentation to discuss particles dissemination inside a closed space (e.g., classroom, lunch room) and base ideas and proposals for space configuration in the simulations previously observed and analysed from the CFD tool.

▪ **The Structure of the Debate:**

To perform the debate the teacher divides students in groups (4-5 students) and each group is given a time to communicate a set of proposals on the topic ""How can we change the risk of virus transmission by planning or changing the configuration of a space or influencing humans behaviour?". The other groups prepare counter arguments and rebuttals.

▪ **The Rules of the Debate:**

Every member of each group speaks at least once, and the order and content of discourse is previously planned by the team members. Other groups present their counter arguments and if they do not agree with the reasoning of the group that presented before, explain their claims. The groups that agree with the arguments stated at least present 1 critique, counterargument, suggestion, or recommendation. Then is given a time to the group that set the presentation to rebut those counter arguments. The presentation of the counter arguments and rebuttals is made by only 1 member of each group, nominated by the teams.

▪ **Assessment of the Debate:**

The evaluation of the debate is left to the teacher's discretion, but it undoubtedly involve the following criteria:

- The group that presented the most reliable proposals.
- The group that best defended their point of view.
- The group that best refuted the arguments of the other groups.

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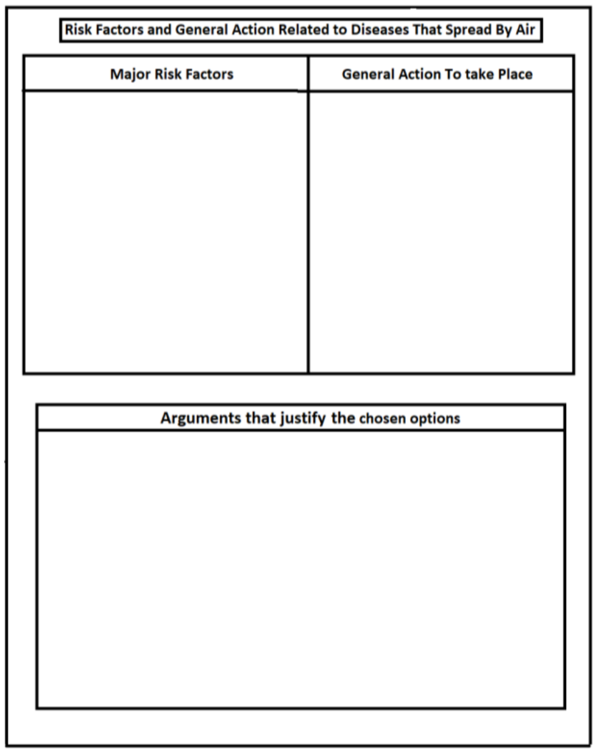
- **Activity 2/Task 1**

At the end of lesson 5, the topic of lesson 6 is introduced. Student focus on what they have learnt from the previous lessons to point out several risk factors for acute respiratory diseases, such as COVID-19 and Flu. Then they are asked to propose a series of actions to be taken, at the individual and school level, to prevent a growing number of cases, after the first case is identified. A worksheet **(DER4)** is distributed to the students and they provide a list of risk factors and actions to be taken by students and school community to reduce the risk of airborne diseases (this may include the reorganization of spaces and dynamics by students and school administrators). Additionally, the worksheet contains a field where students can write facts, arguments that justify their ideas. An example of a worksheet template to be distributed to the groups, so that they can efficiently organize their reasoning and proposals, is observed in the image below. The activity is started in classroom environment and completed outside the classroom.


Risk Factors and General Action Related to Diseases That Spread By Air

Major Risk Factors	General Action To take Place

Arguments that justify the chosen options

Students are asked to base their arguments on reliable sources and scientific information (the following may be used as examples):

- https://www.healthline.com/health/disease-transmission#indirect-contact **(DER10)**
- https://www.medicalnewstoday.com/articles/317632#common-airborne-diseases **(DER11)**
- https://www.webmd.com/lung/what-are-airborne-diseases **(DER12)**

- **Learning Objects employ in this lesson:**
  - Droplets transmission in closed spaces. **(DER2)**
  - Different breathing regimes and their influence on droplets transmission (e.g., coughs, sneezes, common talking, etc.) **(DER3)**
  - Worksheets **(DER4)**
  - Elements inherent to the spaces and their influence on droplets transmission. **(DER5)**
  - https://www.healthline.com/health/disease-transmission#indirect-contact **(DER10)**

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- https://www.medicalnewstoday.com/articles/317632#common-airborne-diseases **(DER11)**
- https://www.webmd.com/lung/what-are-airborne-diseases **(DER12)**

Lesson 6: Addressing Risk Factors and Proposing General Action to Improve Public Health

The main goals to achieve in this class, in a student's perspective, are:

- Identifies factors that influence droplets' dissemination.
- Identifies sources of risk in the environment.
- Identifies measures and proposes general action to fight airborne diseases.

➢ **Lesson Summary:**

In lesson 6 students, based on what they have learnt in previous classes, identify several risk factors for acute respiratory diseases, and present general action to prevent and mitigate the fast spreading of such conditions, as well as having proposals that are a great contribute for the school and community health.

➢ **Activity 1**

Lesson 6 starts with a classroom debate within the groups (and moderated by the teacher). Each group has a fixed time to argument on the factors associated with the fast growth of cases of COVID-19 (example of airborne disease), and then propose actions that may mitigate the dissemination of such disease. The teacher remembers the rules of the debate, which are similar to the debate conducted in lesson 5. Then the teacher may use **DER6** to present consolidated information on the topic.

➢ **Activity 2**

At the end of the lesson, the teacher introduces the school project, described in autonomous section of the scenario. Each group is challenged to build a presentation or poster **(DER6)** that contains images, text, infographics, graphical representations, with the conclusions drawn from the analysis of the case studies. Students are encouraged to refer to the scientific articles they consulted in the inquiry-based process, to explain the findings coming from the simulations, and based on that, make their proposals. The best presentation format of the project results is discussed, and notes taken by the groups during the debates are consulted during the process. This student scientific and creative work will later be presented at the open schooling event, where the school community is willing to participate on the showcasing of project results and debate.

➢ **Learning Objects employ in this lesson:**

- Strategies to mitigate the dissemination of airborne diseases (*images, maps, infographics, graphics*) **(DER6)**

Supplementary learning resources and educational activities

Inviting STEM organizations.
Share simulations with other schools in a repository platform (to be visible but not editable).
Reflect on other schools' simulations.
Improve existing and explore new simulations.
Interact with professionals.
Disseminate to parents' associations and civil organizations.

School Research Project

Topics

- Airborne Transmission Process.
- Airborne Diseases.

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- Computational Fluid Dynamics Tool (CFD).
- How a ventilation System Helps mitigate the dissemination of airborne diseases.
- Public Health.
- Scientific information.
- Responsible citizenship.

Challenge: explore the simulator, build your simulations and report!

Development process (summary):
Based on the knowledge coming from lessons 1-6, students will go to the laboratory of the mechanical engineering department at ISEL and will interact with the computational tool. They can build their own spaces, change environmental conditions, see the differences, describe the simulations, and report their case studies on a short report. Then teacher proposes successive debates about the scientific reports in the form of "research seminars" taking place in the school or in the science club. Students, parents, school community and relevant local stakeholders attend the event and understand how the rapid growth of new cases of airborne diseases, such as COVID-19, or other acute respiratory diseases such as Flu, is influenced by individual behaviour and environmental factors. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community level).

Teaching-learning process milestones:
Students will be able to:
1. Develop critical reasoning (e.g., analysing, organizing, debating, and sharing information about the simulations outputs).
2. Develop digital skills (e.g., finding, reviewing, and using different online resources to develop the activities).
3. Understand how a Computational Fluid Dynamics (CFD) Tool is handled and its relevance for managing public health threats.
4. Use concepts of physics science to explain the process of droplets dissemination in closed spaces.
5. Understand several factors that influence droplets' dissemination.
6. Understand how a ventilation system might mitigate the spreading of airborne disease.
7. Develop the ability to construct different types of arguments, counterarguments, and rebuttals in order to make decisions regarding socio-scientific questions.
8. Develop the ability to debate socio-scientific questions.
9. Influence community's perceptions and knowledge about respiratory viruses transmission and airborne diseases.
10. Develop responsible citizenship and critical health literacy.

Teaching-learning process for school project (summary):
1. Collection of evidence (data, articles, pictures)
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Evaluation of CFD simulation results.
4. Design reports referring to the CFD simulation results.
5. Design criteria for arguments evaluation.
6. Design rubric for evaluation of public debate.
7. Design an agenda for the open schooling event.
8. Create a brochure/power-point related to measures to be taken to prevent and mitigate the dissemination of acute respiratory diseases and distribute it in open schooling event.

Organization of the open schooling event:

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1. Each project output (simulations and report) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair).
2. Students will communicate policy measures using STEM-based argumentation. Students appeal to the action of all in health of the community, providing great understanding that preventing the spreading of a disease is a responsibility of all, not only of the ministry of health or healthcare providers.
3. Students, parents, school community and relevant local stakeholders attend the event and understand how the incidence of acute respiratory diseases is influenced by individual behaviour and environmental factors. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community level).

Target Audience for Recommendations
Other schools that use the repository platform.
Social NGOs.
Decision makers.
General public.
Mass media.
Families.
Friends.
Future students.

Public Debate and Recommendations (based on research results)
Presentation of the report of simulations by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.
Interaction between schools informing school how their report (in the repository platform) enhanced the B-school project and study.
Networking between schools with similar environment.
Discussion and feedback.
Produce a revised report based on the reports from other schools.
Make recommendations for public spaces.
Dissemination of final report and recommendations in the school website and inform the major stakeholders (public transport companies, shopping centres, hospitals, etc.).

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20. Specifications for an educational scenario on the topic of “Energy sources, and public health impact”

Main Partner responsible: ISEL

Context and relevance of the scenario for public health education

Air pollution is a global issue with well-documented public health effects. While some of the consequences of pollution are unpredictable in terms of climate change, others such as heat stress, chronic respiratory and cardiovascular diseases, cancers, are supported by considerable evidence. Energy supply chains highly contribute to air pollution, which now causes over 7 million deaths every year, with over 4 million deaths from household air pollution, and over 3.5 million from outdoor air pollution. Given the nature of the Earth as an energy-dependent system, the educational scenario supports physics teachers in organising classroom debate on energy transition towards more carbon-neutral environments. The learning experience prepares youths to become aware of energy sources and the importance of renewable sources in the sustainability of the Earth as a viable ecosystem. The impact of different sources of energy is discussed, with a focus on rationalization, economic and environmental impacts. With this scenario, teachers will be promoting awareness on implications of energy choices on air pollution, on the planet and for community health.

Estimated duration

6 classes of 40-45 minutes (lesson 1 – lesson 6).
6 sessions of 40-45 minutes for school project (session 7 – session 12)

Classroom organization requirements

From lesson 1 to lesson 6 students work alone or occasionally in groups.
From lesson 7 to lesson 12 students form four- or five-member groups which carry out the school project. The use of computer is required.

Prerequisite knowledge and skills

Basic knowledge of software and browsers.

Content Glossary

Air Pollution - It is the release into the atmosphere of various gases, finely divided solids, or which could be dispersed as liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic, or aesthetic effects.

Chemical Reactions - A process in which one or more substances, the reactants, are converted into one or more different substances, the products. Substances are either chemical elements or compounds. A chemical reaction rearranges the constituent atoms of the reactants to create different substances as products.

Climate Change - Refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle. The consequences of climate changes, nowadays includes, among others, intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms and biodiversity declining.

Combustion – A chemical reaction between substances, usually including oxygen and usually accompanied by the generation of heat and light in the form of flame.

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Primary Energy - Is an energy form found in nature that has not been subjected to any human engineered conversion process. It can be energy contained in raw fuels, or it can be other forms of energy, including waste, received as input to a system. Primary energy can be non-renewable or renewable.

Energy Conservation Principle - Principle of physics according to which the energy of interacting bodies or particles in a closed system remains constant.

Energy Transfer process – Energy transfer is the process by which energy is relocated from one system to another, for example, through the transfer of heat, work or mass transfer. Thermal energy transfers only occur in three ways: through **conduction, convection, and/or radiation**. When thermal energy is transferred between neighbouring molecules that are in contact with one another, this is called conduction. Convection is the transfer of heat energy in a fluid. Radiation is the transfer of heat energy through space by electromagnetic radiation.

Energy Transformation Process - Energy transformations are processes that convert energy from one type (e.g., kinetic, gravitational potential, chemical energy) into another. Any type of energy use must involve some sort of energy transformation. For example, the transformation of oil, gas, or hydraulic power into electric power.

Indoor Air Pollution - Refers to chemical, biological, and physical contamination of indoor air. It may result in adverse health effects. In developing countries, the main source of indoor air pollution is biomass smoke which contains suspended particulate matter (5PM), nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (Ca), formaldehyde and polycyclic aromatic hydrocarbons (PAHs).

Outdoor Air Pollution - It´s often referred to as ambient air. The common sources of outdoor air pollution are emissions caused by combustion processes from motor vehicles, solid fuel burning and industry. Other pollution sources include smoke from bushfires, windblown dust, and biogenic emissions from vegetation (pollen and mould spores).

Renewable Energies - Are ways to generate energy from (theoretically) unlimited natural resources. These resources are either available with no time limit or replenish more quickly than the rate at which they are consumed. Renewable energies are also often referred to as “green energies” or “clean energies”. Still, this doesn’t mean that these energies aren’t harmful to the environment and have zero impact. Nonetheless, they have a low environmental impact compared to fossil fuels.

Sustainable Energy Management - Combines management skills with an understanding of responsible energy resources use and the development of sustainable sources of energy (e.g., wind, solar, biomass, hydro, geothermal, etc.)

Pedagogical glossary

Active Learning. A teaching and learning approach that “engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.”.

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and being its aim the production of a lot and divergent ideas.

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Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills.

Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Sources: https://www.britannica.com/; Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

Indicative Literature

(WHO) – Air Pollution - https://www.who.int/health-topics/air-pollution#tab=tab_1
Our World in Data – Energy Production and Consumption - https://ourworldindata.org/energy-production-consumption
Our World in Data – Energy Mix - https://ourworldindata.org/energy-mix
WMO and UNEP (World Meteorological Organization and United Nations Environment Programme), 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report - https://msuweb.montclair.edu/~lebelp/PSC643IntPolEcon/IPCCClimateChange2007.pdf

Competences / Learning Goals

Key Competences
STEM/ personal, social

Knowledge
Physics concepts:

- Energy production.
- Energy transfer.
- Energy conservation.
- Primary energy and fuels.

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- Renewable energy sources.
- Non-renewable energy sources.

Environmental health concepts:
- Environmental determinants of health.
- Pollution, climate change.
- Indoor air pollution, sources.
- Outdoor air pollution, sources.
- Air pollution as a risk factor for non-communicable diseases (e.g.: chronic pulmonary disease).

Epidemiology and health economics concepts:
1. Indicators of disease burden related with air quality loss (e.g.: deaths caused by indoor and outdoor air pollution).

Social and global health concepts:
1. Sustainable Development Goals (SDG 3 in relationship with 7, 11, 12, 13)
2. Growing urbanization and environmental health challenges.
3. Public policy on air pollution and energy-related issues.

Knowledge - outcome assessment:
1. Recognizes that the production of carbon dioxide is the primary factor driving anthropogenic climate change.
2. Defines the concept of primary energy and its sources.
3. Identifies several ways of energy production and energy transfer.
4. Recognizes the difference between renewable and non-renewable energy sources.
5. Identifies the advantages of using renewable energies and challenges associated with the use of these type of energy.
6. Identifies measures and proposes general action to fight climate change.

Skills (abilities/competences)
General: curiosity; collaboration; critical thinking; self-awareness, citizenship, debate, public speaking and presentation, brainstorming participation, problem definition, problem solving, analysis and discussion of evidence, argumentation, hypothetical-deductive reasoning, inductive reasoning, problem based learning, understand scientific principles and models, critical thinking, teamwork, reading and understanding a simulation motion, understanding the applications of mathematical models, assess risks and take decisions.

Specific:
- Finding, analysing, and interpreting scientific data, texts and dynamic graphical representations to establish the relationships between energy sources, air pollution and climate change events.
- Analysing the general energy production process.
- Analysing how the energy supply chains impact carbon emissions to the atmosphere.
- Analysing the consequences of air pollution in terms of damage to the environment, global warming, and climate change events.
- Analysing the consequences of air pollution to public health.
- Understanding the environmental and economic impacts of most important sources of energy available on the planet.
- Obtaining, assessing, and communicating evidence related with sources of energy and implications in terms of indoor and outdoor air pollution.

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- Obtaining, assessing, and communicating evidence related to implications of pollution in the health of individuals.
- Analysing personal and community risks associated with pollutants emissions to the atmosphere.
- Understanding patterns of undesirable behaviour regarding household energy consumption.
- Understanding practical strategies to effectively reduce energy waist, move to renewable sources of energy and minimize ecological footprint.

Skills – outcome assessment:

1. Selects appropriate concepts, indicators, and evidence to characterize and relate energy sources, causes of air pollution and climate change events.
2. Can anticipate the consequences of anthropogenic activities in an individual, community and societal perspective.
3. Can anticipate the consequences of energy waste in an individual, community, and societal perspective.
4. Can propose concrete action towards adopting a lifestyle that is eco-friendly in his/her/others routines.
5. Feels able to reduce his/her own ecological footprint by moving to a more environmental-friendly lifestyle (e.g., soft transportation instead of car; avoid wood burning fireplaces).
6. Feels able to influence the adoption of eco-friendly options regarding energy use by others (e.g., family, peers, friends).
7. Can identify the problems and challenges of the community in relation to SDG 7 (affordable and clean energy) and connects them with other SDGs (particularly to SDG 3 - health and well-being).

Affective/Attitudes Behaviour (*beliefs)*

- Adopting general attitudes regarding the rationale use of energy.
- Adopting attitudes towards minimizing the ecological footprint by reducing energy needs and moving to sustainable energy sources.
- Engaging public speaking and debating of measures to reduce environmental and household risks, with a particular focus on public policy concerned with SDG 7 (affordable and clean energy).

Attitudes and behaviour - outcome assessment:

1. Believes that a civic and conscient behaviour in terms of energy use is fundamental to minimize air quality loss in the local community.
2. Believes that lifestyles influence climate change, emissions of pollutants to the atmosphere and air quality at the community level.
3. Believes that pollution is an environmental determinant of health.
4. Reproves patterns of energy waste in his/her living environment (e.g., non-efficient management of basic resources such as water or electricity).
5. Is committed to engage public discourse on issues related with energy supply chain management, energy efficiency and how these factors can influence the incidence of climate change related events.
6. Believes that personal and community options in terms of energy use have impacts on the effectiveness of energy management and on the concentrations of indoor and outdoor pollutants.
7. Is committed to communicate and actively participate in the challenges of the community in relation to energy consumption.

Learning goals and outcomes

- ✓ Uses online tools to plot tables, graphs, and maps, using updated data.
- ✓ Analyses how the consequences of unconscious behaviour can contribute to the increase of climate changes.
- ✓ Obtains, evaluates, and communicates data and scientific information about energy sources, energy production and energy transfer.

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- ✓ Gives examples on how climate changes are already affecting the planet and humans' life and well-being.
- ✓ Uses evidence to propose measures and methods to better rationalize energy consumption and communicates them to the community leadership.
- ✓ Describes different approaches to protect, develop and influence community health.
- ✓ Uses evidence to propose measures and methods to fight climate changes and communicates them to the community leadership.

Assessment methods

- ✓ Outcome assessment
    - Quantitative – questionnaire in paper.
    - Qualitative - students project.

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content
- Energy conservation principle.
- Energy transfer processes (conduction, convection, and radiation).
- Combustion.
- Chemical reactions.
- Sustainable Energy Management.
- Renewable Energies.
- Process of Transformation of Primary Energies (Oil, Coal, etc..), into Useful and Sustainable Energy (Electric Energy).
- Sources of indoor and outdoor air pollution.
- Air pollution as environmental determinant of health and associated medical conditions.
- Burden of disease attributable to ambient air pollution.

Non-STEM content
- Lifestyles, Urbanisation and Climate Change.
- Strategies to maintain quality of life and sustain basic needs with low energy consumption.
- Strategies to have access to clean and affordable energy and avoid waste.

Digital learning objects (LOs) and Digital Educational Resources (DERs)

New:
- Interactive Game on primary energies and energy consumption and rationalization**. [LO1]**
- Evidence about Primary Energy and sources (*infographic).* **(DER1)**
- Worksheets. **(DER2)**
- Energy consumption and a country's wealth/development (*infographic).* **(DER3)**
- Management and energy production (*infographic).* **(DER4)**
- Renewable energy sources - advantages of its use (*infographic).* **(DER5)**
- Sources of Air Pollution (*infographic).* **(DER6)**
- Climate Change (*infographic).* **(DER7)**

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- Consequences of Climate Change *(images, infographic).* **(DER8)**
- Consequences of Air pollution (*images, infographic).* **(DER9)**
- Strategies to reduce energy waste, fight climate change and reduce air pollution (*infographic).* **(DER10)**

Available resources (link):
https://www.dropbox.com/sh/o8s73tgwz3g8e43/AAAtG1PaWvmO7TvIxP5JTpzVa?dl=0

From other sources/high-quality platforms:

- Sources of Primary Energy (Images)

- https://www.sciencephoto.com/media/339586/view/a-jack-pump-used-for-oil-extraction; (Oil Extraction). **(DER11)**
- https://www.britannica.com/science/solar-energy (Solar Energy). **(DER12)**
- https://www.dw.com/en/wind-power-costs-renewable-energy/a-60046761 (Wind Energy). **(DER13)**
- https://education.nationalgeographic.org/resource/natural-gas (Natural Gas) **(DER14)**
- https://www.innovationnewsnetwork.com/hydropower-vs-wind-energy-securing-the-worlds-electricity-supply/6440/ (Hydraulic Power). **(DER15)**

- Primary Energy and respective sources

- https://www.sciencedirect.com/topics/engineering/primary-energy-source **(DER16)**
- https://www.eia.gov/tools/glossary **(DER17)**
- https://www.eia.gov/energyexplained/us-energy-facts/ **(DER18)**
- https://data.oecd.org/energy/primary-energy-supply.htm **(DER19)**

- Information on how Energy Consumption varies over the years

- https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html **(DER20)**
- https://yearbook.enerdata.net/ **(DER21)**
- https://ourworldindata.org/renewable-energy; **(DER22)**
- Renewables in Electricity Production | Statistics Map by Region | Enerdata **(DER23)**
- https://afse2017.sciencesconf.org/143355/Article_su.pdf **(DER24)**

- Advantages and disadvantages of using renewable Energy Sources

- https://www.empower-solar.com/blog/the-advantages-disadvantages-of-switching-to-solar-energy/ **(DER25)**
- https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy **(DER26)**
- https://www.vedantu.com/physics/non-renewable-energy **(DER27)**
- https://greengarageblog.org/21-advantages-and-disadvantages-of-non-renewable-energy **(DER28)**
- https://www.un.org/en/climatechange/raising-ambition/renewable-energy **(DER29)**
- https://www.nationalgeographic.com/environment/article/fossil-fuels **(DER30)**
- https://zbw.eu/econis-archiv/bitstream/11159/7697/1/1771636475_0.pdf **(DER31)**
- http://jocet.org/papers/092-J30008.pdf **(DER32)**
- https://www.researchgate.net/profile/Naeem-Abas/publication/274718268_Review_of_Fossil_Fuels_and_Future_Energy_Technologies/resources/5a1183f3aca27287ce293c6d/Review-of-Fossil-Fuels-and-Future-Energy-Technologies.pdf **(DER33)**

- Economical, Social, and Evironmental Impacts - energy sources

- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Measuring-the-Economics_2016.pdf **(DER34)**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

- https://www.renewableenergymagazine.com/emily-folk/the-many-economic-benefits-of-renewable-energy-20190312 **(DER35)**
- https://www.sciencedirect.com/science/article/pii/S1364032118303447 **(DER36)**
- https://journals.sagepub.com/doi/pdf/10.1260/0144598054530011 **(DER37)**
- https://escholarship.org/content/qt4wz9x840/qt4wz9x840.pdf **(DER38)**
- https://escholarship.org/content/qt4wz9x840/qt4wz9x840.pdf (DER39)
- https://www.ukogplc.com/page.php?pID=74 **(DER40)**
- https://shift.newco.co/2018/03/21/how-oil-came-to-control-the-world/ **(DER41)**
- https://www.forbes.com/sites/judeclemente/2015/04/19/three-reasons-oil-will-continue-to-run-the-world/?sh=2026a72143f9 **(DER42)**
- https://www.hindawi.com/journals/aess/2016/2707989/ **(DER43)**
- https://aip.scitation.org/doi/pdf/10.1063/1.4993039https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6607187/ **(DER44)**
- https://www.worldwater.org/wpcontent/uploads/2013/07/chapter_4_fossil_fuel_and_water_quality.pdfhttps://earthworks.org/issues/sources-of-oil-and-gas-air-pollution/ **(DER45)**
- https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021EF002558 **(DER46)**

Teaching-learning activities

Principal target:
Physics classes
7th grade (+/- 12 years old students)
4-6 sessions/classes of 40-45 minutes
Physics teachers integrate other colleagues in the enactment of the scenario (e.g., sciences, ICT teachers), as it aims to be interdisciplinary.

Topics of each lesson:

Lesson 1: Identify and compare primary energy sources.
Lesson 2: Search, understand and debate how energy consumption changes over the year, the month, and the day.
Lesson 3: Explore combinations of primary energies to satisfy energy consumption needs.
Lesson 4: Quantify the energy share of each primary energy.
Lesson 5: Identify measures and desirable behaviours to reduce energy consumption without loss of comfort and basic needs.
Lesson 6: Impacts of energy consumption rationalization.

Lesson 1: Identify and compare primary energy sources

The main goals to achieve in this class, in a student's perspective, are as follows:

- Defining the concept of primary energy and its sources.
- Finding, analysing, and interpreting scientific data, texts and dynamic graphical representations to establish the relationships between energy sources.

➢ **Lesson Summary:**
In this class, the concept of "Primary Energy" and its sources are explored.

➢ **Activity 1**
The teacher describes the plan for the next classes, which are directly related to a project. The teacher presents the work scope:
1. Students explore/study concepts related to primary energies and sources available on the planet.

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2. Students study how energy consumptions changes over the years, by searching and analysing reliable data and scientific information.
3. Students debate and explore how we can efficiently satisfy households consumption needs in an interactive way, by playing a game; students combine different sources of primary energy and explain the reasons why they choose one source in detriment of another.
4. Students analyse how excessive energy consumption, as well as energy waste impacts the society at different levels (in a social, health, environmental and economic perspective). Some problems can be listed such as the contamination of soils and water, air pollution, etc.
5. Students present a series of measures and recommendations to prevent or mitigate the excessive exploration and consumption of energy, as well as energy waste, at the school and community spaces.
6. Students present the findings coming from the project (evidence, proposals, and recommendations) to the community, in an open schooling event.

➢ **Activity 2**

In lesson 1, the concept of "Primary Energy" is explored. The teacher describes the main sources of primary energy after promoting a brainstorming on the topic. During the brainstorming (that captures preconceptions and misconceptions on the topic) students strive to answer, "What is Primary Energy?", "What are the primary energy sources that you know?".

Then a worksheet is presented to the students **(DER2).** Students answer the questions individually and then form groups (3-4 students) to discuss their responses and reasoning. The worksheet contains images of primary energy sources and students are asked to identify the energy source that is being displayed. Some images that may be used in the worksheet can be retrieved from the following resources:

- https://www.sciencephoto.com/media/339586/view/a-jack-pump-used-for-oil-extraction; (Oil Extraction). **(DER11)**
- https://www.britannica.com/science/solar-energy (Solar Energy). **(DER12)**
- https://www.dw.com/en/wind-power-costs-renewable-energy/a-60046761 (Wind Energy). **(DER13)**
- https://education.nationalgeographic.org/resource/natural-gas (Natural Gas) **(DER14)**
- https://www.innovationnewsnetwork.com/hydropower-vs-wind-energy-securing-the-worlds-electricity-supply/6440/ (Hydraulic Power) **(DER15)**

It should be given to students the necessary time to fulfil the worksheet, and an internal discussion with the teacher starts. The groups with the teacher's moderation briefly discuss their answers.

➢ **Activity 3**

After filling the worksheet and discuss their reasoning about the stated issue, students are introduced to the main sources of primary energy, such as mechanical energy in the form of hydraulic and wind energy (being those renewable energies) or energy from hydrocarbons (namely fossil fuels such as oil or natural gas). This information is compiled in a couple of slides/presentation that also integrates information coming from the resources mentioned below:

- https://www.sciencedirect.com/topics/engineering/primary-energy-source; **(DER16)**
- https://www.eia.gov/tools/glossary/index.php?id=Primary%20energy; **(DER17)**
- https://www.eia.gov/energyexplained/us-energy-facts/ **(DER18)**
- https://data.oecd.org/energy/primary-energy-supply.htm **(DER19)**

Then the teacher presents the cards containing the different sources of primary energy that will be explored in the gaming activity **(LO1),** to be conducted in lesson 3, and discusses the parameters/words identified in the cards, which characterize energy sources. Such parameters/words are:

1. The Chemical Symbol.
2. S.I. units.

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3. Calorific Power.
4. CO_2 emissions.
5. State at room temperature.
6. Producing countries.
7. Forms of storage.
8. Ways of transport.
9. Efficiency of power plants.
10. Starting time.
11. Out of service time.

- **Activity 4**

At the end of the lesson, the teacher proposes a simple inquiry task: students are asked to indicate some primary energy sources and make comparisons between them. The driven questions may be: “1. Please identify the most adequate definition of what is a primary energy. A) It is a primary energy source, that didn’t suffer any transformation. B) It is a source of energy that can only be obtained in the sea. C) It is a source of any form of energy available in nature before being converted or transformed.” “2. Please identify 3 sources of primary energy. A) Solar Energy, Electric energy, Hydraulic energy. B) Chemical Energy, Nuclear Energy. C) Electric Energy, Wind Energy, Solar Energy.” “3. Can Electric Energy be considered a primary energy? A) Yes, because is a source of energy in its raw form. B) No, because is a source of energy available in nature before being converted. C) No, because is a source of energy generated from a conversion of a primary energy such as hydraulic or solar energy.”
Answers:
1. C)
2. B)
3. C)

Students search to answer the questions in group work. The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback when needed. The teacher understands if students resort to reliable sources of information and the difficulties they faced to obtain the answers. To obtain more information about this last issue, the teacher may also launch the question "What were the main difficulties you face in collecting reliable information and answering the questions?".

Learning objects of this lesson:

- Evidence about Primary Energy and sources **(DER1)**
- Worksheet **(DER2)**
- https://www.sciencephoto.com/media/339586/view/a-jack-pump-used-for-oil-extraction; (Oil Extraction). **(DER11)**
- https://www.britannica.com/science/solar-energy (Solar Energy). **(DER12)**
- https://www.dw.com/en/wind-power-costs-renewable-energy/a-60046761 (Wind Energy). **(DER13)**
- https://education.nationalgeographic.org/resource/natural-gas (Natural Gas**) (DER14)**
- https://www.innovationnewsnetwork.com/hydropower-vs-wind-energy-securing-the-worlds-electricity-supply/6440/ (Hydraulic Power). **(DER15)**
- https://www.sciencedirect.com/topics/engineering/primary-energy-source; **(DER16)**
- https://www.eia.gov/tools/glossary/index.php?id=Primary%20energy; **(DER17)**
- https://www.eia.gov/energyexplained/us-energy-facts/ **(DER18)**
- https://data.oecd.org/energy/primary-energy-supply.htm **(DER19)**

Lesson 2: Search, understand and debate how energy consumption varies over the year, the month and the day

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The main goals to achieve in this class, in a student's perspective, are as follows:

- Identifies several ways of energy production and energy transfer.
- Recognizes the difference between renewable and non-renewable energy sources.
- Obtains, evaluates, and communicates data and scientific information about energy sources, energy production, energy transfer and energy consumption.

➢ **Lesson Summary:**

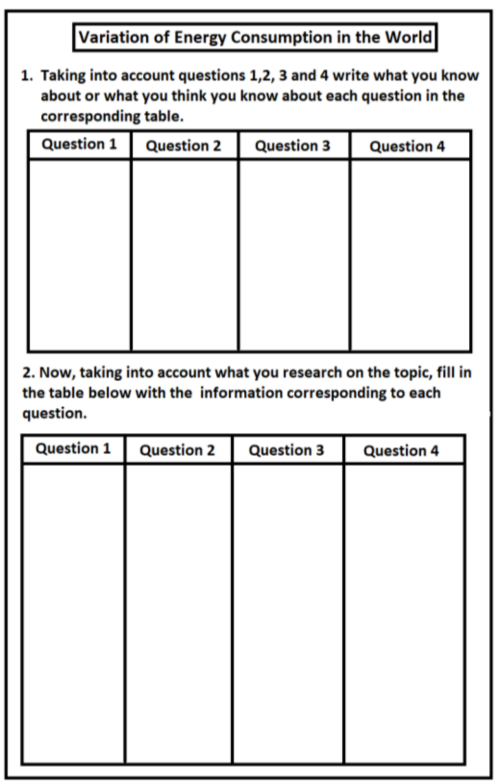
Lesson 2 increases students' knowledge about the sources of energy that are most consumed in the world, and how consumption varied over the months and years.

➢ **Activity 1**

Students are organized in groups to answer the following questions:

1. "How much energy is consumed in the world?"
2. "What are the main sources of energy consumed in the world?
3. There are differences between countries?

The questions are answered by students in a simple worksheet **(DER2).** The teacher explains to students that they can answer these questions with images, graphs, etc.. An example of worksheet template to be distributed to students so that they can efficiently organize their ideas and reasoning, is observed in the image below.**).** In addition, to address the ethical and social concerns associated to the issue, the worksheet may include the following questions: 3. How energy consumption affects daily life?" 4. Is there any cause/effect relationship between the development of countries and energy consumption?".


Variation of Energy Consumption in the World

1. Taking into account questions 1,2, 3 and 4 write what you know about or what you think you know about each question in the corresponding table.

Question 1	Question 2	Question 3	Question 4

2. Now, taking into account what you research on the topic, fill in the table below with the information corresponding to each question.

Question 1	Question 2	Question 3	Question 4

The teacher explains to students that they will be the ones who search for the answers, and they should base them in reliable sources, data and scientific information, which can be communicated

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in the most varied ways, as prior mentioned. The teacher provides scientific references to support students work. Such references can be retrieved from the following links:
- https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html **(DER20)**
- https://yearbook.enerdata.net/ **(DER21)**
- https://ourworldindata.org/renewable-energy; **(DER22)**
- Renewables in Electricity Production | Statistics Map by Region | Enerdata **(DER23)**

In this phase, students look up for information themselves and later discuss their reasoning in groups. Additionally, the teacher explains that they should always check the following before taking the information for granted:
- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for additional information in scientific articles, because those two mentioned conditions are almost always guaranteed. Examples of articles may be retrieved from the following links:
- https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html **(DER20)**
- https://ourworldindata.org/renewable-energy **(DER22)**
- https://afse2017.sciencesconf.org/143355/Article_su.pdf **(DER24)**

The teacher moves around the classroom, supervises and supports students work by making reflective and supportive questions, and provides feedback to students when needed.

- **Activity 2**

At the end of lesson 2 a basic inquiry task to the groups is proposed. Students indicate what sources of energy are most used in the world and how energy consumption varied over the years. This topic may be driven by the following questions: “1. Please identify what energy source is most consumed in the world. A) Nuclear Energy. B) Solar Energy. C) Oil.” “2. What is the percentage of electricity that comes via renewable energy? A) 5 to 10%. B) 20 to 30%. C) 40 to 50%.”
Answers:
1. C)
2. B)

Students search to answer the questions in group work (within the groups previously formed). The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback to the students when needed. The teacher understands if students resorted to reliable sources of information, and the difficulties they faced to obtain the answers. To obtain more information about this last issue, the teacher can include the question "What were the main difficulties you faced in the process?"

- **Learning objects of this lesson:**

- Evidence about Primary Energy and Sources. **(DER1)**
- Worksheet. **(DER2)**
- Evidence about Energy consumption and a country’s wealth/development. **(DER3)**
- Management and energy Production. **(DER4)**
- https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html **(DER20)**
- https://yearbook.enerdata.net/ **(DER21)**
- https://ourworldindata.org/renewable-energy; **(DER22)**
- Renewables in Electricity Production | Statistics Map by Region | Enerdata **(DER23)**

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- https://afse2017.sciencesconf.org/143355/Article_su.pdf **(DER24)**

Lesson 3: Explore combinations of primary energies to satisfy energy consumption needs

The main goals to achieve in this class, in a student's perspective, are as follows:

- Recognize the difference between renewable and non-renewable energy sources.
- Obtain, evaluate, and communicate data and scientific information about energy sources, energy production and energy transfer.
- Disapprove patterns of energy waste in his/her living environment.
- Adopting attitudes towards minimizing the ecological footprint by reducing energy needs and moving to sustainable energy sources.

➢ **Lesson Summary:**

In this lesson, students learn how to combine different sources of primary energies to efficiently solve a real-life problem, in an interactive way, by playing a game. Students will choose different sources of primary energy to efficiently satisfy houses energy consumption needs.

➢ **Activity 1**

Students already have basic knowledge on primary energies, energy sources and energy consumption worldwide. At this phase students will relate different sources of primary energy by playing a game **(LO1)**. Groups will decide on the best primary energy that can be transformed into electrical energy, that will later be consumed in a house. A series of cards are distributed to the groups where several parameters that characterize each primary energy source are described. Such parameters are as follows:

1. The Chemical Symbol.
2. S.I. units.
3. Calorific Power.
4. CO_2 emissions.
5. State at room temperature.
6. Producing countries.
7. Forms of storage.
8. Ways of transport.
9. Efficiency of power plants.
10. Starting time.
11. Out of service time.

Based on the information contained in each card, the groups select the best energy primary source to be transformed into electrical energy for satisfying a consumption (such as household or for a country). The principle of energy rationalization is promoted and linked with the consequent reduction of energy waste. The reward goes to the group that answers right and faster. The teacher assesses the answers and arguments of the groups and only valid ones get 1 point to the respective group.

➢ **Activity 2**

Based on the data that each group collected in the previous lessons, as well as teacher presentations and the information contained in the cards, students are asked to fill a worksheet **(DER2)** about sources of energy. A template that might be distributed to the students/groups so that they can efficiently organize their reasoning is observed in the image below.

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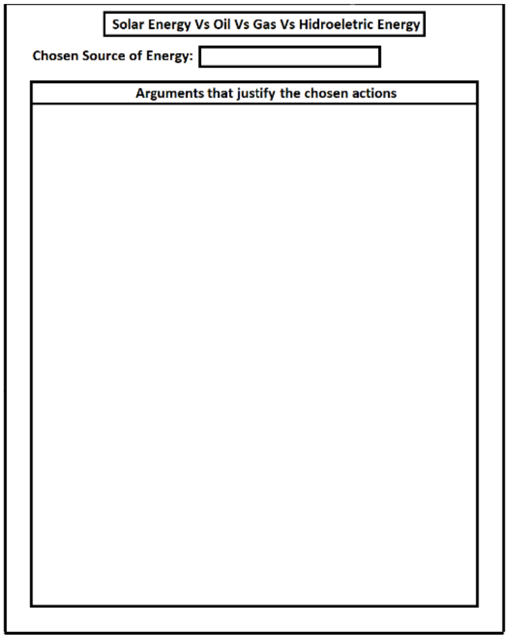
Solar Energy Vs Oil Vs Gas Vs Hidroeletric Energy

Chosen Source of Energy:

Arguments that justify the chosen actions

- **Learning objects of this lesson:**
- Interactive Game on primary energies and energy consumption and rationalization. **(LO1)**
- Worksheet. (**DER2)**

<u>Lesson 4: Quantify the energy share of each primary energy</u>

The main goals to achieve in this class, in a student's perspective, are as follows:

- Recognize the difference between renewable and non-renewable energy sources.
- Obtain, evaluate, and communicate data and scientific information about energy sources, energy production and energy transfer.
- Recognizes that the production of carbon dioxide is the primary factor driving anthropogenic climate change.
- Selects appropriate concepts, indicators, and evidence to characterize and relate energy sources, causes of air pollution and climate changes phenomena.

- **Lesson Summary:**

The lesson explores details on how different forms of energy are used in the world.

- **Activity 1**

At the beginning of the class, a series of questions are made to the students to understand their initial perceptions on the main differences between energy sources consumed in the world. Such questions might be:

1. "What are the main differences between a non-renewable and a renewable energy?",
2. "Can renewable energy sources produce the same amount of energy that non-renewable sources produce?".

The teacher can even take a specific topic like "Solar Energy vs Oil Energy" and understand the students' perceptions on this subject (a renewable vs a non-renewable energy). These questions, or others that the teacher deems appropriate within the scope of the lesson, are presented to students in a worksheet **(DER2).** An example of worksheet template to be distributed to the students/groups in order that they can efficiently organize their ideas can be observed in the image below.

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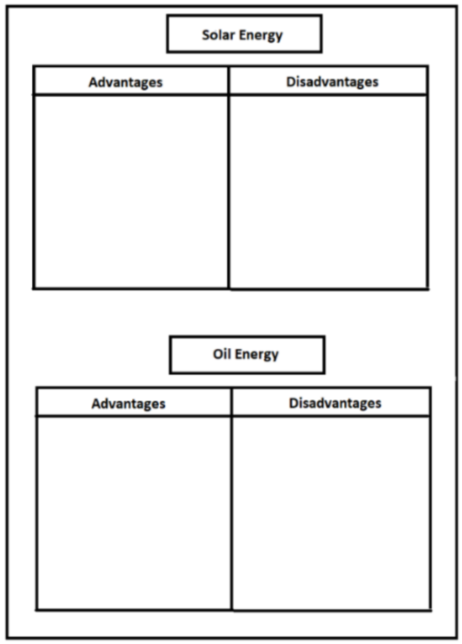

This distinction will both address the issues related with energy consumption (discussed in the previous lessons), climate change phenomena and how the usage of renewable energies in the long term can mitigate the problem. The worksheet might include additional specific questions such as: "How the use of Renewable Energy supports climate action and prevents climate changes events? ,"Can we establish a cause/effect relationship between the use of Fossil Fuels like Oil and air pollution and climate changes events?".Students may fill in the worksheet with text, graphical representations, diagrams, images, etc. The teacher asks students to look for the answers to the stated questions, and then, discuss their reasoning in the groups previously formed. The teacher remembers that answers should be based on reliable scientific sources, data and information. The following resources may be used:

- https://www.empower-solar.com/blog/the-advantages-disadvantages-of-switching-to-solar-energy/ **(DER25)**
- https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy **(DER26)**
- https://www.vedantu.com/physics/non-renewable-energy **(DER27)**
- https://greengarageblog.org/21-advantages-and-disadvantages-of-non-renewable-energy **(DER28)**
- https://www.un.org/en/climatechange/raising-ambition/renewable-energy **(DER29)**
- https://www.nationalgeographic.com/environment/article/fossil-fuels**(DER30)**

The teacher moves around the classroom and supervises students work, by making reflective and supportive questions and providing feedback when needed. The teacher remembers students that they should check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for information in scientific articles because those two mentioned conditions are almost always guaranteed. A set of examples that can be retrieved from the following resources:

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- https://zbw.eu/econis-archiv/bitstream/11159/7697/1/1771636475_0.pdf **(DER31)**
- http://jocet.org/papers/092-J30008.pdf **(DER32)**
- https://www.researchgate.net/profile/Naeem-Abas/publication/274718268_Review_of_Fossil_Fuels_and_Future_Energy_Technologies/resources/5a1183f3aca27287ce293c6d/Review-of-Fossil-Fuels-and-Future-Energy-Technologies.pdf **(DER33**)

➢ **Activity 2**

After groupwork, the teacher uses **DER5, DER6, DER7 and DER8** to explain the advantages and disadvantages obtained from the consumption of different energy sources and makes clear distinctions between renewable and non-renewable energies. The teacher explores the impact of use of each one and explains its current level of use. For better explanation of the topic, the teacher supports discourse on a presentation that also integrates **DER25 to DER33**.

➢ **Activity 3**

The teacher formulates an assessment task.
"1. Please identify an advantage of using renewable energy sources. A) Renewable energies produce more CO_2 emissions than non-renewable energy sources. B) Renewable energies reduce harmful air pollutants. C) Renewable energy sources produce more electric energy in comparison with non-renewable sources."
"2. Does the use of renewable energy impacts air quality? A) Yes, one of the main advantages of using a renewable energy source is that they´re called "clean energy source" and therefore can significantly reduce the carbon dioxide emissions to the atmosphere and improve air quality. B) No, renewable energy sources compared to non-renewable sources are associated to more carbon dioxide emissions to the atmosphere and to the decrease of air quality. C) No, because renewable energy sources produce similar carbon emissions to the atmosphere and so doesn't impact air quality."

Answers:

1. B)
2. A)
3.

➢ **Learning objects of this lesson:**

- Worksheet. (**DER2)**
- Renewable Energy Sources and the advantages of its use. **(DER5)**
- Evidence about Sources of Air Pollution. **(DER6)**
- Evidence about Climate. Change **(DER7)**
- https://www.empower-solar.com/blog/the-advantages-disadvantages-of-switching-to-solar-energy/ **(DER25)**
- https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy **(DER26)**
- https://www.vedantu.com/physics/non-renewable-energy **(DER27)**
- https://greengarageblog.org/21-advantages-and-disadvantages-of-non-renewable-energy **(DER28)**
- https://www.un.org/en/climatechange/raising-ambition/renewable-energy **(DER29)**
- https://www.nationalgeographic.com/environment/article/fossil-fuels **(DER30)**
- https://zbw.eu/econis-archiv/bitstream/11159/7697/1/1771636475_0.pdf **(DER31)**
- http://jocet.org/papers/092-J30008.pdf **(DER32)**
- https://www.researchgate.net/profile/Naeem-Abas/publication/274718268_Review_of_Fossil_Fuels_and_Future_Energy_Technologies/resources/5a1183f3aca27287ce293c6d/Review-of-Fossil-Fuels-and-Future-Energy-Technologies.pdf**(DER33)**

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Lesson 5: Identify measures and behaviours to rationalize energy consumption without loss of comfort and basic needs

The main goals to achieve in this class, in a student's perspective, are as follows:

- Identify measures and proposes general action to rationalize energy consumption.
- Uses evidence to build argumentation on energy rationalization.
- Anticipate the consequences of anthropogenic activities such as excessive energy exploration and consumption in an individual, community, and societal perspective.
- Anticipate the benefits of energy rationalization in an individual, community and societal perspective.

➢ **Lesson Summary:**

The lesson is supported on critical debate with students about the need to change energy consumption habits in the general population in order to reduce the various problems listed in previous classes, such as climate change, air pollution, energy poverty, etc.

➢ **Activity 1**

Students are organised in the groups previously formed and focused by the teacher in a real-life problem. First, to conduct an effective debate, the teacher agrees with students on the nature of the debate, by addressing the following:

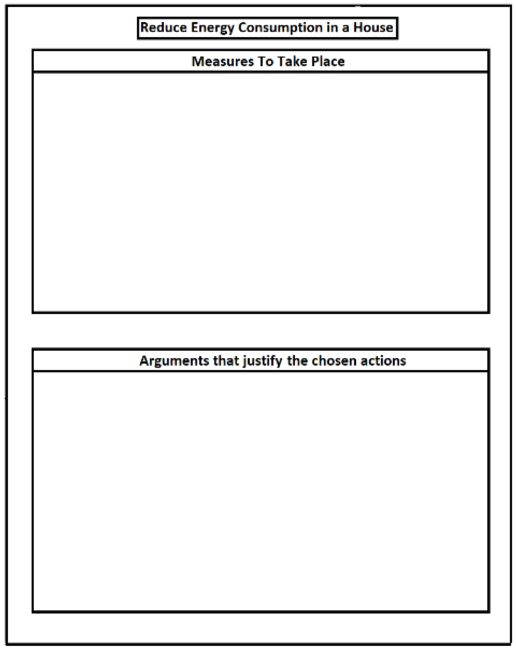
▪ **The main focus of the Debate:**

The debate theme is "Reduce energy consumption in a house", considering the energy consumption in the different divisions of the house and inhabitant behaviours. Students formulate a series of actions to be adopted to reduce energy consumption. Then each group presents the measures they selected to solve the problem/need**.**

▪ **The Structure of the Debate:**

To perform the debate the teacher divides the class into groups. Based on the scientific data collected in the previous lessons, as well teacher materials and presentations, students form a series of arguments that justify why they choose that/those option(s). A worksheet **(DER2)** with several fields can be given to the groups so they can list the selected measures and the supportive arguments **(DER10).** Images, data, graphs, infographics may be built or identified by students in multiple sources to support argumentation. An example worksheet template to be distributed to the groups so that they can efficiently organize their reasoning for the debate, can be observed in the image below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.



- **The Rules of the Debate:**

The debate is promoted between the different groups regarding the several measures that each group elected as the best. The teacher stablishes a time for the groups to present their evidence and arguments. Every member of each group speaks at least once, and the order and the content of speaking is planned by the team members. At the end of each presentation, other groups present their counter arguments and if they do not agree with the reasoning of the group that presented before, explain their claims. The groups that agree with the arguments stated, at least present one critique, counterargument, suggestion, or recommendation. Then is given to the group that set the presentation a time to rebut those counter arguments. The presentation of the counter arguments and rebuttals should be made by only one member of each group, nominated by the teams.

- **Assessment of the Debate:**

The evaluation of the debate is left to the teacher's discretion, but it undoubtedly involves the following criteria:

- The group that presented the most reliable information and from the most varied sources.
- The group that best defended their points of view.
- The group that best refuted the arguments of the other groups.

➢ **Learning objects of this lesson:**

- Worksheet. **(DER2)**
- Strategies to decrease energy waste, fight climate change, and combat air pollution (*infographic).* **(DER10)**

<u>Lesson 6: energy consumption rationalization</u>

The main goals to achieve in this class, in a student's perspective, are as follows:

- Anticipate the consequences of anthropogenic activities in an individual, community, and societal perspective.
- Analysing the consequences of air pollution in public health.

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- Understanding the environmental and economic impacts of most important sources of energy available on the planet.
- Obtaining, assessing, and communicating evidence related with sources of energy and implications in terms of indoor and outdoor air pollution.

➢ **Lesson Summary:**

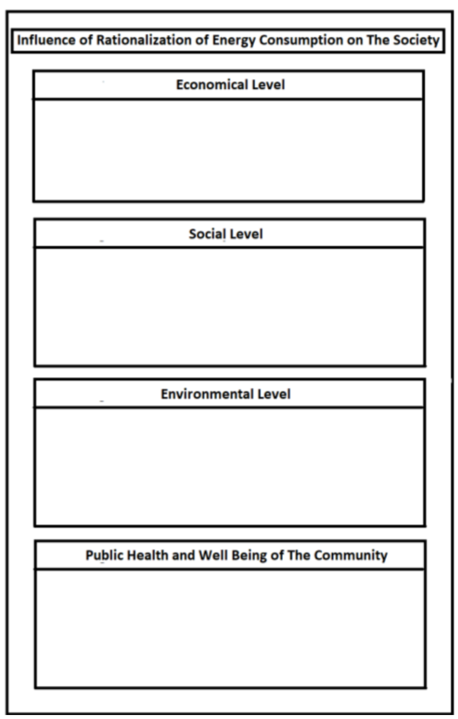
In lesson 6, the teacher explores knowledge coming from the previous lessons to explain the influence of energy rationalization at different levels, such as economic, social, environmental, public health. In this lesson is also defined the work plan for an open schooling event.

➢ **Activity 1**

Students are organised in the previous groups to map impacts of energy rationalization at economic, social, environmental and public health level. They should base their answers on trustful sources and scientific information. The teacher might provide some resources for students to base their work such as:

- https://greengarageblog.org/21-advantages-and-disadvantages-of-non-renewable-energy **(DER28)**
- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Measuring-the-Economics_2016.pdf **(DER34)**
- https://www.renewableenergymagazine.com/emily-folk/the-many-economic-benefits-of-renewable-energy-20190312 **(DER35)**

The information that each group collects be discussed and held by the group in consensus. A worksheet **(DER2)** is distributed to the groups, so they efficiently organize ideas, reasoning and the data collected to support their choices. An example of worksheet template to be distributed to the groups so that they can efficiently organize their ideas and reasoning is observed in the image below.



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The teacher moves around the classroom and supervises students work, by making reflective and supportive questions and providing feedback when needed. The teacher remembers students that they should always check the following issues before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for information in scientific articles, because those two mentioned conditions are almost always guaranteed. A set of examples can be retrieved from the following resources:

- https://www.sciencedirect.com/science/article/pii/S1364032118303447 **(DER36)**
- https://journals.sagepub.com/doi/pdf/10.1260/0144598054530011 **(DER37)**

➢ **Activity 2**

Students collect and discuss the information they found and set a presentation to the class. Then the teacher might present the information retrieved from resources mentioned in activity 1. A discussion is set around the findings about both works. The teacher can identify a couple of issues that he/she considers relevant and that the groups didn't have addressed in the inquiry process. Such issues might be, for example, "Is there a causal relationship between a country's wealth and its level of energy consumption?", "Which countries consume more energy? Developed or underdeveloped countries". **(DER3, DER7, DER8)**

➢ **Activity 3**

The purpose of this activity is creating awareness on how to fight air pollution and climate change by energy rationalization, and how the called "clean energies" and conscient behaviour of the population plays a main role in mitigating the problem **(DER10).** The teacher asks groups to gather specific scientific data on how the control of primary energies influences the global economy. The teacher may address this issue by asking students to answer a couple of questions:

1. "How the control of raw materials influences the world economy?"
2. "How is the level of air pollution in countries that mainly use renewable energy, in comparison to those that mainly use fossil fuels?" **(DER9**).

These questions drive students research through scientific data and may be answered in a worksheet (DER2) that the teacher provides to each student. An example of worksheet template to be distributed so that students can efficiently organize their reasoning is observed in the image below.

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Analysis of the influence of energy consumption reduction in the economic, energetic and social levels

"How the control of raw materials influences the world economy?"	"How is the level of air pollution in the countries that use renewable energies the most, in comparison with the ones that use fossil fuels the most?"

1. Considering the research you carried out, and the table completed above, answer the main question of this activity, "How the control of primary energies influences the global economy?"

To answer these questions, students look up for reliable information themselves, and later discuss their reasoning in groups (3/4 students). Additionally, the teacher remembers students that they should check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for information in scientific articles, because those two mentioned conditions are almost always guaranteed. Examples of similar articles can be retrieved from the following resources:

- https://escholarship.org/content/qt4qs5f42s/qt4qs5f42s.pdf **(DER38)**
- https://escholarship.org/content/qt4wz9x840/qt4wz9x840.pdf **(DER39)**

The teacher moves around the classroom and supervises students work, by making reflective and supportive questions and providing feedback when needed. Some complementary evidence that may support students in this activity can be retrieved from the following resources:

- https://www.ukogplc.com/page.php?pID=74 **(DER40)**
- https://shift.newco.co/2018/03/21/how-oil-came-to-control-the-world/ **(DER41)**
- https://www.forbes.com/sites/judeclemente/2015/04/19/three-reasons-oil-will-continue-to-run-the-world/?sh=2026a72143f9 **(DER42)**

➢ **Activity 4**

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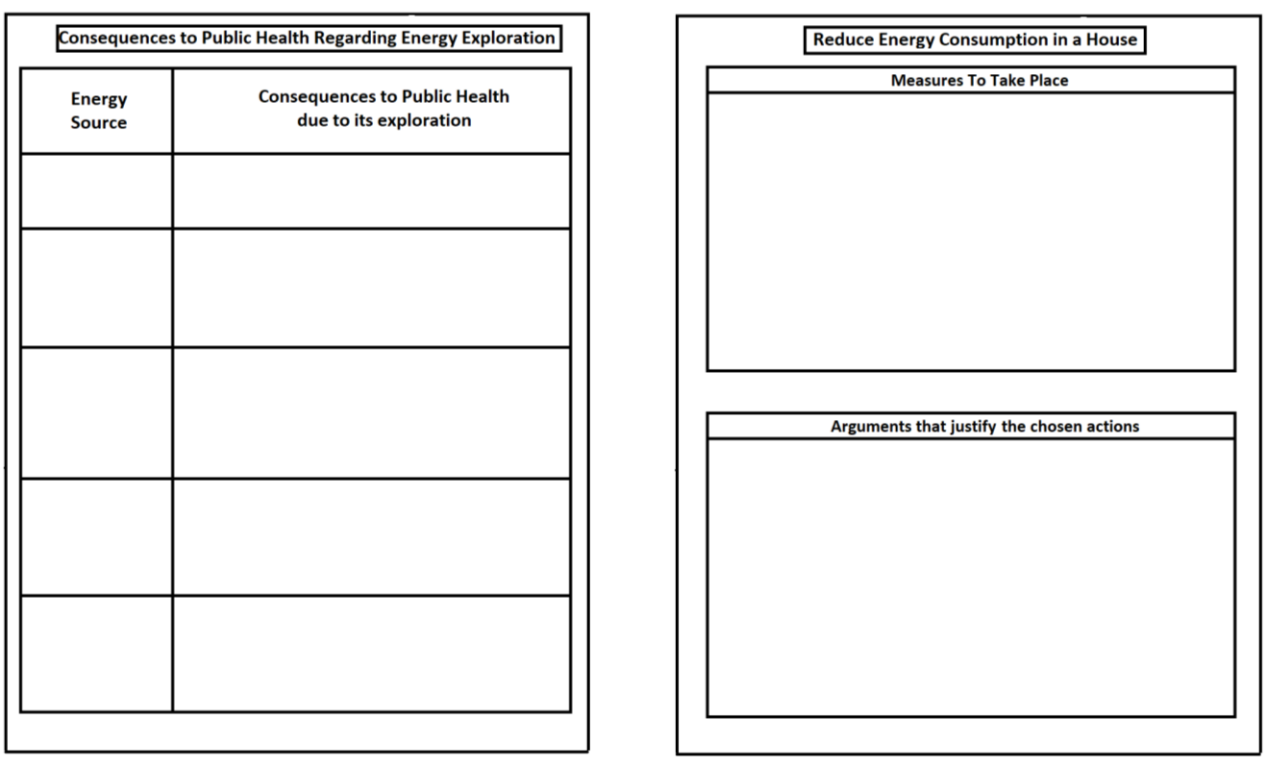
Students propose a series of measures that people might take to reduce energy consumption in their houses and turn it into a more efficient pattern **(DER10)**. The activity is initiated in the classroom and concluded by the students during homework. Students list their arguments concerning the relationships between energy consumption, air pollution and public health consequences, as well as environmental and economic impacts of the most important sources of energy available on the planet. Students should make a connection between energy exploration conducted by human action, and the resulting consequences for wildlife, environment and public health, such as the growing incidence of chronic respiratory conditions, cardiovascular diseases, and cancers. They should refer to the main problems that arise from energy exploitation such as soil and water contamination, atmospheric pollution, etc. **(DER8, DER9).** A worksheet **(DER2)** is distributed (to the previous groups of students) so they organize facts and clarify their reasoning. An example of worksheet template to be distributed to the students so that they can efficiently organized their reasoning, is observed on the following image. Some scientifical evidence that may support students in this task can be retrieved from the following resources:

- https://www.hindawi.com/journals/aess/2016/2707989/ **(DER43)**
- https://aip.scitation.org/doi/pdf/10.1063/1.4993039 **(DER44)**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6607187/ **(DER45)**
- https://www.worldwater.org/wp-content/uploads/2013/07/chapter_4_fossil_fuel_and_water_quality.pdf **(DER46)**
- https://earthworks.org/issues/sources-of-oil-and-gas-air-pollution/ **(DER47)**
- https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021EF002558 **(DER48)**

The filled worksheets are kept by the teacher and used during the school project.



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- **Learning Objects of this lesson:**
  - Worksheets. **(DER2)**
  - Evidence about the relation between Energy Consumption and a country's wealth/development (*infographic*). **(DER3)**
  - Evidence about Climate Change (*infographic*). **(DER7)**
  - Evidence about Consequences of Climate Change *(images, infographic).* **(DER8)**
  - Evidence about Consequences of Air pollution (*images, infographic*). **(DER9)**
  - Strategies to decrease energy waste, fight climate change, and combat air pollution (*infographic*). **(DER10)**
  - https://greengarageblog.org/21-advantages-and-disadvantages-of-non-renewable-energy **(DER28)**
  - https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Measuring-the-Economics_2016.pdf **(DER34)**
  - https://www.renewableenergymagazine.com/emily-folk/the-many-economic-benefits-of-renewable-energy-20190312 **(DER35)**
  - https://www.sciencedirect.com/science/article/pii/S1364032118303447 **(DER36)**
  - https://journals.sagepub.com/doi/pdf/10.1260/0144598054530011 **(DER37)**
  - https://escholarship.org/content/qt4qs5f42s/qt4qs5f42s.pdf **(DER38)**
  - https://escholarship.org/content/qt4wz9x840/qt4wz9x840.pdf **(DER39)**
  - https://www.ukogplc.com/page.php?pID=74 **(DER40)**
  - https://shift.newco.co/2018/03/21/how-oil-came-to-control-the-world/ **(DER41)**
  - https://www.forbes.com/sites/judeclemente/2015/04/19/three-reasons-oil-will-continue-to-run-the-world/?sh=2026a72143f9 **(DER42)**
  - https://www.hindawi.com/journals/aess/2016/2707989/ **(DER43)**
  - https://aip.scitation.org/doi/pdf/10.1063/1.4993039 **(DER44)**
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6607187/ **(DER45)**
  - https://www.worldwater.org/wp-content/uploads/2013/07/chapter_4_fossil_fuel_and_water_quality.pdf **(DER46)**
  - https://earthworks.org/issues/sources-of-oil-and-gas-air-pollution/ **(DER47)**
  - https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021EF002558 **(DER48)**

Supplementary learning resources and educational activities

- Inviting STEM organisations.
- Debate on households and organisations consumption, climate change and public health impact.
- Discuss energy data and phrases from media, Environmental NGO, Social NGO, Government, EU and rest of the world.
- Preliminary discussion on how countries produce energy.
- Compare the primary energies available for each country.
- Compare energy efficiency measures in each country.
- Discuss the Governments' policy for energy rationalization.
- Discuss measures to reduce air pollution and climate change events.
- Interact with STEM professionals.

School Research Project

Topics

- Type of energies in systems.
- Direction in which energy is transferred.

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- Renewable from non-renewable energy sources (advantages and disadvantages of their use and consequences for the sustainability of the Earth, interdisciplinary perspective).
- Distinguish temperature from heat, relating them through examples.
- Choices that promote a rational use of energy.
- Consequences for the environment of the emission of pollutants from combustion reactions, propose mitigation and adaptation measures.
- Climate change as one of the major current environmental problems.
- Air pollution and climate change.
- Air pollution as an environmental determinant of health.

Research management, design and administration
Challenge: build a poster or infographic about Energy Rationalization!

Method (summary): students are organized in groups; each group addresses several ways to conduct energy rationalization in their school. The project challenges each group of students to create and present an infographic that synthetizes a) What they have learned throughout the teaching-learning sequence; b) Actions to reduce energy consumption at the school level; c) Relevant outcomes for environment and public health due to application of such measures.
By following this process, at the end of the project students will have understood the importance of rationale use of energy.

Development process: Building upon the knowledge acquired in previous classes, students seek to make observations in school environment and identify a series of actions to be adopted by the school community to rationalize energy consumption.
In the development of the project, students carry out a survey/observations of school community infrastructure and people behaviour on the subject. The teacher discusses with students possible questions to assess the attributes of the school in the topic of energy consumption and possible methods to get the answers. The advantages and limitations of the alternatives are discussed. Then a brainstorming of possible questions to address the topic is promoted by the teacher: 1. Are there solar panels at school? 2. Is there any strategy ongoing to save energy? 3. Is there any strategy ongoing to avoid waste of water? 4. Is there any strategy ongoing to create a more sustainable environment at school? 5. What are the school's energy consumption needs?
The output of the project is a list of school attributes, strengths and weaknesses and proposals to be adopted by the school community to mitigate long-term risks (e.g., escalation of the problem of climate change, increased air pollution, increased incidence of chronic respiratory diseases, etc.). Proposals for energy rationalization should be linked with benefits that the change in behaviour can bring to the school community health and well-being.

Teaching-learning process milestones:
Students will be able to:
1. Develop critical reasoning (e.g., analysing, organizing, debating, and sharing information regarding lesson 3 – students are asked to satisfy households energy consumption needs having at their disposable several primary energy sources).
2. Develop digital skills (e.g., finding, reviewing, and using high-quality online resources to develop the activities).
3. Understand the concept of "Primary Energy" and its importance.
4. Understand the concepts of "Energy Production, Transfer, Conservation" and its importance.
5. Understand the impact at different levels (e.g., economic, social, health) of excessive energy exploration and consumption, as well as energy waste.

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6. Develop the ability to build arguments, counterarguments, and rebuttals, to make a decision regarding socio-scientific questions.
7. Develop the ability to debate socio-scientific questions.
8. Investigate community's perceptions and knowledge concerning energy waste and excessive energy consumption.
9. Develop responsible citizenship and critical health literacy.

Teaching-learning process for school project (summary):
1. Collection of evidence (data, information, articles, pictures).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Design criteria for arguments evaluation.
4. Design rubric for evaluation of public debate.
5. Design an agenda for the open schooling event.
6. Create a brochure and/or presentation with measures to be taken to efficiently satisfy energy consumption needs in different environments (e.g., school, house) and distribute it in open schooling event.

Organization of the open schooling event:
1. Each project output (brochures/presentation) is shared by the students with the school community in a relevant setting (e.g., exposition centre, municipality, garden, museum, science fair).
2. Students will communicate policy measures using STEM-based argumentation. Students appeal to the action of all in health of the community, providing great understanding that preventing energy waste is a responsibility of all, not only of the government and municipalities.
3. Students, parents, school community and relevant local stakeholders attend the event and understand how energy waste is influenced by individual behaviour and environmental factors. They also get high-level understanding on strategies to minimize energy poverty and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the level).

Data Analysis and Reporting
Data filtration.
Define minimum representative data collected.
Data categorization.
Data presentation formats.
Internal presentation.
Report writing.
Develop and create communication material.

Target Audience for Recommendations
- Social NGOs.
- Decision makers.
- General public.
- Mass media.
- Families.
- Friends.

Public Debate and Recommendations (based on research results)
Gamming between schools with similar environment: compare choices.
Gamming between schools with different environment: understand interconnection options and the European Energy Market operation.

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Discussion and feedback.
Produce communication information.
Make recommendations for energy consumption reduction.
Dissemination of final report and recommendations in the school website.

Main partner responsible: ISEL

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21. Specifications for an educational scenario on the topic of "noise pollution and quality of life"

Context

Noise pollution is a societal problem, particularly prevalent in city environment, with well-documented public health impacts. Exposure to noise can negatively affect a whole day of work, or even a night's sleep, reduce day-to-day productivity and harm people health and quality of life. According to the World Health Organization, noise pollution is one of the most important determinants of health. According to the European Environment Agency (EEA), noise is responsible for 16,600 premature deaths and more than 72,000 hospitalizations every year in Europe. For the protection of wildlife and humans' health and well-being, public discussions under the topic should be taken frequently, and assessments of noise intensity in specific situations/contexts/environments are recommended, to compare with the recommended limits. The scenario makes available for students a tool that supports upload of audio files and displays histograms, spectrograms, frequency, and amplitude values. A table with identified and expected risks is developed for each frequency, amplitude, and duration time, based on scientific studies. Therefore, the learning experience prepares youths to measure noise levels and become aware of risky environments, sources of noise pollution, and how this threat can have an effect on the health and quality of life of the community.

Estimated duration

6 classes of 40-45 minutes (lesson 1 – lesson 6)
6 sessions of 40-45 minutes for school project (session 7 – session 12)

Classroom organization requirements

From lesson 1 to lesson 5 students work alone or occasionally in groups.
From lesson 6 to lesson 12 students form four- or five-member groups which carry out the school project. The use of computer is required.

Prerequisite knowledge and skills

Basic knowledge of software and browsers.

Content Glossary

Amplitude – In physics, it is the maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium position. It is equal to one-half the length of the vibration path.

Decibels - It is used as a unit for expressing the ratio between two physical quantities, usually amounts Of acoustic or electric power, or for measuring the relative loudness of sounds. One decibel (0.1 bel) equals 10 times the common logarithm of the power ratio.

Frequency – In physics, it is the number of waves that pass a fixed point in unit time; also, the number of cycles or vibrations undergone during one unit of time by a body in periodic motion. A body in periodic motion is said to have undergone one cycle or one vibration after passing through a series of events or positions and returning to its original state.

Loudness – It is the attribute of a sound that determines the magnitude of an auditory sensation and that primarily depends on the amplitude of the sound wave involved.

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Noise - Noise is defined as unwanted sound. In engineering, noise has the additional connotation of signals varying over time without meaning, whereas sound connotes meaningful signals. From a physics standpoint, there is no distinction between noise and desired sound, as both are vibrations through a medium, such as air or water.
Noise pollution – It is an unwanted or excessive sound that can have deleterious effects on human health, wildlife, and environmental quality. Noise pollution is commonly generated inside many industrial facilities and some other workplaces, but it also comes from highway, railway, and airplane traffic and from outdoor construction activities.

Period – Period refers to the time that takes to do something. Frequency and period are distinctly different, yet related, quantities. Frequency refers to how often something happens. Period refers to the time it takes something to happen. Frequency is a rate quantity. Period is a time quantity. Frequency is the cycles/second. Period is the seconds/cycle. In Physics period is the time required for one complete cycle of vibration to pass a given point.

Sound – It´s a pressure wave which is created by a vibrating object. These vibrations set particles in the surrounding medium (typical air) in vibrational motion, thus transporting energy through the medium. Since the particles are moving in parallel direction to the wave movement, the sound wave is referred to as a longitudinal wave.

Timbre – It is a parameter used to distinguish between two sounds when they are of the same frequency. Every sound we hear depends on its source. Sound timbre is known as the characteristic waveform of sound that depends on the material from which it produces.

Vibration – It´s the oscillating, reciprocating, or other periodic motion of a rigid or elastic body or medium forced from a position or state of equilibrium. It can also be defined as the analogous motion of the particles of a mass of air or the like, whose state of equilibrium has been disturbed, as in transmitting sound.

Wave - A wave can be described as a disturbance that travels through a medium from one location to another location. Consider a slinky wave as an example of a wave. When the slinky is stretched from end to end and is held at rest, it assumes a natural position known as the **equilibrium or rest position**.

Wave-length – It´s the distance between corresponding points of two consecutive waves.

Pedagogical glossary

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills. C) Inquiry based learning: By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection

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and organization, variable handling, data driven conclusion making and communicating over scientific issues.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.
Sources: https://www.britannica.com/; Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

Indicative Literature

WHO, Health topics-Noise, https://www.who.int/europe/health-topics/noise#tab=tab_1
Singh, N., & Davar, S. C. (2004). Noise pollution-sources, effects and control. Journal of Human Ecology, 16(3), 181-187..

Murphy, E, King.A, E. (2022). Environmental Noise Pollution, Noise mapping, Public Healt, and Policy, Elsevier, Second Edition. - ISBN: 9780128201015

Competences / Learning Goals

Key Competences
STEM/ personal, social

Knowledge
Physics concepts:
- Noise.
- Pitch.
- Timbre.
- Decibels.
- Wave Sound.

Environmental health concepts:
- Environmental determinants of health.
- Noise pollution, health impacts.
- Noise pollution, sources.
- Noise pollution as a risk factor for the quality of life.

Epidemiology and health economics concepts:
- Indicators of loss of quality of life due to noise pollution (e.g.: decrease of productivity in work, school, etc…).

Social and global health concepts:
- Sustainable Development Goals (SDG 3 in relationship with other SGDs).
- Growing urbanization and environmental health challenges.
- Public policy on noise pollution and its determinants.
- Relationship between lifestyle and noise pollution (determinants of health).

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Knowledge - outcome assessment:
1. Distinguishes noise from sound.
2. Characterizes the units and parameters of noise.
3. Characterizes the impact of regular exposure to noise in humans' health.
4. Identifies ways and equipment that measure, reduce or mitigate exposition to noise.
5. Identifies relevant action to address challenges related with harmful noise exposition at the community and societal level.

Skills (abilities/competences)
General: curiosity; collaboration; critical thinking; self-awareness, citizenship, debate, public speaking and presentation, brainstorming participation, problem definition, problem solving, analysis and discussion of evidence, argumentation, hypothetical-deductive reasoning, inductive reasoning, problem-based learning, understand scientific principles and models, planning and carrying out a research-based project, critical thinking, teamwork, understanding the applications of mathematical models and take decisions.

Specific:
- ✓ Finding, analysing, and interpreting noise diagrams.
- ✓ Researching, discussing, and communicating evidence on effects of harmful noise exposition to wildlife and humans' health.
- ✓ Analysing practical strategies to reduce exposure to noise.
- ✓ Analysing scientific evidence to explain phenomena related to noise pollution and produce argumentation.
- ✓ Understanding the importance of using a computational tool to solve day-to-day problems.

Skills – outcome assessment:
1. Selects appropriate concepts, measures, and indicators to measure noise levels.
2. Can anticipate the consequences for wildlife and humans' health of regular exposure to noise pollution.
3. Can propose concrete action towards reducing exposure to noise in his/her/others routine and living environments.

Affective /Attitudes/Behavior *(beliefs)*
Noise pollution perception attitudes, measures towards limiting the increase, intellectual curiosity, respect for plurality of viewpoints.
- ✓ Adopting general risk perception attitudes.
- ✓ Adopting attitudes towards minimizing the risk of noise exposure, specially identified damaging frequencies and tones.
- ✓ Engaging public speaking and debate of measures to reduce risks.

Affective, Attitudes and behaviour - outcome assessment:
1. Believes that a civic and conscient behavior in relation to noise is fundamental to minimize the loss of quality of life in the local community.
2. Believes that individual behavior influences the regulation of noise levels and therefore the risk of noise pollution and loss of quality of life at the community level.
3. Believes that noise pollution is an environmental determinant of health.
4. Reproves patterns of risky and unhealthy behavior in his/her living environment (e.g., at night, systematically reduces noise levels).
5. Adopts a healthy lifestyle in relation to noise exposition (e.g.: reduces the sound of personal equipment).
6. Is committed to communicate and address the problems and challenges of the community related to the effects of noise pollution and loss of quality of life.

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Learning goals and outcomes

- ✓ Uses computational tools to plot tables, graphs, and other data that supports noise measurement and characterization.
- ✓ Obtains, evaluates, communicates data and scientific evidence regarding noise impacts on wildlife and humans' health.
- ✓ Uses evidence to build argumentation on noise impacts in community health.
- ✓ Gives examples of sources of noise pollution affecting the community health and quality of life.
- ✓ Describes different strategies to protect, develop and influence community health.

Assessment methods

- Outcome assessment
    - Quantitative – questionnaire in paper.
    - Qualitative - students project.

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content

- Sound and wave.
- Vibration.
- Frequency.
- Amplitude.
- Period.
- Wave-length.
- Timbre.
- Decibels.

Non-STEM content

- Living conditions, urbanization, lifestyles.

Digital learning Objects (DLOs) and Digital Learning Resources (DERs)

New:

- Online tool with the creation and interpretation of a Spectral density graphic. **(LO1)**
- Noise pollution (*infographic).* (**DER1)**
- Worksheets. **(DER2)**
- Noise sounds, noise levels and noise exposition *(infographic***). (DER3)**
- Consequences of noise pollution to public health *(infographic***). (DER4)**
- Strategies to reduce noise pollution (*infographic).* **(DER5)**

Available resources (link): https://www.dropbox.com/sh/n6mj1r903gw3ngf/AAASwRERfcVj9N1-H6IMp7Jva?dl=0

From other sources/high-quality platforms:

- Physics of sound and noise

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- https://www.researchgate.net/figure/A-sinusoidal-sound-wave-showing-characteristics-of-wavelength-the-length-of-a-complete_fig2_320323376 **(DER8)**
- http://www.planetoftunes.com/sound-audio-theory/sound-waveform-diagrams.php **(DER9)**
- https://www.geeksforgeeks.org/speed-of-sound/ **(DER10)**
- https://www.britannica.com/science/sound-physics **(DER11)**
- https://www.vedantu.com/physics/difference-between-sound-noise-music **(DER12)**
- https://www.youtube.com/watch?v=bjh7OcWWCnU **(DER13)**
- https://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html **(DER14)**
- https://www.hear.com/resources/all-articles/what-is-spectral density graphic-how-to-read-it/ **(DER18)**
- https://www.babyhearing.org/what-is-an-spectral density graphic **(DER19) (Image)**
- https://www.animations.physics.unsw.edu.au/jw/sound-pitch-loudness-timbre.htm **(DER27)**
- https://www.animations.physics.unsw.edu.au/jw/dB.htm **(DER28)**
- https://www.pasco.com/products/guides/sound-waves **(DER33)**

- Noise Pollution: causes, effects

- https://docs.wind-watch.org/Goines-Hagler-2007-Noise_pollution__a_modern_plague.pdf **(DER6)**
- https://www.cell.com/current-biology/pdf/S0960-9822(19)30863-2.pd **(DER7)**
- https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
- https://education.nationalgeographic.org/resource/noise-pollution **(DER16)**
  https://www.medicalnewstoday.com/articles/noise-pollution-health-effects#mental-health **(DER17)**
- https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1073.7951&rep=rep1&type=pdf **(DER20)**
- https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1084.7395&rep=rep1&type=pdf **(DER21)**
- https://stylesatlife.com/articles/how-to-prevent-noise-pollution/ **(DER22)**
- https://www.conserve-energy-future.com/causes-and-effects-of-noise-pollution.php **(DER23)**
- https://brieflands.com/articles/jjhs-60312.html **(DER24)**
- https://pdfs.semanticscholar.org/c0fb/8e0224e560d8ebb259bba70f9f23de8a6cc4.pdf **(DER25)**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4608916/ **(DER26)**
- https://www.science.org.au/curious/earth-environment/health-effects-environmental-noise-pollution **(DER29)**
- https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf **(DER30)**
- Noise-Pollution-Human-Health-A-Review.pdf (researchgate.net) **(DER43)**
- download (psu.edu) **(DER44)**
- Paper3610-614.pdf (ijmcr.com) **(DER45)**

- Noise Pollution: sources, prevention

- https://stylesatlife.com/articles/how-to-prevent-noise-pollution/ **(DER22)**
- Noise (Sound) Pollution - Sources, Types, Effects and Reduction Tips (stylesatlife.com) **(DER40)**
- https://www.conserve-energy-future.com/easy-and-practical-ways-to-reduce-noise-pollution.php **(DER41)**
- https://sunandsoundwindows.com/blog/11-ways-to-prevent-noise-pollution-list/ **(DER42)**

- Noise and Sound Measurement

- https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf **(DER30)**
- 7200440a 99..103 (researchgate.net) **(DER31)**
- The Fundamentals of Sound and its Measurement (ingentaconnect.com) **(DER32)**
- https://www.quebec.ca/en/health/advice-and-prevention/health-and-environment/the-effects-of-environmental-noise-on-health/noise-measurement **(DER34)**
- https://www.sciencelearn.org.nz/resources/573-measuring-sound **(DER35)**
- https://www.schoolnet.org.za/PILAfrica/en/webs/19537/physics4.html **(DER36)**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

- https://www.instrumentchoice.com.au/news/how-do-you-measure-noise-levels **(DER37)**
- https://www.vernier.com/files/manuals/slm-bta/slm-bta.pdf **(DER38)**
- Noise Measurement - The Effects of Environmental Noise on Health | Gouvernement du Québec (quebec.ca) **(DER39)**

Teaching -learning activities (lesson plan/ learning trajectory)

Principal target:
Physics classes
8th grade (+/- 14 years old students)
4-6 sessions/classes of 40-45 minutes
Physics teachers integrate other colleagues in the enactment of the scenario (e.g., ICT, science, mathematics, and English teachers), as it aims to be interdisciplinary.

Topics of each lesson:
Lesson 1: Sound and Noise.
Lesson 2: Noise, sources, types of exposure, pollution and impacts.
Lesson 3: Physics Concepts related to sound and wave.
Lesson 4: Analysing test cases of noise.
Lesson 5: Action to reduce noise exposition and pollution.
Lesson 6: Noise pollution, individual behaviour, quality of life.

Lesson 1 : Sound and Noise
The main goals to achieve in this class, in a student's perspective, are:
- Distinction between noise and sound.
- Characterization of the general impact of regular exposure to noise in humans' health.
- Researching, discussing, and communicating evidence on effects of harmful noise exposition to wildlife and humans' health.

➢ **Lesson Summary:**
The lesson explores sound and noise by addressing concepts such as wave, timbre, frequency, wavelength, etc.

➢ **Activity 1**
The teacher describes the plan for the next classes, which are directly related to a project. The teacher presents the scope of the work:
1. Students will study and analyse problems related to noise exposure by seeking scientific information on the subject (noise, standards, limits, sources of noise exposition, how to measure).
2. Students will analyse and describe different sources of harmful noise exposition and identify the most important sources throughout search of scientific data and information.
3. Students will discuss in classroom environment the major causes and consequences of noise pollution at different levels (e.g., wildlife, environment, health).
4. Students will analyse and discuss real cases of noise exposure and noise pollution by recording sounds, with a sound record application, and by several measurements in living environments, with a decibel meter, and then characterize the noises recorded.
5. Students will find solutions to mitigate the issues identified, based on the research and experimental work conducted in the prior activities, considering the consequences of noise pollution for public health.
6. The evidence coming from the students' activities, proposals and recommendations is presented to the community in the open schooling event.

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- **Activity 2**

In lesson 1, the concepts of "Sound and Noise" are explored. The teacher describes the main sources of noise after promoting a brainstorming on the topic. During the brainstorming (that captures preconceptions and misconceptions on the topic) students strive to answer, "What is noise?", "What are the causes?", "What are the effects", "There are any impacts of noise in wildlife? And in humans' health and well-being?", "What is the difference between noise and sound?", "What are the parameters used by physics researchers and professionals to characterize sound?".

In order to facilitate student ideas and their subsequent research, a worksheet is presented to the students (DER2) to fill in their inicial answers**.**
Students answer the questions individually and then form groups (3-4 students) to discuss their responses and reasoning. In this phase, students look up for information themselves and later discuss their reasoning in groups. Additionally, the teacher explains that they should always check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for additional information in scientific articles, because those two mentioned conditions are almost always guaranteed. Examples of articles may be retrieved from the following links:

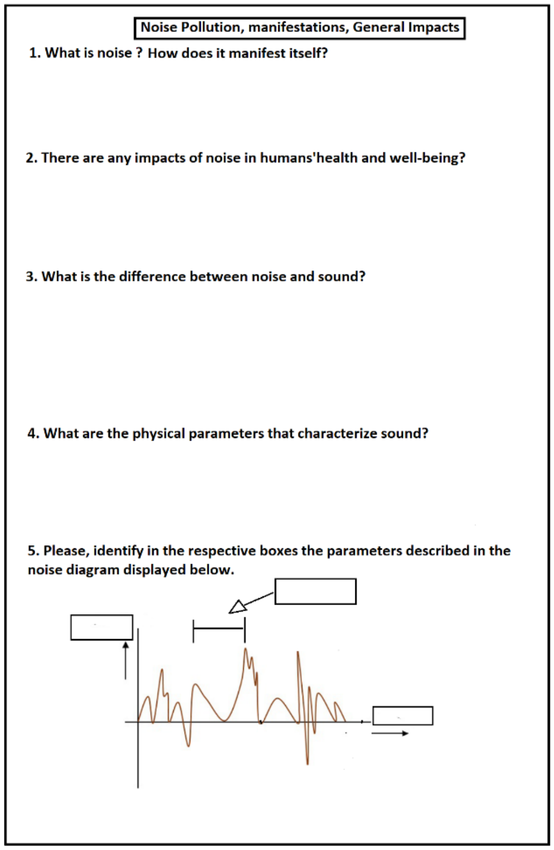
- https://docs.wind-watch.org/Goines-Hagler-2007-Noise_pollution__a_modern_plague.pdf **(DER6)**
- https://www.cell.com/current-biology/pdf/S0960-9822(19)30863-2.pdf **(DER7)**

The worksheet may also contain images and students identify what is being displayed (e.g., the teacher could add in the worksheet the image of a sound diagram, and ask the students to identify what they see, and which parameters that characterize sound are observed). Some images that contain this type of information can be retrieved from following resources:

- https://www.researchgate.net/figure/A-sinusoidal-sound-wave-showing-characteristics-of-wavelength-the-length-of-a-complete_fig2_320323376 **(DER8)**
- Understanding waveforms, https://swphonetics.com/praat/tutorials/understanding-waveforms/ **(DER9)**
- https://www.geeksforgeeks.org/speed-of-sound/ **(DER10)**

The teacher moves around the classroom, supervises and supports students work by making reflective and supportive questions, and provides feedback to students when needed. An example of worksheet template to be distributed for group work can be seen in the image below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.


Noise Pollution, manifestations, General Impacts

1. What is noise ? How does it manifest itself?

2. There are any impacts of noise in humans'health and well-being?

3. What is the difference between noise and sound?

4. What are the physical parameters that characterize sound?

5. Please, identify in the respective boxes the parameters described in the noise diagram displayed below.

➢ **Activity 3**

After managing an internal discussion between the students/groups about their reasoning (teacher defines a time limit for the students to complete the worksheet and discuss their responses and reasoning within the formed groups), the teacher provides credible and organized information about the concepts under study by exploring the resources mentioned above. Then the teacher summarizes the contents **(DER3).** The presentation is based on the digital learning resources (particularly **DER3**) and information retrieved from the following resources:

- https://www.britannica.com/science/sound-physics **(DER11)**
- https://www.vedantu.com/physics/difference-between-sound-noise-music **(DER12)**
- https://www.youtube.com/watch?v=bjh7OcWWCnU (**DER13)**
- https://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html **(DER14)**
- https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
- https://education.nationalgeographic.org/resource/noise-pollution **(DER16)**
- https://www.medicalnewstoday.com/articles/noise-pollution-health-effects#mental-health **(DER17)**

Additionally, the teacher introduces students' examples of spectral density graphics they will analyse and discuss in the subsequent classes. Some examples can be seen in the images below **(DER18 & DER19).**

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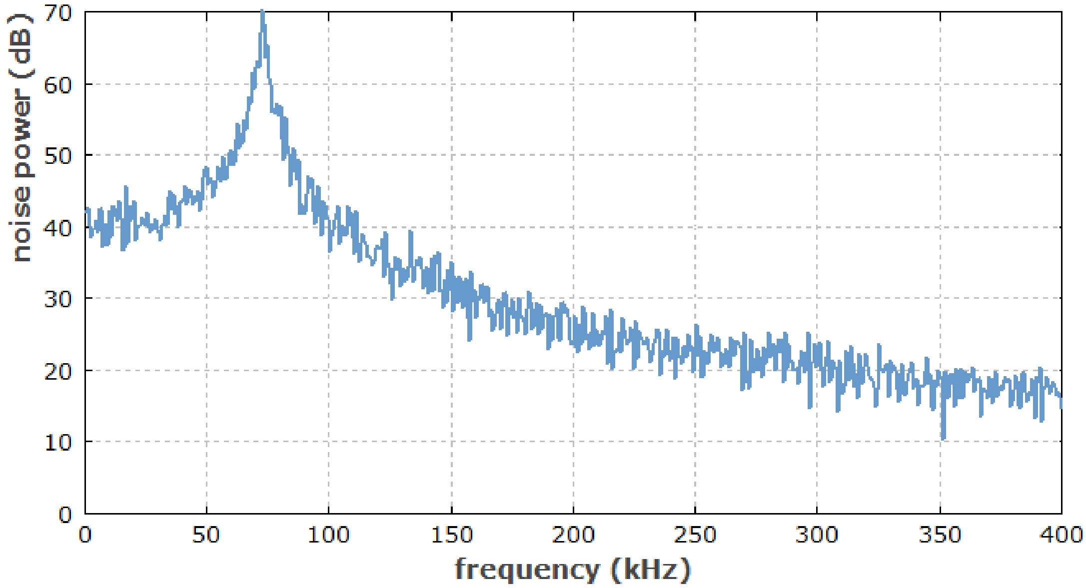

- **Activity 4**

At the end of the session, the teacher proposes an inquiry-based task driven by the following questions: "1. Noise can be characterized as…? A) Any sound reproduced. B) Any unwanted sound considered unpleasant, loud, or disruptive to hearing. C) Sometimes a sound that we want to reproduce." 2. Sound can be characterized by… A) Only frequency (in Hz); B) Only power (in dB); C) frequency (in Hz and power (in dB); ". 3. What is the main difference between sound and noise? A) There´s no difference between sound and noise, they´re both the same. B) Sound is something pleasant to hear and noise is an unwanted sound. C) Noise is all the sound that we want to reproduce; ". 4. The continuous exposure to noise can cause…? A) A significant improvement off hearing capacities. B) People to be more attentive. C) Progressive loss of hearing capacities and loss of concentration in daily situations."
Answers:

1. B)
2. C)
3. B)
4. C)

Students search to answer the questions in group work. The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback when needed. The teacher understands if students resort to reliable sources of information and the difficulties they face to obtain the answers. To obtain more information about this last issue, the teacher may also launch the question "What were the main difficulties you face in collecting reliable information and answering the questions?".

- **Learning objects employed in this lesson:**
  - Worksheets **(DER2).**
  - https://docs.wind-watch.org/Goines-Hagler-2007-Noise_pollution__a_modern_plague.pdf **(DER6)**
  - https://www.cell.com/current-biology/pdf/S0960-9822(19)30863-2.pdf **(DER7)**
  - https://www.researchgate.net/figure/A-sinusoidal-sound-wave-showing-characteristics-of-wavelength-the-length-of-a-complete_fig2_320323376 **(DER8)**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

- http://www.planetoftunes.com/sound-audio-theory/sound-waveform-diagrams.php **(DER9)**
- https://www.geeksforgeeks.org/speed-of-sound/ **(DER10)**
- https://www.britannica.com/science/sound-physics **(DER11)**
- https://www.vedantu.com/physics/difference-between-sound-noise-music **(DER12)**
- https://www.youtube.com/watch?v=bjh7OcWWCnU **(DER13)**
- https://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html **(DER14)**
- https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
- https://education.nationalgeographic.org/resource/noise-pollution **(DER16)**
- https://www.medicalnewstoday.com/articles/noise-pollution-health-effects#mental-health **(DER17)**
- https://www.hear.com/resources/all-articles/what-is-spectral density graphic-how-to-read-it/ **(DER18)**
- https://www.babyhearing.org/what-is-an-spectral density graphic **(DER19)**

Lesson 2: Noise, sources, types of exposure, pollution and impacts

The main goals to achieve in this class, in a student's perspective, are as follows:

- Study parameters of physics science used to analyse noise.
- Give examples of sources of noise pollution affecting the community health and quality of life.
- Using evidence to build argumentation on noise impacts in the health of the community.
- Analysing scientific evidence to explain phenomena related to noise pollution and produce argumentation.

➢ **Lesson Summary:**

Lesson 2 increases students' knowledge about noise pollution, noise source, and noise consequences to public health.

➢ **Activity 1**

The sources of noise pollution to be explored are:

- Traffic Noise.
- Aircraft Noise.
- Construction Noise.
- Animals Noise.
- Catering and Nightlife Noise.

Students are organized in groups to answer the following questions:1. Can you define "noise pollution"? I this sense, can you identify sources of this kind of pollution? Can you give some examples? How does this affect the health and lifestyles of the persons?. "Which sources of noise pollution are you familiar with?". 2. "Is the impact for humans' health caused by different sources of noise pollution the same?". A simple worksheet **(DER2)** with the questions is distributed and students point out their initial perceptions on sources of noise pollution and which ones are most harmful **(DER1, DER4)**. This worksheet also contains a field for students to write their answers after research. An example of a worksheet template can be observed in the image below.

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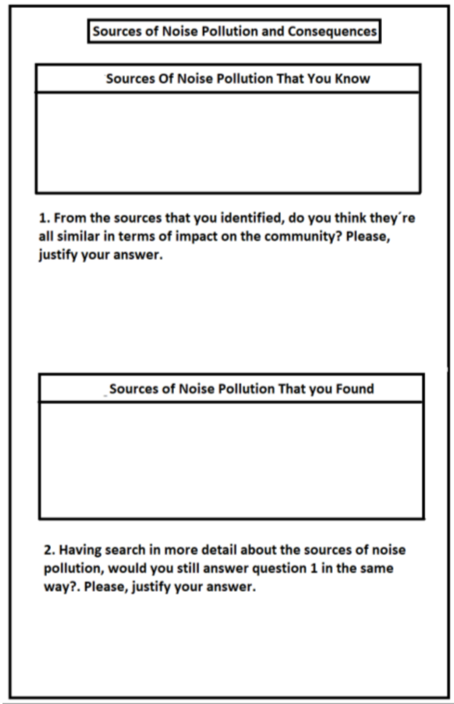
Sources of Noise Pollution and Consequences

Sources Of Noise Pollution That You Know

1. From the sources that you identified, do you think they´re all similar in terms of impact on the community? Please, justify your answer.

Sources of Noise Pollution That you Found

2. Having search in more detail about the sources of noise pollution, would you still answer question 1 in the same way?. Please, justify your answer.

In this phase, students look up for information themselves and later discuss their reasoning in groups. Additionally, the teacher explains that they should always check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for additional information in scientific articles, because those two mentioned conditions are almost always guaranteed. Examples of articles may be retrieved from the following links:

- https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
- https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1073.7951&rep=rep1&type=pdf **(DER20)**
- https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1084.7395&rep=rep1&type=pdf **(DER21)**

- https://stylesatlife.com/articles/how-to-prevent-noise-pollution/ **(DER22)**
- https://www.conserve-energy-future.com/causes-and-effects-of-noise-pollution.php **(DER23)**

➢ **Activity 2**

The teacher explores sources of noise that are harmful for public health, through noise characterization based on parameters such as decibels, timbre and the physics of sound-wave propagation. Then a relationship is made between the level of these parameters and possible risks for humans' health and quality of life (e.g., long periods of exposition to high-intensity noise can cause progressive hearing loss). (**DER4)** Then the teacher proposes an inquiry-based activity. Students answer the questions: "How can we quantify the level of severity of noise pollution?", "What parameters are used to quantify the sound/or noise?" and "What are the main risks to public health from exposure to noise pollution?". Then a worksheet **(DER2)** is provided, where students identify which parameters are used to quantify sound and which community risks arise from noise pollution. The same worksheet also contains two fields where, based on their research,

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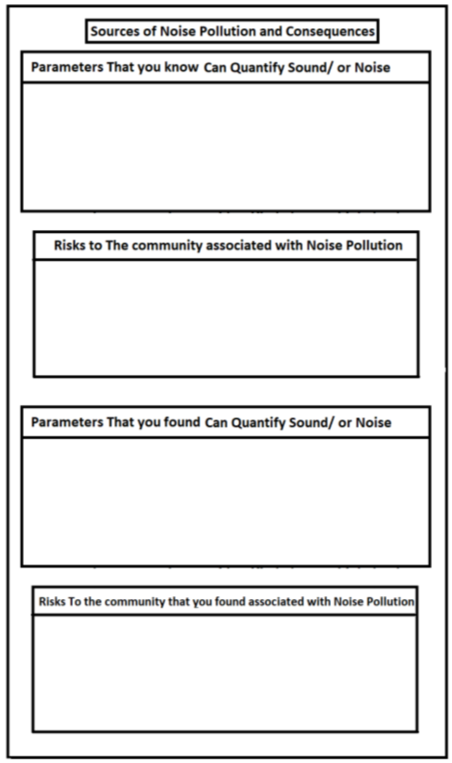
students again answer those questions. An example of worksheet template to be distributed to the students/groups so that they can efficiently organized their ideas and reasoning, can be observed in the image below.


Sources of Noise Pollution and Consequences

Parameters That you know Can Quantify Sound/ or Noise

Risks to The community associated with Noise Pollution

Parameters That you found Can Quantify Sound/ or Noise

Risks To the community that you found associated with Noise Pollution

Students answer the questions individually and then form groups (3-4 students) to discuss their responses and reasoning. Additionally, the teacher explains that they should always check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

Then the teacher encourages students to look for additional information in scientific articles, because those two mentioned conditions are almost always guaranteed. Examples of articles may be retrieved from the following links:

- https://www.britannica.com/science/sound-physics **(DER11)**
- https://www.vedantu.com/physics/difference-between-sound-noise-music **(DER12)**
- https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
- https://www.conserve-energy-future.com/causes-and-effects-of-noise-pollution.php **(DER23)**
- https://brieflands.com/articles/jjhs-60312.html **(DER24)**
- https://pdfs.semanticscholar.org/c0fb/8e0224e560d8ebb259bba70f9f23de8a6cc4.pdf **(DER25)**
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4608916/ **(DER26)**
- https://www.animations.physics.unsw.edu.au/jw/sound-pitch-loudness-timbre.htm **(DER27)**
- https://www.animations.physics.unsw.edu.au/jw/dB.htm **(DER28)**
- https://www.science.org.au/curious/earth-environment/health-effects-environmental-noise-pollution **(DER29)**
- https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf **(DER30)**

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The teacher moves around the classroom, supervises and supports students work by making reflective and supportive questions, and provides feedback when needed.

- **Activity 3**

At the end of the lesson, after internal discussion with the groups about their responses and reasoning (teacher defines a time limit for the students to complete the worksheet of the activities 1 and 2 and discuss their reasoning within the formed groups), the teacher provides students organized and structured information about the concepts they were asked to explore **(DER11, DER12, DER15, DER23-DER30).**

Students are asked to research outside the classroom the impact that noise pollution has on their country and how this problem is being handled by their government. **(DER4, DER5).** They are divided in the same groups of the previous lessons.They will build a power-point presentation on the stated issue to be presented in an open schooling event. (To be discussed later in lesson 6). The students look out for information about how the problem is affecting their country, that is, evidence that clearly shows the impact that noise pollution has in their country. Once they have found this information, they also look for data related with the current legislation and monitoring measures, etc., that are being implemented by their government to mitigate noise pollution.

- **Learning objects employed in this lesson:**
  - Evidence about the existence of noise pollution. **(DER1)**
  - Worksheets. **(DER2)**
  - Evidence about Consequences of noise pollution to the public health. **(DER4)**
  - https://www.britannica.com/science/sound-physics **(DER11)**
  - https://www.vedantu.com/physics/difference-between-sound-noise-music **(DER12)**
  - https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
  - https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1073.7951&rep=rep1&type=pdf **(DER20)**
  - https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1084.7395&rep=rep1&type=pdf **(DER21)**
  - https://stylesatlife.com/articles/how-to-prevent-noise-pollution/ **(DER22)**
  - https://www.conserve-energy-future.com/causes-and-effects-of-noise-pollution.php **(DER23)**
  - https://brieflands.com/articles/jjhs-60312.html **(DER24)**
  - https://pdfs.semanticscholar.org/c0fb/8e0224e560d8ebb259bba70f9f23de8a6cc4.pdf **(DER25)**
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4608916/ **(DER26)**
  - https://www.animations.physics.unsw.edu.au/jw/sound-pitch-loudness-timbre.htm **(DER27)**
  - https://www.animations.physics.unsw.edu.au/jw/dB.htm **(DER28)**
  - https://www.science.org.au/curious/earth-environment/health-effects-environmental-noise-pollution **(DER29)**
  - https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf **(DER30)**

Lesson 3: Physical Concepts Related to Sound and Wave

The main goals to achieve in this class, in a student's perspective, are as follows:

- Selecting appropriate concepts, measures, and indicators to measure noise levels.
- Analysing scientific evidence to explain phenomena related to noise pollution and produce argumentation.
- Finding, analysing, and interpreting noise diagrams.

Lesson Summary:

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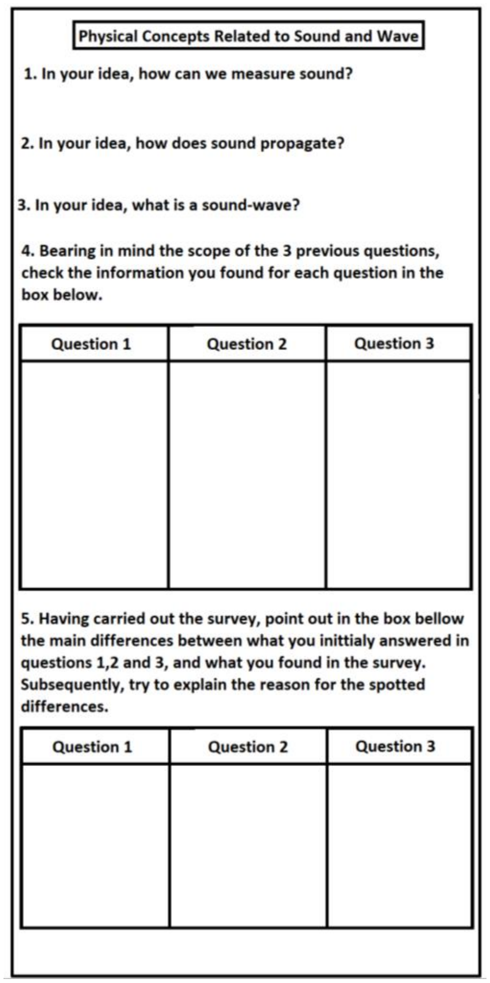
This lesson explores the physical concepts of sound and wave. Students learn that sound behaves like a wave and propagates in different ways depending on the environment in which the wave is being propagated. (Gas, liquid, or solid).

- **Activity 1**

The teacher starts the topic with open questions such as "What is a sound-wave?", "How can we measure sound?" and "How does sound propagate?". A worksheet **(DER2)** is distributed to students where they can map their ideas and describe their preconceptions about the issues mentioned above. The worksheet also contains a space where students point out what they found during the research process. **(DER3).** Then students indicate the primary differences between their preconceptions, and what they´ve found in the research activity. An example of a similar structure of a worksheet(s) to be distributed to the students/groups so that they can efficiently organize their reasoning, can be observed in the image below.


Physical Concepts Related to Sound and Wave

1. In your idea, how can we measure sound?

2. In your idea, how does sound propagate?

3. In your idea, what is a sound-wave?

4. Bearing in mind the scope of the 3 previous questions, check the information you found for each question in the box below.

Question 1	Question 2	Question 3

5. Having carried out the survey, point out in the box bellow the main differences between what you inittialy answered in questions 1,2 and 3, and what you found in the survey. Subsequently, try to explain the reason for the spotted differences.

Question 1	Question 2	Question 3

Students look up for this information themselves and later discuss their reasoning in groups (3/4). Additionally, the teacher explains that they should always check the following, before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older the document, data or information is, greater the chances are of being outdated.

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Then the teacher encourages students to look for information in scientific articles because those two mentioned conditions are almost always guaranteed.
The teacher moves around the classroom, supervises, and supports students work, by making reflective and supportive questions and providing feedback when needed. The teacher has organized and structured information on the topic, which can be retrieved from the following sources:

- https://www.researchgate.net/profile/M-Kathleen-Philbin/publication/12139749_Measuring_Sound_in_Hospital_Nurseries/resources/584df4b308ae4bc89933151a/Measuring-Sound-in-Hospital-Nurseries.pdf **(DER31)**
- https://www.ingentaconnect.com/content/aalas/jaalas/2007/00000046/00000001/art00002?crawler=true **(DER32)**
- https://www.pasco.com/products/guides/sound-waves **(DER33)**
- https://www.quebec.ca/en/health/advice-and-prevention/health-and-environment/the-effects-of-environmental-noise-on-health/noise-measurement **(DER34)**
- https://www.sciencelearn.org.nz/resources/573-measuring-sound **(DER35)**
- https://www.schoolnet.org.za/PILAfrica/en/webs/19537/physics4.html **(DER36)**

➢ **Activity 2**

At the end of the activity, and after the internal discussion between the groups about their reasoning is held (teacher defines a time limit for the students to complete the worksheet of the activities 1 and 2 and discuss their reasoning with the formed groups), the teacher provides them credible and organized information about the concepts that were asked to be investigated, exploiting the resources mentioned above. The information required can be found in the digital learning resources and on the following resources**:(**

- https://www.researchgate.net/profile/M-Kathleen-Philbin/publication/12139749_Measuring_Sound_in_Hospital_Nurseries/resources/584df4b308ae4bc89933151a/Measuring-Sound-in-Hospital-Nurseries.pdf (DER31)
- https://www.ingentaconnect.com/content/aalas/jaalas/2007/00000046/00000001/art00002?crawler=true (DER32)
- https://www.pasco.com/products/guides/sound-waves (DER33)
- https://www.quebec.ca/en/health/advice-and-prevention/health-and-environment/the-effects-of-environmental-noise-on-health/noise-measurement (DER34)
- https://www.sciencelearn.org.nz/resources/573-measuring-sound (DER35)
- https://www.schoolnet.org.za/PILAfrica/en/webs/19537/physics4.html (DER36)

➢ **Activity 3**

Students measure sounds by using a decibel meter or a MP4 audio record tool. The teacher explains how a decibel meter is handled, and how to correctly read a sound-wave. The teacher presents these subjects with a power-point or a tutorial video. The information required can be found in the digital learning resources and on the following resources:

- https://www.instrumentchoice.com.au/news/how-do-you-measure-noise-levels **(DER37)**
- https://www.vernier.com/files/manuals/slm-bta/slm-bta.pdf **(DER38)**

➢ **Activity 4**

After presenting how a decibel meter works, the class is divided in groups of 3-4 students. The groups, accompanied by the teacher, perform measurements of classroom sounds, and they can go outside the classroom to record the sound levels in school areas. Every source of noise pollution that can be analysed is mapped in lesson 2. Students take notes of the measurements obtained because they will have to work with this data in the following classes. A worksheet **(DER2**) can be provided to students so that they can better organize the collected data. An example of a similar structure of a worksheet to be distributed to the students/groups in order that they can efficiently organized their reasoning, can be observed in the image below.

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Physical Concepts Related to Sound and Wave

Sources of Noise Pollution	Noise Measurements

During the activity the teacher collects feedback from the students about their difficulties with the handling of the equipment, and ask constructive questions about it, to improve the students' comprehension and performance on the task.

- **Learning objects employed in this lesson:**
  - Worksheets. **(DER2).**
  - Evidence of several data related to noise sounds, noise levels and noise exposition *(infographic)*. **(DER3)**
  - https://www.researchgate.net/profile/M-Kathleen-Philbin/publication/12139749_Measuring_Sound_in_Hospital_Nurseries/resources/584df4b308ae4bc89933151a/Measuring-Sound-in-Hospital-Nurseries.pdf **(DER31)**
  - https://www.ingentaconnect.com/content/aalas/jaalas/2007/00000046/00000001/art00002?crawler=true **(DER32)**
  - https://www.pasco.com/products/guides/sound-waves **(DER33)**
  - https://www.quebec.ca/en/health/advice-and-prevention/health-and-environment/the-effects-of-environmental-noise-on-health/noise-measurement **(DER34)**
  - https://www.sciencelearn.org.nz/resources/573-measuring-sound **(DER35)**
  - https://www.schoolnet.org.za/PILAfrica/en/webs/19537/physics4.html **(DER36)**
  - https://www.instrumentchoice.com.au/news/how-do-you-measure-noise-levels **(DER37)**
  - https://www.vernier.com/files/manuals/slm-bta/slm-bta.pdf **(DER38)**

<u>Lesson 4: Analysing Test Cases of Noise Pollution</u>

The main goals to achieve in this class, in a student's perspective, are as follows:

- Researching, discussing, and communicating evidence on effects of harmful noise exposition to wildlife and humans' health.
- Analysing scientific evidence to explain phenomena related to noise pollution and produce argumentation.
- Finding, analysing, and interpreting noise diagrams.
- Characterization of the units and parameters of noise.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

- **Lesson Summary:**

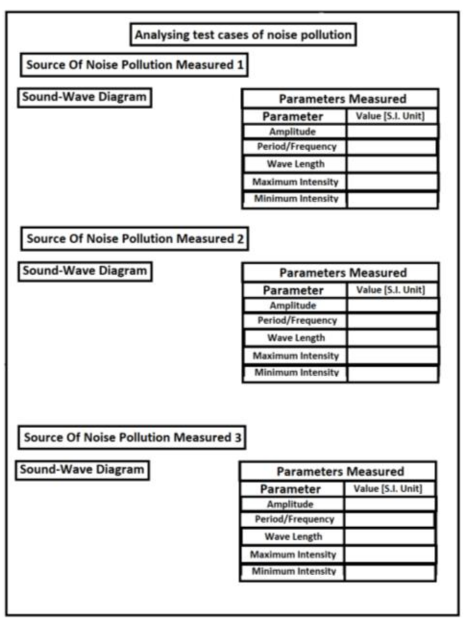
In this lesson the physics concepts previously taught are applied on the subject "noise pollution and its long-term consequences".

- **Activity 1**

The class is divided into the same groups that were formed in lesson 3, and each group organizes the data collected in lesson 3 to discover if the noises recorded goes beyond the recommended limit, mentioned in lesson 1. Students organize the data recorded by describing and constructing a Spectral density graphic and the sound-wave curve and eventually detecting the wave-length and the period/frequency of the different noises recorded. This activity should be conducted with the help of the online tool developed for this scenario **(LO1)** where the students online download the tool, the noise levels recorded with the decibel meter/MP4 and the tool coverts these data into a Spectral density graphic. Then, the students should analyse the referred spectral density graphics and describe the measured sounds having in mind the parameters that were addressed in the previous lessons as well as the recommended limit for noise sounds also addressed in the prior classes. Additionally, the recommend limit for noise sounds can be found directly in the following resources:

- https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf (**DER30)**
- Noise Measurement - The Effects of Environmental Noise on Health | Gouvernement du Québec (quebec.ca) **(DER39)**

To help the students organize their reasoning, they should fill in a worksheet (DER2), where they should draw the respective sound-wave curve, based on the noise measurements recorded for each source of noise pollution as well as the spectral density graphic produced. This worksheet also contains an additional table, where students record the parameters that characterize the sound, for each source of noise pollution, such as amplitude, period/frequency, etc. Students indicate if the noises they measured exceed the limits, considering the recommended limits. An example of a similar structure of a worksheet to be distributed to the groups can be observed in the image below.


Analysing test cases of noise pollution

Source Of Noise Pollution Measured 1

Sound-Wave Diagram

Parameters Measured	
Parameter	Value [S.I. Unit]
Amplitude	
Period/Frequency	
Wave Length	
Maximum Intensity	
Minimum Intensity	

Source Of Noise Pollution Measured 2

Sound-Wave Diagram

Parameters Measured	
Parameter	Value [S.I. Unit]
Amplitude	
Period/Frequency	
Wave Length	
Maximum Intensity	
Minimum Intensity	

Source Of Noise Pollution Measured 3

Sound-Wave Diagram

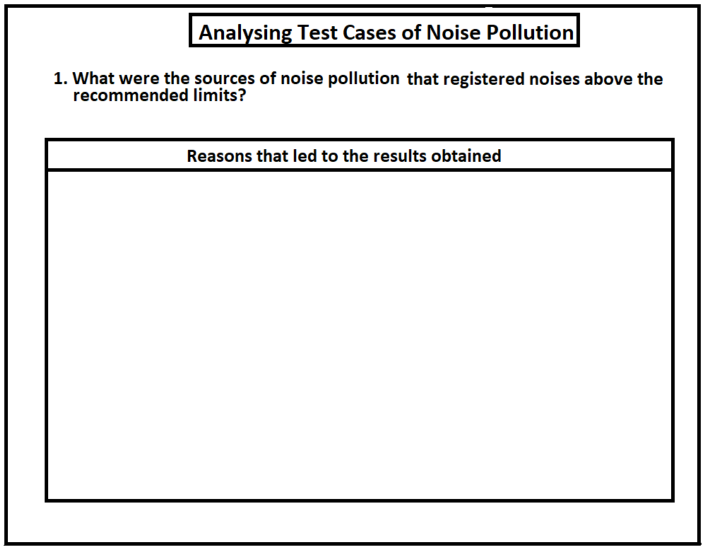
Parameters Measured	
Parameter	Value [S.I. Unit]
Amplitude	
Period/Frequency	
Wave Length	
Maximum Intensity	
Minimum Intensity	

The teacher collects feedback from the students about their difficulties/challenges in the activity and ask constructive questions, to improve the students' performance on the task.

- **Activity 2**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

Each group presents their measurements, and mention in which circumstances they obtained values above recommended limits. **(DER1).** They explain those values and correlate them to the respective sources of noise pollution. The teacher defines a time for each group to present, and all the elements of the group speak at least once. The groups discuss their findings and compare the audio sound-wave curves they have drawn, the parameters they marked, and the spectral density graphics registered. The worksheet mentioned above should provide a space to better organize the answers, and reasons why they obtained those values. **(DER3)**


Analysing Test Cases of Noise Pollution

1. What were the sources of noise pollution that registered noises above the recommended limits?

Reasons that led to the results obtained

- ➢ **Learning objects employed in this lesson:**
  - Online tool with the creation and interpretation of a Spectral density graphic. **(LO1)**
  - Evidence about the existence of noise pollution. **(DER1)**
  - Worksheets. **(DER2)**
  - Evidence of several data related to noise sounds, noise levels and noise exposition *(infographic).* **(DER3)**
  - https://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf **(DER30)**
  - Noise Measurement - The Effects of Environmental Noise on Health | Gouvernement du Québec (quebec.ca) **(DER39)**

Lesson 5: Action to reduce noise pollution

The main goals to achieve in this class, in a student's perspective, are as follows:

- Analysing scientific evidence to explain phenomena related to noise pollution and produce argumentation.
- Researching, discussing, and communicating evidence on effects of harmful noise exposition to wildlife and humans' health.
- Uses evidence to build argumentation on noise impacts in the health of the community.
- Proposing concrete action towards reducing exposure to noise pollution in his/her/others routine and living environments.
- Identifies relevant action to address challenges related with harmful noise exposition at the community and societal level.

➢ **Lesson Summary:**

Promotion of a debate regarding sources of noise pollution and general action to avoid or mitigate it.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

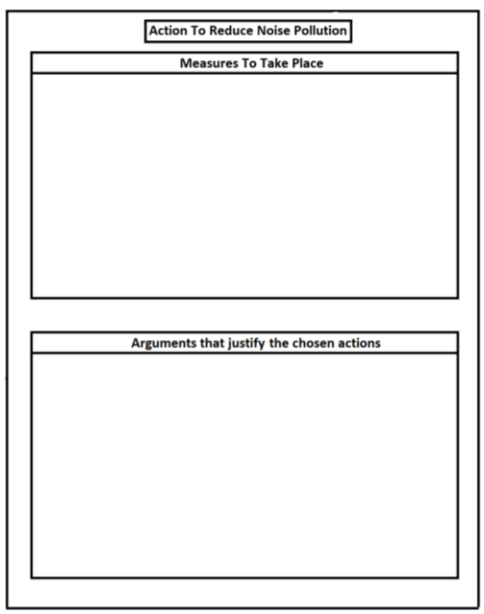
➢ **Activity 1**

The teacher conducts a classroom debate where groups created to develop the activities of lesson 4 discuss the evidence they got from their measurements. To conduct an effective debate, the teacher and the students should discuss the nature of the debate, by addressing the following issues:

- **The main focus of the Debate:**
  The debate theme is "General Action to Reduce Noise Pollution", considering the evidence/data collected in lesson 3, and analysed in lesson 4. Students identify the main impacts of noise pollution and propose actions to prevent or mitigate the problem. **(DER4, DER5)**

- **The Structure of the Debate:**

To perform the debate the teacher divides the class in the groups previously formed and each group presents the measures they selected to solve the problem/need. Based on the scientific data collected in the previous lessons, as well as the power-point presentation of the teacher, students form a series of arguments that justify why they choose that/those option(s). A worksheet **(DER2)** with several fields can be given to the groups where they can list the selected measures, and the supportive arguments **(DER5).** Graphs and infographics may be built or identified by students to support argumentation. An example worksheet template to be distributed to the groups so that they can efficiently organize their reasoning, can be observed in the image below.



- **The Rules of the Debate:**

The debate is promoted between the different groups and reasons for choosing that action and not another emerge. Each group should be given a certain amount of time (the teacher should stablish the time for the activity) to present their evidence and arguments. Every member of each group should speak at least once, and the order and the content of speaking should be planned by the team members. At the end of each presentation, other groups present their counter arguments and if they do not agree with the reasoning of the group that presented before, explain their claims. The groups that agree with the arguments stated at least present 1 critique, counterargument, suggestion, or recommendation. Then is given a time to the group that set the presentation to rebut those counter arguments. The presentation of the counter arguments and rebuttals should be made by only 1 member of each group, nominated by the teams.

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- **Assessment of the Debate:**

The evaluation of the debate is left to the teacher's discretion, but it undoubtedly involves the following criteria:

- The group that presented the most reliable information and from the most varied sources.
- The group that best defended their points of view.
- The group that best refuted the arguments of the other groups.

- **Activity 2**

After the debate, the teacher provides students with accurate and structured information about the topic of the debate which can be retrieved from the following resources:

- https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
- https://www.medicalnewstoday.com/articles/noise-pollution-health-effects#mental-health **(DER17)**
- Noise (Sound) Pollution - Sources, Types, Effects and Reduction Tips (stylesatlife.com) **(DER40)**
- https://www.conserve-energy-future.com/easy-and-practical-ways-to-reduce-noise-pollution.php **(DER41)**
- https://sunandsoundwindows.com/blog/11-ways-to-prevent-noise-pollution-list/ **(DER42)**

- **Learning objects employed in this lesson:**
  - Evidence about consequences of noise pollution to the public health. **(DER4)**
  - Strategies to reduce noise pollution. **(DER5)**
  - https://www.iberdrola.com/sustainability/what-is-noise-pollution-causes-effects-solutions **(DER15)**
  - https://www.medicalnewstoday.com/articles/noise-pollution-health-effects#mental-health **(DER17)**
  - Noise (Sound) Pollution - Sources, Types, Effects and Reduction Tips (stylesatlife.com) **(DER40)**
  - https://www.conserve-energy-future.com/easy-and-practical-ways-to-reduce-noise-pollution.php **(DER41)**
  - https://sunandsoundwindows.com/blog/11-ways-to-prevent-noise-pollution-list/ **(DER42)**

Lesson 6: Noise pollution, individual behavior, quality of life

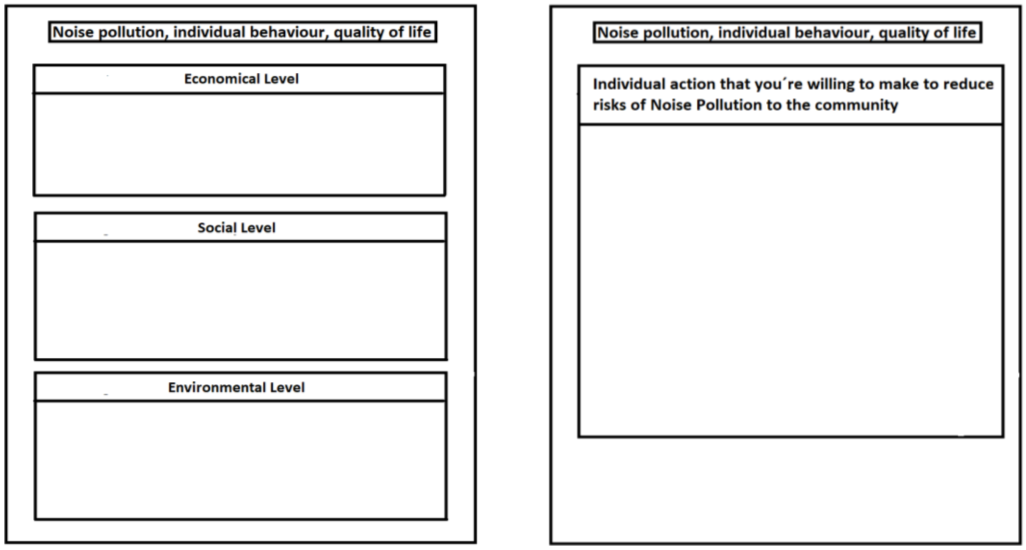
- **Lesson Summary:**

To explore the general economic and social impacts of reducing noise pollution in the community. It is also addressed the work plan for an open schooling event.

- **Activity 1**

The teacher promotes an inquiry-based activity: students look for evidence/facts that explain the impact that noise pollution can have at various levels, the main ones being social, economic, and environmental. To increase students' interest and level of connectivity with the topic, the teacher can ask questions such as "What can we do individually to mitigate the risks of noise pollution?", or "What are you individually willing to do to combat this problem?". To facilitate the students' research, a worksheet **(DER2**) is given to each student, so that they can point risks associated to noise pollution, at the social, economic, and environmental level and later, point out the risks they found in the research related to each of these levels.. **(DER4).** The worksheet also contains a space for students to mark their measures to prevent the risks associated to noise pollution in the community. An example of a similar structure of worksheet to be distributed to the students/groups in order that they can efficiently organized their reasoning, can be observed in the images below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.



Students write their initial ideas, and the teacher asks them to look up for this information themselves, by searching for reliable sources, and later discuss their reasoning in groups (3/4). Then the teacher expresses that they should always check the following before taking the information for granted:

- The source and author of the information.
- The date it was published, because the older a document, data or information is, greater the chances of being outdated.

The teacher encourages students to look for information in trustful databases (e.g.: WHO database) and scientific articles, so that these two conditions are guaranteed. During the activity the teacher moves around the classroom, supervises and supports students work, while making reflective and supportive questions and providing feedback when needed. The teacher organizes and structures information on the topic, which may be gattered from the following resources:

- https://www.researchgate.net/profile/Hiral-Jariwala/publication/319329633_Noise_Pollution_Human_Health_A_Review/resources/59a54434a6fdcc773a3b1c49/Noise-Pollution-Human-Health-A-Review.pdf **(DER43)**
- https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1064.851&rep=rep1&type=pdf **(DER44)**
- http://ijmcr.com/wp-content/uploads/2021/12/Paper3610-614.pdf **(DER45)**

➢ **Activity 2**

This section introduces the activities to be presented at an open schooling event. Students should describe in a form of a power-point or a poster the gathered data regarding the actions that can be taken to mitigate the risk of noise pollution at the community level. **(DER5)**

A worksheet **(DER2)** is given to the groups so that they can list their chosen actions, and the respective supportive arguments. Additionally, students address the work conducted in task 1, following lesson 2, where they listed the monitoring measures that were being taken by their government to mitigate and combat noise pollution.

An example of a similar structure of a worksheet to be distributed to the groups in order that they can efficiently organized their reasoning, can be observed in the image below.

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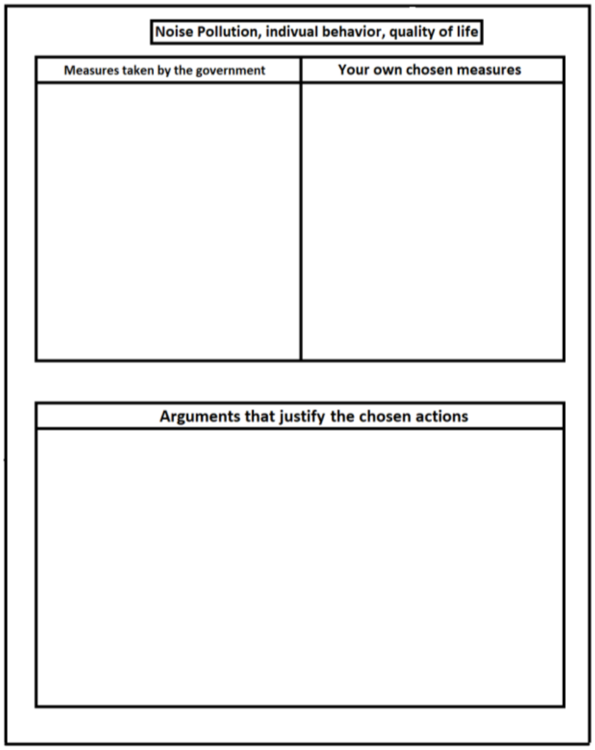

Effective presentation formats for an open schooling event, such as infographics and posters could also be produced to help the students clarify their reasoning. This scientific work is presented to the community through a debate where students present their chosen actions and supportive arguments to the community about the importance of changing behaviour and lifestyles to mitigate noise pollution, and thus improve health and quality of life. The debate is led and moderated by the teacher, in the same way as the debate in lesson 5, where the school community is willing to participate in the showcasing of the project results, and debate.

- **Learning objects employed in this lesson:**
  - Worksheets. **(DER2).**
  - Consequences of noise pollution to the public health (infographic). **(DER4)**
  - Strategies to reduce noise pollution (infographic). **(DER5)**
  - https://www.researchgate.net/profile/Hiral-Jariwala/publication/319329633_Noise_Pollution_Human_Health_A_Review/resources/59a54434a6fdcc773a3b1c49/Noise-Pollution-Human-Health-A-Review.pdf **(DER43)**
  - https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1064.851&rep=rep1&type=pdf **(DER44)**
  - http://ijmcr.com/wp-content/uploads/2021/12/Paper3610-614.pdf **(DER45)**

Supplementary learning resources and educational activities

1. Teleconference with STEM professionals (e.g., medical expert, policy maker, public health authority, officer of the municipality working on urban and environmental health, data scientist or technology developer, researchers of PAFSE consortium). Students make questions to experts with a particular focus on: a) future academic choices and career paths; b) identifying policy measures to fight noise pollution, and increase quality of life in their community.

2. Visit to national museum of sound and image

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Students make questions to experts with a particular focus on: a) future academic choices and career paths; b) identifying policy measures to fight noise pollution, and increase quality of life in their community.

School Research Project

Topics

- Correlate, from experimental activities, the intensity, pitch, and timbre of a sound with the characteristics of the wave and identify pure sounds.
- Interpret spectral density graphics, identifying the level of sound intensity and hearing and pain thresholds.
- Identify sources of noise pollution, in different environments, using sound level meters, and based on research, critically evaluate the consequences of noise pollution on human beings, proposing prevention and protection measures.
- Incidence of diseases related with high level exposition to noise pollution.
- Action supporting health promotion and disease prevention in the community.

Research management, design and administration (summary topics)

Identification of daily spaces where noise pollution is clear.
Decide for daily spaces where noise pollution is not considered a problem.
Record sounds in places.
Define and insert data in the online tool.
Promote reflection and discussion on risks and protective behaviour.
Aid in the report elaboration that will be available in the repository platform.

Challenge: build an infographic about Noise Pollution: Consequences and Measures!

Method (summary):

Students are organized in groups; each group addresses several ways to conduct prevent noise pollution in their environment. The project challenges each group of students to create and present an infographic that synthetizes a) What they have learned throughout the teaching-learning sequence; b) Actions to combat noise pollution at the school level; c) Relevant outcomes due to application of such measures. By following this process, at the end of the project students will have understood the importance of preventing noise pollution.

Development process:

Building upon the knowledge acquired in previous classes, and by following inquiry-based approach, the groups seek to make observations in school environment and identify a series of actions to be adopted by the school community to diminish the risks of noise pollution.

In the development of the project, students carry out a survey/observations of school community behaviour related to subject. The teacher discusses with students' possible questions to assess the attributes of the school in the subject of noise pollution and possible methods to get the answers. The advantages and limitations of the alternatives are discussed. Then a brainstorming of possible questions to address the topic is promoted by the teacher: 1. Are any policy regarding noise pollution being taken by the school? 2. Is there any strategy ongoing to limit noise sounds? 3. Was the issue of noise pollution ever addressed in the school community? 4. What are the school's community perception on this subject?

The output of the project is a list of school attributes, strengths and weaknesses and proposals to be adopted by the school community to mitigate long-term risks (e.g., escalation of the problem of deafness increased by noise pollution, etc.). Proposals are linked with benefits that the change in behaviour can bring to the school health and well-being.

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- Organization of an open schooling event.
- Identification of noise pollution sources.
- Identification of the problems that arise from noise pollution.
- Identification of the level of harmfulness of each stated noise pollution source.
- Highlight of several alternative actions to prevent noise pollution.
- Highlight the benefits to the health and quality of life of the community if they adopt those proposals.

Teaching-learning process milestones:
Students will be able to:
1. Develop critical reasoning (e.g., analysing, organizing, debating, and sharing information regarding lesson 4 where it is asked to produce a sound-wave curve and a Spectral density graphic and interpret the observe data).
2. Develop digital skills (e.g., finding, reviewing, and using different online resources to develop the activities).
3. Understand the concept of "Noise and Sound" and how are they characterized.
4. Understand the concepts of "Noise pollution", its causes, effects and can it be prevented.
5. Understand how to analyse in a scientific way noise and sound measurements.
6. Develop the ability to construct different types of arguments, counterarguments, and rebuttals in order to make a decision regarding socio-scientific questions.
7. Develop the ability to debate socio-scientific questions.
8. Investigate community's perceptions and knowledge concerning noise pollution, its causes, effects and how can it be prevented.
9. Develop responsible citizenship and critical health literacy.

Teaching-learning process for school project (summary):
1. Collection of evidence (data, articles, pictures).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Design criteria for arguments evaluation.
4. Design rubric for evaluation of public debate.
5. Design an agenda for open schooling event.
6. Create a brochure/power-point related to measures to be taken to combat noise pollution and distribute it in open schooling event.

Organization of the open schooling event:
1. Each project output (communication brochures/power-point) is presented by the students in a community setting (e.g., exposition centre, municipality, garden, museum, science fair).
2. Students will communicate policy measures using STEM-based argumentation. Students appeal to the action of all in health of the community, providing great understanding that preventing noise pollution is a responsibility of all, not only of the ministry of health or healthcare providers.
3. Students, parents, school community and relevant local stakeholders attend the event and understand how the incidence of energy waste is influenced by individual behaviour and environmental factors. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the level).

Data Analysis and Reporting
Data filtration.
Define minimum representative data collected.
Data categorization.
Data presentation formats.
Internal presentation.
Report writing.

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Target Audience for Recommendations
Other schools that use the repository platform.
Social NGOs.
Decision makers.
General public.
Mass media.
Families.
Friends.
Future students

Public Debate and Recommendations (based on research results)

Discussion and feedback.
Analyse reports from other schools.
Define and insert data in the simulator.
Produce communication information.
Make recommendations for reduction of noise in workplaces and public spaces.
Dissemination of final report and recommendations in the school website and information to the mainstakeholders (public transport companies, shopping centres, hospitals, etc.).

Main Partner responsible: ISEL

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22. Specifications for an educational scenario on the topic of "The role of environment and animal health in zoonotic diseases and pandemics"

Context

The COVID-19 pandemic has highlighted the potential of zoonotic diseases to affect human health outcomes. Therefore, it is crucial to understand how environmental changes can affect the dynamics and distribution of zoonotic diseases, so that we can improve our ability to predict epidemics and control them. Additionally, the environmental changes associated with the climate change scenario may lead to changes in health threats to both animal and human beings, multiplying existing health problems. The sustainable development goals are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.
The learning experience supports youths in understanding these public health threats in an integrative manner, and reach high-level comprehension on how STEM (science, technology, engineering, mathematics) may address these issues, contributing to evidence-based personal decision-making and public policy.

Scientific content and its relevance to public health education

A zoonosis is any disease or infection that can be transmitted from vertebrate animals to humans. More than 60% of the 1,700 infectious diseases that affect humans come from animals like the Sars-Cov-2, Ebola, Hiv, SARS, MERS, Swine, and Avian flu, Zika, etc. pandemics, after starting from sporadic phenomena limited to rural areas, have become a global emergency. Emerging zoonoses are a growing threat to global health and have caused huge economic damage in the past 20 years because they have important impacts on public health, livestock economies, and wildlife conservation. Many of the zoonoses are not just problems confined to remote areas but are serious threats to global public health.
The repeated and frequent outbreak of pandemics can also be attributed to human activities. In particular, the creation of enormous intensive domestic animal farms, the indiscriminate use of antibiotics on intensive breeding farms, the destruction of forests, the consumption of the meat of wild animals (bush meat) and the illegal animal trade are all factors contributing to the insurgence and the transmission of zoonotic diseases from animals to humans. One Health is defined as a cooperative, multisectoral and interdisciplinary approach that operates at a global, national, regional and local level, the aim is to improve human health by monitoring the human-animal-environment interface. This approach sees the health of humans, animals and ecosystems as an interconnected network, rather than problems to be tackled individually. Key concepts of One Health include viewing the health of all species as needing to be balanced, focusing on health assessment and disease prevention rather than exclusively on treatment and promoting a strong collaborative endeavor between human and veterinary medicine.
Climate change can have a complex impact that also influences human and animal health. The changes in climatic conditions have forced pathogens and vectors to develop adaptation mechanisms. Such development has resulted in the diseases becoming resistant to conventional treatments due to their augmented resilience and survival techniques, thus further favoring the spread of infection.
Education that improves environment, climate and One Health literacy helps building consensus and strenghtened communities, becoming the foundation for the acquisition of the expertise required to contribute to the solution of climate and environment problems.

Estimated duration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

5 classes of 40-45 minutes (lesson 1 – lesson 5)
5-6 sessions of 40-45 minutes for school project (session 6 – session 12)

Classroom organization requirements

From lesson 1 to lesson 5 students work alone or occasionally in groups.
From lesson 6 to lesson 12 students form four- or five-member groups which carry out the school project. The use of computer may be required.

Prerequisite knowledge and skills

Basic knowledge of software and browsers.

Content glossary

Air pollution. The presence of contaminant or pollutant substances in the air at a concentration that interferes with human health or welfare, or produces other harmful environmental effects.

Burden of disease. The burden of disease is a measurement of the gap between a population's current health and the optimal state where all people attain full life expectancy without suffering major ill-health.

Carbon footprint. Measures CO2 emissions associated with fossil fuel use.

Climate change. A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Capacity building. In health promotion, capacity building is the development of knowledge, skills, commitment, partnerships, structures, systems and leadership to enable effective health promotion actions.

Collaboration. A recognized relationship among different sectors or groups, which have been formed to take action on an issue in a way that is more effective or sustainable than might be achieved by the public health sector acting alone.

Determinants of health. The range of personal, social, economic and environmental factors that determine the healthy life expectancy of individuals and populations.

Disease prevention. Disease prevention describes measures to reduce the occurrence of risk factors, prevent the occurrence of disease, to arrest its progress and reduce its consequences once established. Primary prevention is directed towards lowering the prevalence of risk factors common to a range of diseases (such as tobacco and alcohol use, obesity and high blood pressure) in order to prevent the initial occurrence of a disorder, for example through behaviour change advice. **Secondary prevention** is directed towards early detection of existing disease with a view to arresting or delaying the progression of the disease and its effects, for example through screening and other early detection programs such as routine health checks. **Tertiary prevention** generally refers to disease management strategies and/or rehabilitation intended to avoid or reduce the risk of deterioration or complications from established disease, for example through patient education and physical therapy

Ecological Footprint. The impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated. More simply, it is the amount of the environment necessary to produce the goods and services necessary to support a particular lifestyle.

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Environmental determinants of health. The physical conditions in which people live and work that have an impact on health.

Environmental health. Aspects of human health and disease that are determined by factors in the environment. It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect health. Environmental health includes both the direct pathological effects of chemicals, radiation and some biological agents, and the effects (often indirect) on health and well-being of the broad physical, psychological, social and aesthetic environment, which includes housing, urban development, land use and transport.

Environmental impact. Impacts on human beings, ecosystems and man-made capital resulting from changes in environmental quality related, since it is nearly impossible to produce, transport, or consume energy without significant environmental impact. The environmental problems directly related to energy production and consumption include air pollution, climate change, water pollution, thermal pollution, and solid waste disposal.

Environmental risk. Likelihood, or probability, of injury, disease, or death resulting from exposure to a potential environmental hazard.

Evidence. Information such as analyzed data, published research findings, results of evaluations, prior experience, expert opinions, any or all of which may be used to reach conclusions on which decisions are based.

Global Warming. Increase in Earth's temperature caused by the increase in greenhouse gas emissions that has been occurring since the mid-19th century.

Greenhouse effect. Warming of the atmosphere due to the reduction in outgoing solar radiation resulting from concentrations of gases such as carbon dioxide.

Greenhouse gas. Gas that contributes to the natural greenhouse effect. The Kyoto Protocol covers a basket of six greenhouse gases (GHGs) produced by human activities: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Annex I Parties' emissions of these gases taken together are to be measured in terms of carbon dioxide equivalents on the basis of the gases' global warming potential. An important natural GHG that is not covered by the protocol is water vapour.

Health. A state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.

Health literacy. Health literacy represents the personal knowledge and competencies that accumulate through daily activities, social interactions and across generations. Personal knowledge and competencies are mediated by the organizational structures and availability of resources that enable people to access, understand, appraise and use information and services in ways that promote and maintain good health and well-being for themselves and those around them.

Health promotion. Health promotion is the process of enabling people to increase control over, and to improve their health.

Incidence. The number of cases of disease that have their onset during a prescribed period of time. It is often expressed as a rate. Incidence is a measure of morbidity or other events that occur within a specified period of time.

Infectious. Capable of causing infection or disease by entrance of organisms (e.g., bacteria, viruses, protozoan, fungi) into the body, which then grow and multiply. Often used synonymously with “communicable”.

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Life expectancy. The average number of years an individual of a given age is expected to live if current age-specific mortality rates continue to apply.

Morbidity. A measure of disease incidence or prevalence in each population, location or other grouping of interest.

Mortality. A measure of deaths in each population, location or other grouping of interest.

Health behaviour. Any activity undertaken by an individual for the purpose of promoting, protecting, maintaining or regaining health, whether or not such behaviour is objectively effective towards that end.

Health education. Health education is any combination of learning experiences designed to help individuals and communities improve their health by increasing knowledge, influencing motivation and improving health literacy.

Health for All. The attainment by all the people of the world of a level of health that will permit them to lead a socially and economically productive life regardless of who they are or where they live.

Health outcomes. A change in the health status of an individual, group or population that is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status.

Health policy. Health policy refers to decisions, plans, and actions that are undertaken to achieve specific health care goals within a society.

Health promoting schools. A health promoting school can be characterised as a school constantly strengthening its capacity as a healthy setting for living, learning and working.

Healthy life expectancy. Healthy life expectancy is a population-based measure of the proportion of expected life span estimated to be healthful and fulfilling, or free of illness, disease and disability according to social norms and perceptions and professional standards.

Health status. The state of health of a person or population assessed with reference to morbidity, impairments, anthropological measurements, mortality, and indicators of functional status and quality of life.

Investigation. A systematic, thorough and formal process of inquiry or examination used to gather facts and information in order to understand, define and resolve a public health issue.

One Health. A collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment.

Partnerships for health. A recognized relationship between two or more partners to work cooperatively towards a set of shared health outcomes in a way that is more effective, efficient, sustainable, or equitable than could be achieved by one partner acting alone.

Pollution prevention. The use of materials, processes, or practices to reduce, minimise, or eliminate the creation of pollutants or wastes. It includes practices that reduce the use of toxic or hazardous materials, energy, water, and/or other resources.

Prevalence. The number of cases of a disease, infected people or people with some other attribute present during a particular interval of time.

Prevention. Action taken to reduce known risks.

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Prevention principle. This principle allows action to be taken to protect the environment at an early stage. It is now not only a question of repairing damages after they have occurred, but to prevent those damages occurring at all. This principle is not as far-reaching as the precautionary principle. It means in short terms: it is better to prevent than repair.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Research. Activities designed to develop or contribute to knowledge, e.g., theories, principles, relationships, or the information on which these are based. Research may be conducted simply by observation and inference, or by using experiment, in which the researcher alters or manipulates conditions in order to observe and study the consequences of doing so.

Skills for health (life skills). Skills for health consist of personal, interpersonal, cognitive, and physical skills that enable people to control and direct their lives, and to develop the capacity to live with and produce change in their environment to make it conducive to health.

Social determinants of health. The social determinants of health are the social, cultural, political, economic and environmental conditions in which people are born, grow up, live, work and age, and their access to power, decision-making, money and resources that give rise to these conditions of daily life.

Sustainable behaviour. Behaviour that minimises the negative impact of one's actions on the physical, social and economic environment.

Sustainable Development Goals (SDGs). Also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The 17 SDGs are integrated—that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability.

Waste. Any substance or object that the holder discards or intends or is obliged to discard, namely those identified in the European Waste List.

Well-being. Well-being is a positive state experienced by individuals and societies. Similar to health, it is a resource for daily life and is determined by social, economic and environmental conditions.

Zoonosis. An infectious disease that has jumped from a non-human animal to humans.

Zoonotic pathogens. Bacteria, virus, parasitic, or unconventional agents, that can spread to humans through direct contact or through food, water or the environment.

<u>Pedagogical glossary</u>

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills. C) Inquiry based learning: By the term inquiry-based learning we refer to the engagement of students in

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learning activities during which they practice several scientific inquiry skills. Students make use of these skills to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organization, variable handling, data driven conclusion making and communicating over scientific issues. **Information.** Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Lifelong learning. A broad concept where education that is flexible, diverse and available at different times and places is pursued throughout life. It takes place at all levels—formal, non-formal and informal—utilizing various modalities such as distance learning and conventional learning.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Sources: Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

Indicative literature

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Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, literacy, citizenship

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Knowledge
Overarching Concepts: holistic approaches, the role of the environment in disease

Medical and Veterinary science concepts:
- Zoonotic diseases
- Epidemics and pandemics

Epidemiology and health economics concepts:
- Indicators of burden of disease
- Economic impact of pandemics

Social and global health concepts:
- Health, health literacy, quality of life.
- Relationship between environment, zoonotic diseases, and epidemics (environmental determinants of health).
- Climate change impact in environment and human and animal health
- Sustainable Development Goals (SDG 3, SDG 13 and their relationship with other SDGs).
- Public policy on climate change mitigation, adaptation and environmental determinants.

Knowledge - outcome assessment:
6. Recognizes and characterizes the environmental factors that affect human and animal health.
7. Identifies the disruptive changes in animal health that influence the emergence of zoonotic diseases.
8. Identifies the most important characteristics of pandemics.
9. Identifies measures and proposes general action to mitigate and adapt to climate change.
10. Identifies relevant changes of climate change and identifies suitable indicators to monitor the changes.
11. Identifies the environmental determinants of health and understands their relationship with climate change and SDGs.
12. Identifies relevant action to address environmental challenges at the community and societal level.

Skills (abilities/competences)
General: project-based thinking, evidenced-based decision-making, public speaking and argue, understanding how to protect animal and human health and the environment.

Specific:
- ✓ Finding, analyzing and interpreting scientific data, texts and dynamic graphical representations to understand zoonotic diseases.
- ✓ Understanding the difference between facts and opinions, understanding how to find fake claims, evaluate the reliability of health-related information, based on multiple factors affecting the reliability of information.
- ✓ Understanding the relevance of scientific evidence to explain phenomena related to several environmental changes (e.g., air pollution, climate change), animal health and zoonotic diseases and produce argumentation.
- ✓ Obtaining, assessing, and communicating evidence related to zoonotic diseases.
- ✓ Assessing personal and community behavioral patterns that endanger the environment and health.
- ✓ Analyzing the consequences of environmental changes at individual and community level.
- ✓ Understanding appropriate strategies to reduce personal and community impact on environment and getting access to the relevant resources.

Skills – outcome assessment:
5. Selects appropriate concepts, indicators and evidence to characterize environment changes that can cause harm to human and animal health.

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6. Can anticipate the consequences of changes in the environment (e.g., air pollution, biodiversity loss, climate change) in environmental determinants of health and the emergence of zoonotic diseases.
7. Can adopt mitigation measures (e.g., using public transportation instead of private car).
8. Can propose concrete action towards mitigation of environment degradation in their/others routine.
9. Feels able to influence the adoption of environment degradation mitigation measures by others (e.g., family, peers, friends).
10. Selects appropriate sources to characterize climate change and other environmental changes impacting human and animal health in a scientific perspective.
11. Is able to identify the problems and challenges of the community in relation to environmental degradation (e.g., air pollution, climate change) and connect them with SDG 3 (health and well-being) and find the relevant resources to address them.

Affective/Attitudes Behaviour (*beliefs)*

- ✓ Adopting environmental protection attitudes.
- ✓ Critical thinking, problem solving, communication, intellectual curiosity, attentiveness, support for safety.
- ✓ Adopting attitudes towards minimizing the impact of environment degradation in human and animal health.
- ✓ Adopting attitudes supporting sustainable development, urban and environmental health challenges.
- ✓ Engaging public speaking and debating of measures to mitigate environmental degradation.

Attitudes and behavior - outcome assessment:

11. Believes that environmental degradation is a relevant factor in the emergence of pandemics.
12. Believes that scenarios such as climate change influence the incidence of zoonotic diseases.
13. Believes that is important to adopt measures to prevent environmental degradation.
14. Reproves patterns disregarding climate change in our communities.
15. Is committed to communicate and address the problems and challenges of the community in relation to the environmental determinants of health and to contribute to the SDGs.

Learning goals and outcomes

- ✓ Uses online tools to plot tables, graphs, and maps, using updated data.
- ✓ Analyzes the consequences of zoonotic diseases on human beings and environment.
- ✓ Obtains, evaluates, and communicates data and scientific information about environmental determinants of health and zoonotic diseases.
- ✓ Uses evidence to build argumentation on climate change.
- ✓ Gives examples of environmental issues affecting the prevalence of zoonotic diseases in the community.
- ✓ Describes different approaches to protect, develop and influence global health.
- ✓ Uses evidence to propose measures and methods to fight climate change and communicates them to the community leadership.

<u>Assessment methods</u>

- ✓ Outcome assessment
    - o Quantitative – questionnaire in paper.
    - o Qualitative - students project: a. systems map; b. Infographic

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of

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people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content
- Origin of zoonotic diseases.
- Zoonotic diseases and human health.
- ONE HEALTH approach developed by the WHO.
- Environmental degradation (e.g. climate change, air pollution, biodiversity loss) and health.
- Data analysis

Digital Learning Objects (LO) and Digital Educational Resources (DER)

https://www.canva.com/design/DAFG3GytvBc/MYhHEXDyMszrEafBLOVO4Q/watch?utm_content=DAFG3GytvBc&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

New:
7. Hidden treasure game with post-its [LO1]
8. Environmental determinants of health [DER1]
9. Smart and green cities [DER2]
10. Main determinants of health with link to the sustainable development goals [DER3]
11. SDG 3, SDG 7 and SDG 13 [DER4]
12. SDG 3 connected with the other SDGs [DER5]
13. Zoonotic diseases [DER6]
14. One health [DER7]
15. Data from surveillance systems for zoonotic diseases [DER8]
16. Concepts related with climate change (cards game) [LO2]
17. What is climate change? [DER9]
18. How does climate change impact health? [DER10]
19. Decarbonization and health [DER11]
20. Zoonotic diseases and pandemics [DER12]
21. From epidemics to pandemics [DER13]
22. Anthropogenic activities and pandemics [DER14]
23. Cards with mortality data from pandemics [LO3]
24. Questionnaire – quantitative assessment [DER15]
25. Template for students to design the infographics (*canva file*) [DER16]
26. Template for students to brainstorm about climate change action in the community (*canva file*) [DER17]

From other sources/high-quality platforms:

Determinants of Health
- Determinants of Health - WHO [DER18]
- SDGs [DER19]

One health
- From https://www.cahi-icsa.ca/one-health [DER20]
- From https://healthforanimals.org/ [DER21]
- Biodiversity and infectious diseases Q&A WHO [DER22]

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- Climate factors and infectious diseases – IPCC Table [DER23]
- One Health Resources CDC [DER24]

Climate change
- Fast facts on climate and health WHO [DER25]
- Fact sheet – Climate change and health WHO [DER26]
- Climate change and health: What we can do individually to tackle climate change? – Youtube animated video [DER27]
- Climate Action tracker – Map [DER28]
- Fact Sheet PAHO [DER29]

Pandemics
- Article from LabXchange: What is the coronavirus outbreak? [DER30]
- WHO video: COVID-19 Myths Vs Science [DER31]
- Enciclopeda Britannica: Brief history of pandemics [DER32]

Scientific method
- Scientific method - steps [DER33]

Teaching - learning activities

Principal target:
Natural Sciences classes
9th -11th grade (+/- 15-16 years old students)
4-5 sessions/classes of 40-45 minutes
Science teachers integrate other colleagues in scenario implementation (e.g., physics and chemistry, mathematics and English teachers), as it aims to be interdisciplinary.

Lesson 1: Environmental determinants health

- Learning objective: at the end of lesson 1 students should be able to identify and characterize the main environmental determinants of health.
  An environmental determinant of health is, in general, any external agent (biological, chemical, physical, social, or cultural) that can be causally linked to a change in health status. Examples: water, sanitation, air quality, temperature changes. The activities performed during this first lesson aim to engage students in this topic and explore some preliminary ideas.

- Icebreaker moment: assessing the preconceptions and misconceptions of the students on the topic: Hidden treasure game with post-its: write several icebreaker questions on the sticky side of post-it notes and stick them to the board. Have each student take turns choosing one sticky note and answering the question on the back. He can then choose another student in the class to answer the same question. The number of questions should be adequate for the number of students, allowing to have at least one answer to each question [LO1]. Possible questions:
  - Do you consider that environment has an influence in your health?
  - Do you consider that environment has an influence in animals' health?
  - Do you know diseases that affect both humans and animals? Refer some diseases.
  - Which compartments of the environment may affect your health?
  - Does the climate change affect humans' health?

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- Classroom discussion: Taking as a starting point the answers obtained during the icebreaker moment, students will be guided through two questions:
  - How can environment influence health?
  - Are the SDGs interconnected within each other?

  The discussion is conducted in a way students recognize that several environmental factors may influence health, as the air we breathe, the proximity to rivers, temperature, and many others. Students also understand that living conditions relate to the sustainable development goals. These are influences more difficult, but not impossible, to change, as they ask for concerted action of society as a whole. [DER1, DER3, DER4, DER18]

- Activity: Students are asked to map the attributes of healthy and ecofriendly community environments by looking at the images. The attributes are summarized at the whiteboard or flipchart. *Mentimeter webpage* can also be used. The output will be a figure/map where the environmental determinants of health are mapped as well as the related SDGs and the interconnections are reflected. This output will be the starting point for the other lessons of this topic, i.e. a learning resource produced by the students that will be a reference. [DER2, DER5, DER19]

- Learning objects:
  - Hidden treasure game with post-its [LO1]
  - Environmental determinants of health (infographic) [DER1]
  - Smart and green cities [DER2]
  - Main determinants of health with link to the sustainable development goals [DER3]
  - SDG 3, SDG 7 and SDG 13 [DER4]
  - SDG 3 connected with the other SDGs [DER5]
  - Determinants of Health - WHO [DER18]
  - SDGs [DER19]

Lesson 2: Animal health and zoonotic diseases

- Learning objective: at the end of lesson 2 students should be able to define what is a zoonotic disease, give examples of zoonotic diseases and characterize One Health approach. Data registries will be explored by the students, aiming to answer to the following question “what is the most prevalent zoonotic disease in your country?”. A debate will be developed in the lesson’ last section aiming to show the several professions and academic backgrounds needed to work on these topics.

- Teaching-learning: The teaching-learning script take as a starting point the answers obtained during the icebreaker moment for the questions related with animal and human health. The concepts of zoonotic diseases and One Health are explained, highlighting the interface human-animal-environment. Some case-based learning of communicable diseases that originated in animals will be used: vector-borne diseases (e.g malaria), zoonotic influenza, brucellosis, salmonellosis, monkeypox. The surveillance programs for the early identification and monitoring of animal disease will be presented and the need for integrative interventions to prevent the spreading of animal disease and necessary actions in diverse sectors will be emphasized. Students will understand the interface between human, animal and environmental health, and the fact that one determinant afecting one domain will have an effect on the others. [DER6-7, DER20-24]

- Group activity: Students will form groups of 4 elements. Data from surveillance systems previously compiled will be distributed for all the groups and students will be asked to identify the most/less

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prevalent zoonotic disease in their own country/Europe/World. Results will be presented and discussed. [DER8]

- Classroom discussion: Discussion on career options in the field and relevant competences, using inter professional collaboration as examples (e.g., epidemiologist, microbiologist, and veterinarians). A special emphasis is put on the new professional activities related with data science, that supports the activity of surveillance systems and research in health sciences.

- Learning objects:
  - Zoonotic diseases (infographic) [DER6]
  - One health (infographic) [DER7]
  - Data from surveillance systems for zoonotic diseases [DER8]
  - From https://www.cahi-icsa.ca/one-health [DER20]
  - From https://healthforanimals.org/ [DER21]
  - Biodiversity and infectious diseases Q&A WHO [DER22]
  - Climate factors and infectious diseases – IPCC Table [DER23]
  - One Health Resources CDC [DER24]

Lesson 3: Climate change

- Learning objective: at the end of lesson 3 students should be able to explain how climate change influences animal and human health.
  Students become familiar with the concept of climate change and the consequent effects on human health and animal health. The teaching-learning sequence explores relevant keywords and key concepts under the topic of climate change.

- Group activity - Climate Change – card game – to describe and explain relevant concepts: A set of words/concepts related with climate change are mapped in cards. Students are organized in groups. Each group is given a set of words which they distribute randomly between the members without showing the cards to each other (e.g.: 5 students – 10 words/concepts). Each member is given 30-60 seconds to explain the word/concept in hand to other members (e.g. climate change, greenhouse gases, extreme weather conditions, sustainable development goal), without showing or using that one particular word. When the time is out, the words that were identified right brings one point to the group. [LO2]

- Teaching-learning: The teaching-learning script take as a starting point the card game activity and presents some facts aiming to raise awareness for climate change. The World Health Organization (WHO) has categorically termed climate change as the single biggest health threat facing humanity. The adverse effects of climate change are becoming more evident not only on the socioeconomic structures and systems that regulate life on our planet but also on the essential determinants of health such as clean air, safe drinking water, sufficient food and secure shelter. Climate change will only affect the existent inequities in health systems in a colossal manner, further compounding and exacerbating existing health inequalities. On the other hand, animal health is also affected by climate change: biodiversity loss, changes in patterns of migration of species (e.g. birds, mosquitoes, and sea animals), which bring about changes in ecosystems and, in turn, affect human health. [DER9-11, DER25-29]

- Learning objects
  - Concepts related with climate change (cards game) [LO2]
  - What is climate change? [DER9]
  - How does climate change impact health? [DER10]

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- Decarbonization and health [DER11]
- Fast facts on climate and health WHO [DER25]
- Fact sheet – Climate change and health WHO [DER26]
- Climate change and health: What we can do individually to tackle climate change? – Youtube animated video [DER27]
- Climate Action tracker – Map [DER28]
- Fact Sheet PAHO [DER29]

➢ Suggested homework: students perform research work with the purpose of identifying more scientific evidence about climate change and actions to fight it at the individual and community level. They are asked to identify the source of the evidence .

Lesson 4: The origin of pandemics – an interplay of factors

➢ Learning objective: at the end of lesson 4 students should be able to explain what a pandemic is and identify the major drivers of epidemics and pandemics in an environmental perspective. During the teaching-learning activities students explore, analyze and present data relevant to characterize factors contributing to pandemics outbreaks.

➢ Homework of lesson 3: Students present the results of their homework and the entire class discuss the findings.

➢ Teaching-learning: the concepts of epidemics and pandemics are explained, using the example of COVID-19. Thereafter, students have an overview of major factors that influence the emergence of infectious diseases and their evolution through epidemics to pandemics, as well as relevant preventive action at the individual and societal level. A video about the history of pandemics is presented in the classroom. [DER12-14, DER30-32]

➢ Group activity: A set of cards with data of each pandemic is distributed to students. Students must order pandemics considering the attributed mortality. [LO3]

➢ Learning objects:
- Zoonoses and pandemics [DER12]
- From epidemics to pandemics [DER13]
- Anthropogenic activities and pandemics [DER14]
- Cards with mortality data from pandemics [LO3]
- Article from LabXchange: What is the coronavirus outbreak? [DER30]
- WHO video: COVID-19 Myths Vs Science [DER31]
- Enciclopeda Britannica: Brief history of pandemics [DER32]

Lesson 5 - Scientific method, data sources, and way-forward

➢ Learning objective: during this lesson and as wrap-up moment, students are invited to elaborate an infographic about zoonotic diseases, environment and One Health. The scientific method is presented as a guidance for the development of the school project.

➢ Teaching-learning activity: the scientific method is explained. Additionally, information about the difference between scientific facts and misinformation is provided, with some examples. [DER33]

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- Guided activity: Each group will be dedicated to a zoonotic disease. This activity is dedicated to the organization of School Research Project. School Research Project is described down, in an autonomous section.

- Assessment questionnaire [DER15]

- Learning objects:
  - Questionnaire – quantitative assessment [DER15]
  - Scientific method - steps [DER33]

Supplementary learning resources and educational activities

How does a degradable environment impact directly and indirectly on human and animal health?
During session 1 (school research project) is organized:

- Visit to Egas Moniz – Cooperativa de Ensino to visit the facilities that support the development of the degree in Veterinary Medicine (veterinary hospital, laboratories). The visit is guided by the professors and veterinarians working in the facilities. These activities are relevant for students' connections with possible STEM curriculums and careers.

School Research Project

Questions
What is the origin of this zoonotic disease?
How is this zoonotic disease preventable?
What is the relation between climate change, biodiversity loss and pandemics? How these drivers have an impact in the zoonotic disease?

Research management, design and administration
Sessions 1-2
Collection of documents and articles for bibliographical analysis.
Evaluation of the documents based on criteria and selection of the relevant information.
Identify effective presentation formats.

Sessions 3-4
Challenge: build an infographic about the zoonotic disease!
Method *(summary)*: students are organized in groups; each group addresses one zoonotic disease. The project challenges each group of students to create and present an infographic that synthetizes: a) what they have learned throughout the teaching-learning sequence; b) ideas emerged during the visit to the University; c) guided research on policy measures for the community to prevent zoonotic diseases (Phase 1).

Tip: Build your infographic in Canva!

Sessions 5-6
Challenge: collect data about community' perceptions and knowledge of the learned concepts: climate change, environmental health, animal health, zoonotic diseases. Students build a brief questionnaire (some questions are proposed in the scenario) and thereafter analyze the answers, trying to identify the community knowledge gaps and where is most important to develop knowledge dissemination activities in the future. In the end, build an infographic to summarize the results.

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Before starting the infographics, take a look at these infographics and texts! These will help you to have some ideas on how to organize the information.
Citizens' perceptions
Facts about zoonotic diseases

Development process:
The project is based on guided research about zoonotic diseases, climate change, and environmental issues around them. The six sessions will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.
During the sessions 1-2, students will perform bibliographic search using keywords provided by the teachers (e.g. zoonotic disease, prevalence, Portugal, transmission). Students will be asked to select the adequate data sources for their specific topic (zoonotic disease); this selection will be checked by the teachers mainly regarding the fiability of information. Thereafter, students will select the adequate data to answer the question guiding this project. Students will be asked to identify alternative communication platforms to present results.
During the sessions 3-4, students will be asked to create an infographic dedicated to their specific zoonotic disease, where all the data collected during sessions 1-2 will be used. It is also important to integrate the previous knowlegde obtained throughout the teaching-learning sequence.
During the sessions 5-6, students develop observational and data collection activities within their community. To address the topic, in the session 5, students are asked to perform inquiry-based activities (interviews) in the community (family members, neighbours, commercial stores), answering the following questions:

1. What is climate change?
2. What are environmental determinants of health?
3. What do animal health and human health have in common?
4. What is a zoonotic disease?
5. How does animal health affect the emergence of pandemics?
6. What can we do at our community level to prevent climate change and pandemics?
7. What is your workplace/school doing to fight climate change?
8. What can we do to minimize our impact in the environment?
9. Which government/local initiatives do you know about climate change?

In session 6, with supervising, students will analyze the answers and based on the knowledge from the previous moments of school project and the teaching-learning sequence, they identify the knowledge gaps in the community. These gaps will be important to identify future health literacy activities to be developed. The final infographic should cover suggested action for community leaders and policy makers. Students will be advocating better conditions for their community and show their relationship with citizens health and climate change.

Teaching-learning process milestones:
1. Students will be able to incorporate evidence in their infographic coming from reputable data sources to support their ideas and show media literacy.
2. Students will be able to communicate the merits and limitations of various data and information sources considered in the work process.
3. Students will be able to identify and communicate environmental factors that contribute to climate change in their community.
4. Students will be able to identify and communicate evidence-based policy measures to prevent and mitigate climate change effects in communities.
5. Students will be able to use scientific argumentation to justify policy choices.

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Teaching-learning process for school project (summary):

1. Collection of evidence (data, articles, pictures).
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Identify effective presentation formats.
4. Produce the infographics.
5. Present the infographic in open schooling event.

Organization of the open schooling event:

1. Each project output (infographic) is presented by the students in a community setting (e.g., exposition center, garden, museum, science fair).
2. Students will communicate policy measures using science-based argumentation. Students appeal to the action of all in health of the community, providing great understanding that health literacy and health promotion is a responsibility of all, not only of the ministry of health or healthcare providers.
3. Students, parents, school community and relevant local stakeholders attend the event and understand how pandemics is influenced by a set of social and environmental factors that in turn affect both animal and human health. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, community).

Data Analysis and Reporting

Infographic based on science-driven data and information research.
Content Analysis.
Report writing with most important findings.
Development of presentation.

Target Audience for Recommendations

Parents, science teachers, local community – public.
Public Health, Environment and Animal Health Authorities and other stakeholders (farmers, industry, ma nagers).

Public Debate and Recommendations (based on research results)

Presentation of the infographics by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.
Release of initial draft report and preliminary recommendations for feedback.
Discussion and feedback.
Release of revised report and recommendations for public consultation.
Evidence-based recommendations that follow the ONE HEALTH approach.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: The role of environment and animal health in zoonotic diseases and pandemics"

Knowledge	
1. Recognizes and characterizes the environmental factors that affect human and animal health. Identifies the environmental determinants of health and understands their relationship with climate change and SDGs	**Question 1.1:** What are the main compartments of environment affecting human health? A) air, water, soil, flora, and fauna. B) air, water. C) air, water, soil, flora, and fauna. air, soil. **Question 1.2:**

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	What of the following sentences are NOT true? A) Environment does not have an influence in human and animal health. B) There are diseases that affect simultaneously humans and animals. C) Climate change affects only human health. **Question 1.3.** What are the SDGs more related with climate change? A) SDG 7, 12, 13, 14, 15. B) SDG 13. C) SDG 14 and 15.
2. Identifies the disruptive changes in animal health that influence the emergence of zoonotic diseases.	**Question 2.1:** What are the dimensions of One Health? A) environmental health, human health and animal health. B) environmental health and animal health. C) environmental health and human health. **Question 2.2:** What of these modifications in animals can influence the emergence of zoonotic diseases? A) habitat, temperature, availability of food, human activities. B) only human activities. C) only climate change.
3. Identifies the most important characteristics of pandemics.	**Question 3.1:** Refer three characteristics of pandemics: A) worldwide outbreak, disease, affecting large proportion of population. B) local outbreak, disease affecting large proportion of population. C) local outbreak, disease affecting reduced proportion of population **Question 3.2:** Refer three challenges of pandemics for health systems: A) Health care systems overloaded, inadequate medical supplies, economic and social disrupting. B) Travelling prohibited, food scarcity, jobs losses. C) Educational institutions closed, gymnasiums closed, cultural activities stopped.
4. Identifies measures and proposes general action to mitigate and adapt to climate change.	**Question 4.1:** What are the main characteristics of climate change? A) increase of sea and air temperatures, drought, extreme weather events. B) increase of air temperatures and storms. C) decrease of air temperatures. **Question 4.2:** What are the factors contributing to climate change? A) Greenhouse gases emission, air pollution, deforestation. B) Deforestation. C) Planting new trees.
5. Identifies relevant changes of climate change and identifies suitable indicators to monitor the changes.	**Question 5.1:** What are the best indicators to monitor climate change? A) levels of air pollution, temperatures of sea and air, levels of greenhouse emissions. B) Only temperature of sea and air. C) Only levels of air pollution.

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6. Identifies relevant action to address environmental challenges at the community and societal level.	**Question 6.1:** Which type of actions in your community may be implemented to address the environmental challenges? A) promotion of use of public transportation, have some trees or plants in balconies, and reduce acquisition of plastic products. B) promotion of use of private car. C) increase the acquisition of plastic products. **Question 6.2:** Which type of actions in your community may be implemented to contribute to mitigate climate change? A) Reduce energy consumption, promote the use of 100% and reduce waste production B) Buy only new products (e.g. mobile phones) even when the old one are still working C) Use air conditioning always in the maximum level.
SKILLS	
12. Selects appropriate concepts, indicators and evidence to characterize environment changes that can cause harm to human and animal health.	**Question 1.1** Which data sources may be used to characterize the environment modifications? A) Temperature registries, water quality and air quality data. B) National Statistics on Economic Development. C) Data retrieved by google searches.
13. Can anticipate the consequences of changes in the environment (e.g., air pollution, biodiversity loss, climate change) in environmental determinants of health and the emergence of zoonotic diseases.	**Question 2.1** Which data sources may be used to anticipate the consequences of the environment modifications? A) Notifications of zoonotic diseases B) National Statistics on Economic Development. C) Data retrieved by google searches. **Question 2.2** How can we mitigate the impact of the changes in the environment? A) Scenario planning involving the creation of several potential scenarios that might develop in the future and adaptive management. B) Wait and see what other countries do. C) Do nothing because in the end everything will be solved.
14. Can adopt mitigation measures (e.g., using public transportation instead of private car).	**Question 3.1** What actions can be taken to mitigate the effects of climate change? A) Preserving biodiversity, using public transport, recycling B) Buy new products C) Always travel in your own car

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15. Can propose concrete action towards mitigation of environment degradation in their/others routine.	**Question 4.1** I feel able to adopt individual attitudes in my day-to-day life that lead to mitigate the environment degradation. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 4.2** I feel able to identify actions that lead to mitigate the environment degradation. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree
16. Feels able to influence the adoption of environment degradation mitigation measures by others (e.g., family, peers, friends).	**Question 5.1** I feel able to influence the adoption of actions that help mitigating the effects of climate change by others (family, friends). 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 5.2** I will try to influence the adoption of actions that help mitigating the effects of climate change by others (family, friends). 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree
17. Selects appropriate sources to characterize climate change and other environmental changes impacting human and animal health in a scientific perspective.	**Question 6.1** To find scientific information about the climate change and other environmental changes impacting human and animal health, I should consult the following sources. A) researchers, scientific publications, United Nations SDG tracker. B) newspapers, google, youtube. C) friends, journalists, facebook.
18. Is able to identify the problems and challenges of the community in relation to environmental degradation (e.g., air pollution, climate change) and connect them with SDG 3 (health and well-being) and find the relevant resources to address them.	**Question 7.1** I feel able to identify the main problems my community faces in relation to environmental degradation (e.g., air pollution, climate change) and connect them with SDG 3 (health and well-being). 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 7.2** I can understand how the challenges my community faces are related to environmental degradation (e.g., air pollution, climate change) and connect them with SDG 3 (health and well-being). 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree

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Beliefs, attitudes and behavior There are no correct or incorrect answers; we are only interested in knowing your perspective.	
16. Believes that environmental degradation is a relevant factor in the emergence of pandemics.	**Question 1.1** My participation and actions will increase the mitigation of environmental degradation. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 1.2** The mitigation of environmental degradation is relevant to reduce the emergence of pandemics. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 1.3** My family and friends think that I should adopt actions to contribute to the mitigation of environmental degradation. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree
17. Believes that scenarios such as climate change influence the incidence of zoonotic diseases.	**Question 2.1** The climacteric characteristics are a relevant factor for the development of zoonotic diseases. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 2.2** The climate change influences the incidence of zoonotic diseases. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 2.3.** The mitigation of climate change effects may have an important contribute for the prevention of zoonotic diseases. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree

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18. Believes that is important to adopt measures to prevent environmental degradation.	**Question 3.1** I will try to eat a healthy diet and drink a lot of water in my day-to-day life. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 3.2** I plan to incorporate recycling in my day-to-day life. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 3.3** I plan to donate non-perishable foods and things that I no longer use in the next three months. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 3.4** I plan to save water and electricity in the next three months. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 3.5** I will make an effort to walk, bike or take public transport instead of using car or motorcycle as much as possible in the next three months. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 3.6** Among the following statements, choose the one that best describes what you currently think. 1) I do not promote sustainability in my day-to-day life, and I also have no intention of doing so. 2) I do not promote sustainability in my day-to-day life, but I have been thinking about the possibility of starting to do so. 3) I never or rarely promote sustainability in my day-to-day life, but soon I will start doing it on a regular basis. 4) I do promote sustainability in my day-to-day life regularly, but I have only begun to do so in the last 6 months. 5) I do promote sustainability in my day-to-day life regularly I have been doing so for longer than 6 months.

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19. Reproves patterns disregarding climate change in our communities.	**Question 4.1.** I reprove patterns disregarding climate change in my community. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 4.2.** The identification of obstacles and problems that my community faces are crucial for solving them. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree
20. Is committed to communicate and address the problems and challenges of the community in relation to the environmental determinants of health and to contribute to the SDGs.	**Question 5.1** I will try to communicate the problems related with the influence of environment in human health within my community. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 5.2** I will try to address the challenges posed environmental issues by promoting more sustainable behaviors in my community. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 5.3.** It is important to employ efforts to achieve the SDGs. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 5.4** It is possible to employ efforts to achieve the SDGs. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 5.5** It is common knowledge that it is necessary to employ efforts to achieve the SDGs. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree

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	Question 5.6 I know that a contribute for the attainment of each SDG is a contribute for the attainment of all SDGs because they are interconnected. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree

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23. Specifications for an educational scenario on the topic of "non-communicable diseases"

Main Partner responsible: UNL (School of Public Health)

Context

The educational system has a central role in protecting children and youths' health and well-being.
The educational scenario supports teachers and school community in exploring societal concerns around the determinants of health and prevalence of non-communicable diseases (NCDs) - major causes of premature deaths (< 70 years) worldwide - using updated scientific evidence. The teaching-learning script supports students in understanding this public health threat and understand on how STEM (Science, Technology, Engineering, Mathematics) contribute to approach and fight the major challenges of public health, contribute to evidence-based personal decision-making and public policy. The scenario explores the most important influences on humans' health and strengths abilities to prevent NCDs, by creating awareness on healthy lifestyles, social and environmental influences, and modifiable risk factors. It also supports students' participation in civic society initiatives and in the design of local responses for the issue, while providing significant interactions with the community and STEM related professions (researchers, public health specialists, data scientists, policy makers, enterprises). The scenario is based on the mandatory curriculum of natural sciences at an European level and promotes the following fundamental learnings:

- Distinguish health from quality of life.
- Understand the main determinants of health and well-being.
- Characterize the main non-communicable diseases, indicating the prevalence of associated risk factors.
- Interpret information on the determinants of individual and community health, analysing their importance in the quality of life of a population.
- Critically analyse action strategies in the promotion of individual, family, and community health, starting from issues framed in local, regional or national problems.

Scientific content and its relevance to public health education

NCDs are a leading cause of death, quality of life loss and disability worldwide, caused by a combination of genetic, physiological, environmental and behavioural factors. Successful prevention and control of NCDs depends on the willingness of individuals to make early decisions that prevent or mitigate modifiable risk factors and their disposal to commit to healthy lifestyles. There is evidence that life-long health behaviours are shaped during childhood and adolescence and informed children and youths can also have a contribution for healthy families and sustainable communities. Over half of NCD-related deaths are associated with behaviours that begin or are reinforced during adolescence (WHO, 2022).
On the other hand, the onset of NCDs or related risk factors in children impacts learning achievements. Tobacco and alcohol use, bad nutrition and being physical inactive (*to mention only a few*) all keep children and adolescents from making the most of their education. Well-nourished, physically active children learn better. Overweight and obese children are more likely to suffer from depression, low self-esteem, and other behavioural and emotional difficulties as well as stigmatization, and social isolation. Tobacco (nicotine) and alcohol are addictive, and addiction impairs learning due to its impact in brain structure and function in children. Alcohol use also results in violence, road traffic injuries and unwanted pregnancies (*to mention only a few*), which contributes to school absenteeism.
However, there are gaps in students and citizens access to updated evidence regarding NCDs and health information that is written and simply handed out is often not effective in promoting healthy lifestyles. Active methods, such as face-to-face interactions, have been shown to be more effective in people engagement to promote health, prevent disease, cope with illness and disability, and better health outcomes.

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Fortunately, science curriculums at different levels promote knowledge development regarding NCDs and risks associated with smoking, alcohol consumption, unhealthy diets, physical inactivity, among others. Teachers are challenged to incorporate health and well-being as a central topic in their classes and in teaching science using high-level methods, high-quality learning objects, and updated evidence. This scenario supports them on this mission. It also challenges them to have a contribution for the community health by engaging families in educational activities and reaching the local community with inquiry-based projects and open schooling events leaded by students.

Subject: Science classes
Grade: 9th grade (+/- 14-15 years old students)
Title of educational scenario: individual and socioenvironmental influences on humans health and the burden of non communicable diseases.

Estimated duration

5 sessions of 40-45 minutes (lesson 1 – lesson 5)
5-6 sessions of 40-45 minutes for supplementary learning activities and school project (lesson 6 – lesson 12)

Classroom organization requirements

From lesson 1 to lesson 5 students work alone or occasionally in groups. During lessons 3, 4 and 5 they are asked to work in groups and the use of computer is required.
From lesson 6 to lesson 12 students form four- or five-member groups which carry out the school project. The use of computer may be required.

Content glossary

Air pollution. The presence of contaminant or pollutant substances in the air at a concentration that interferes with human health or welfare, or produces other harmful environmental effects.

Burden of disease. The burden of disease is a measurement of the gap between a population's current health and the optimal state where all people attain full life expectancy without suffering major ill-health.

Capacity building. In health promotion, capacity building is the development of knowledge, skills, commitment, partnerships, structures, systems and leadership to enable effective health promotion actions.

Community action for health. Community action for health refers to collective efforts by communities that are directed towards increasing community control over the determinants of health, and thereby improving health.

Collaboration. A recognized relationship among different sectors or groups, which have been formed to take action on an issue in a way that is more effective or sustainable than might be achieved by the public health sector acting alone.

Community participation. Procedures whereby members of a community participate directly in decision-making about developments that affect the community. It covers a spectrum of activities ranging from passive involvement in community life to intensive action-oriented participation in community development (including political initiatives and strategies).

Critical Thinking: The mental processes used when evaluating information that has been put forth as true. Consists of reflection, examination, and formation of judgement. Information is gathered through communication, experience, reasoning and observation. While based in values of intellect, critical thinking goes beyond subject/matter division.

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Determinants of health. The range of personal, social, economic and environmental factors that determine the healthy life expectancy of individuals and populations.

Disease prevention. Disease prevention describes measures to reduce the occurrence of risk factors, prevent the occurrence of disease, to arrest its progress and reduce its consequences once established. Primary prevention is directed towards lowering the prevalence of risk factors common to a range of diseases (such as tobacco and alcohol use, obesity and high blood pressure) in order to prevent the initial occurrence of a disorder, for example through behaviour change advice. **Secondary prevention** is directed towards early detection of existing disease with a view to arresting or delaying the progression of the disease and its effects, for example through screening and other early detection programs such as routine health checks. **Tertiary prevention** generally refers to disease management strategies and/or rehabilitation intended to avoid or reduce the risk of deterioration or complications from established disease, for example through patient education and physical therapy.

Ecological Footprint. The impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated. More simply, it is the amount of the environment necessary to produce the goods and services necessary to support a particular lifestyle.

Equity/equitable. Equity means fairness. Equity in health means that peoples' needs guide the distribution of opportunities for well-being. Inequities occur as a consequence of differences in opportunity, which result, for example in unequal access to health services, nutritious food or adequate housing. In such cases, inequalities in health status arise as a consequence of inequities in opportunities in life.

Environmental determinants of health. The physical conditions in which people live and work that have an impact on health.

Evidence. Information such as analyzed data, published research findings, results of evaluations, prior experience, expert opinions, any or all of which may be used to reach conclusions on which decisions are based.

Evidence-based: Based on approaches that are proven effective with consistent results when making decisions related to countermeasure strategies and projects.

Health. A state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.

Health behaviour. Any activity undertaken by an individual for the purpose of promoting, protecting, maintaining or regaining health, whether or not such behaviour is objectively effective towards that end.

Health education. Health education is any combination of learning experiences designed to help individuals and communities improve their health by increasing knowledge, influencing motivation and improving health literacy.

Health for All. The attainment by all the people of the world of a level of health that will permit them to lead a socially and economically productive life regardless of who they are or where they live.

Health literacy. Health literacy represents the personal knowledge and competencies that accumulate through daily activities, social interactions and across generations. Personal knowledge and competencies are mediated by the organizational structures and availability of resources that enable people to access, understand, appraise and use information and services in ways that promote and maintain good health and well-being for themselves and those around them.

Health policy. Health policy refers to decisions, plans, and actions that are undertaken to achieve specific health care goals within a society.

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Health promoting schools. A health promoting school can be characterised as a school constantly strengthening its capacity as a healthy setting for living, learning and working.

Healthy life expectancy. Healthy life expectancy is a population-based measure of the proportion of expected life span estimated to be healthful and fulfilling, or free of illness, disease and disability according to social norms and perceptions and professional standards.

Health promotion. Health promotion is the process of enabling people to increase control over, and to improve their health.

Health outcomes. A change in the health status of an individual, group or population that is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status.

Health research. A systematic, thorough and formal process of inquiry or examination used to gather facts and information in order to understand, define and resolve a public health issue.

Health status. The state of health of a person or population assessed with reference to morbidity, impairments, anthropological measurements, mortality, and indicators of functional status and quality of life.

Incidence. The number of cases of disease that have their onset during a prescribed period of time. It is often expressed as a rate. Incidence is a measure of morbidity or other events that occur within a specified period of time.

Infectious. Capable of causing infection or disease by entrance of organisms (e.g., bacteria, viruses, protozoan, fungi) into the body, which then grow and multiply. Often used synonymously with "communicable".

Life expectancy. The average number of years an individual of a given age is expected to live if current age-specific mortality rates continue to apply.

Life expectancy at birth. The average number of years that a newborn could expect to live, if he or she were to pass through life exposed to the sex- and age-specific death rates prevailing at the time of his or her birth, for a specific year, in a given country, territory, or geographic area.

Lifestyle. A way of living based on identifiable patterns of behaviour which are determined by the interplay between an individual's personal characteristics, social interactions, and socio-economic and environmental living conditions.

Morbidity. A measure of disease incidence or prevalence in a given population, location or other grouping of interest.

Mortality. A measure of deaths in a given population, location or other grouping of interest. The death rate; the ratio of the number of deaths per year to a given population.

Noncommunicable diseases. also known as chronic diseases, tend to be of long duration and are the result of a combination of genetic, physiological, environmental and behavioural factors. The main types of NCD are cardiovascular diseases (such as heart attacks and stroke), cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) and diabetes.

Partnerships for health. A recognized relationship between two or more partners to work cooperatively towards a set of shared health outcomes in a way that is more effective, efficient, sustainable or equitable than could be achieved by one partner acting alone.

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Prevalence. The number of cases of a disease, infected people or people with some other attribute present during a particular interval of time.

Public health. An organized activity of society to promote, protect, improve, and – when necessary – restore the health of individuals, specified groups, or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.

Research. Activities designed to develop or contribute to knowledge, e.g., theories, principles, relationships, or the information on which these are based. Research may be conducted simply by observation and inference, or by the use of experiment, in which the researcher alters or manipulates conditions in order to observe and study the consequences of doing so.

Risk: The possibility of an unwanted event; usually the possibility will be quantified as a probability and the event will be described in terms of its consequences, resulting in this definition of risk: Risk= Probability x Consequence

Skills for health (life skills). Skills for health consist of personal, interpersonal, cognitive and physical skills that enable people to control and direct their lives, and to develop the capacity to live with and produce change in their environment to make it conducive to health.

Social capital. Social capital represents the degree of social cohesion that exists in communities. It refers to the processes between people that establish networks, norms and social trust, and facilitate coordination and cooperation for mutual benefit.

Social determinants of health. The social determinants of health are the social, cultural, political, economic and environmental conditions in which people are born, grow up, live, work and age, and their access to power, decision-making, money and resources that give rise to these conditions of daily life.

Sustainability. Meeting the needs of the present without compromising the ability to meet future needs.

Sustainable behaviour. Behaviour that minimises the negative impact of one’s actions on the physical, social and economic environment.

Sustainable Development Goals (SDGs). Also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The 17 SDGs are integrated—that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability.

Well-being. Well-being is a positive state experienced by individuals and societies. Similar to health, it is a resource for daily life and is determined by social, economic and environmental conditions.

Years of life lost (YLL). The number of years of life lost due to premature mortality.

Sources: Public Health Agency of Canada; EuroHealthNet; National Library of Medicine; WHO

Pedagogical glossary

Active Learning. A teaching and learning approach that “engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.”.

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or

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concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills.

Debate Technique. A verbal technique used with the purpose of involving a group in a certain theme that will be exposed. This technique consists of dividing two or more subgroups in which each one participates in the discussion of a general theme and in the construction of a "general commitment" of all.

Group Work. Deepens knowledge, develops research and problem-solving skills; develops attitudes of participation, cooperation, creativity and collaboration; develops teamwork attitudes, social skills and knowledge.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

Lifelong learning. A broad concept where education that is flexible, diverse and available at different times and places is pursued throughout life. It takes place at all levels—formal, non-formal and informal—utilizing various modalities such as distance learning and conventional learning.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Knowledge: a familiarity, awareness or understanding of someone or something, such as facts, information, descriptions, or skills, which is acquired through experience or education by perceiving, discovering, or learning.

Skill: The ability to carry out a task with pre-determined results often within a given amount of time, energy, or both. Skills can often be divided into domain general and domain-specific skills.

Indicative literature

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Muller-Riemenschneider, F, et al. (2008). "Health-economic burden of obesity in Europe." Eur J Epidemiol, 23: 499-509.

World Health Organization. (2002). The world health report 2002: Reducing risks, promoting healthy life. Geneva: World Health Organization.

Competences / Learning Goals

Key Competences

STEM / Personal, social and learning to learn, citizenship

Knowledge

Medical science concepts:

- Major NCDs
- Relationship between NCDs and risk factors.
- Long-term conditions related with NCDs.

Epidemiology and health economics concepts:

- Disease burden
- Indicators of disease burden.

Social ang global health concepts:

- Health, health literacy, quality of life.
- Relationship between lifestyles and NCDs (determinants of health).
- Relationship between living conditions and NCDs (determinants of health).
- Sustainable Development Goals (SDG 3 and its relationship with other SDGs).
- Urbanization and environmental health challenges.
- Public policy on NCDs and its determinants.

Knowledge - outcome assessment:

1. Recognizes and characterizes the major NCDs.
2. Identifies the most important risk factors for each NCD.
3. Identifies measures and proposes general action to fight NCDs.
4. Defines burden of disease and identifies indicators to measure it.
5. Identifies the determinants of health and understands their relationship with NCDs and SDGs.

Skills (abilities/competences)

General: curiosity; collaboration; critical thinking; self-awareness, citizenship

Specific:

✓ Finding, analyzing, and interpreting scientific data, texts and dynamic graphical representations to understand the burden of diseases.

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- ✓ Understanding the difference between facts and opinions, understanding how to find fake claims, evaluate the reliability of health-related information, based on multiple factors affecting the reliability of information.
- ✓ Understanding the relevance of scientific evidence to explain phenomena related to health and illness and produce argumentation.
- ✓ Obtaining, assessing, and communicating evidence related to NCDs.
- ✓ Assessing personal and community risks and patterns of risky and protective behavior.
- ✓ Analyzing the consequences of healthy and unhealthy lifestyles on self and on the community.
- ✓ Analyzing the influence of living conditions on self and on the community.
- ✓ Understand appropriate strategies to reduce personal and community risk and getting access to the relevant resources.

Skills – outcome assessment:

4. Selects concepts, indicators, and evidence to characterize disease burden.
5. Can anticipate the consequences of unhealthy lifestyles.
6. Can adopt a healthy lifestyle
7. Feels able to propose concrete action towards adopting healthy lifestyles in his/her routine.
8. Feels able to influence the adoption of healthy lifestyles by others (e.g., family, peers, friends).
9. Selects appropriate sources to characterize NCDs in a scientific perspective.
10. Can identify the problems and challenges of the community in relation to NCDs, relate them with SDG 3 (health and well-being) and find the relevant resources to address them.

Affective /Attitudes/Behaviour (*beliefs)*

- ✓ Adopting general risk perception attitudes.
- ✓ Adopting attitudes towards minimizing the risk of NCDs (e.g., practicing physical exercise, limiting alcohol and sugar consumption, avoiding exposure to tobacco, protecting the environment).
- ✓ Adopting attitudes supporting health phenomena, sustainable development (target 3.4.1), urban and environmental health challenges.
- ✓ Engaging public speaking and debating of measures to reduce risks, with a particular focus on public policy concerned with community health.

Affective, Attitudes and behavior - outcome assessment:

7. Believes that health is a fundamental component of quality of life.
8. Believes that lifestyles influence the incidence of NCDs.
9. Believes that is important to adopt a healthy lifestyle to prevent NCDs and stay healthy.
10. Reproves patterns of risky and unhealthy behavior in his/her living environment.
11. Adopts a healthy lifestyle.
12. Is committed to communicate and address the problems and challenges of the community in relation to the determinants of health and to contribute to the SDGs.
13. Attitude towards NCDs and a healthy lifestyle.

Learning goals and outcomes

- ✓ Uses online tools to plot tables, graphs, and maps, using updated data.
- ✓ Analyzes the consequences of healthy and unhealthy lifestyles on human beings and environment.
- ✓ Obtains, evaluates, and communicates data and scientific information about NCDs.
- ✓ Uses evidence to build argumentation on NCDs.
- ✓ Gives examples of issues affecting the prevalence of NCDs in the community.
- ✓ Describes different approaches to protect, develop and influence community health.
- ✓ Uses evidence to propose measures and methods to fight NCDs and communicates them to the community leadership.

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<u>Assessment methods</u>

- Outcome assessment
  - Quantitative – questionnaire in paper.
  - Qualitative - students project: a. systems map; b. Infographic

✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

<u>Content</u> (relevant to learning goals & research topics)

STEM content

- Data science on the determinants of health
- Concepts and indicators of disease burden.
- Major noncommunicable diseases. Heart disease, cancer, chronic respiratory disease, diabetes.
- Epidemiology of NCDs.
- Physiopathology and major risk factors for NCDs.
- Data science representations of health and disease phenomena.

Non-STEM content

- Living conditions, urban and modern living, lifestyles.
- Quality and trustfulness of information sources, facts, opinions, fact-checking techniques.

Digital learning objects and educational resources

<u>New:</u>

- Concept of health (*infographic*) [ER1 – ER3]
- Health as a component of quality of life (*infographic*) [ER4 – ER11]
- Health determinants: lifestyles and living conditions (*infographic*) [ER12 – ER22]
- Health determinants and SDGs (*infographic*) [ER23 – ER24]
- SDG 3 is connected with other SDGs (*set of infographics*) [ER25 – ER29]
- General attributes of a healthy community (*images*) (*video*) [ER30 – ER32]
- Features of positive neighborhoods: healthy & eco-friendly (*infographic)* [ER33]
- Health and disease burden - concepts and indicators - LY, QALY, YLD, YLL, premature death (*infographic*) [ER34 – ER38]
- Disease burden of NCDs (*infographic*) [ER39 – ER47]
- NCDs, risk factors, lifestyles, relevant individual action (infographics) [ER48 – ER64]
  - Cardiovascular Disease [ER54 – ER64]
  - Chronic Obstructive Pulmonary Disease [ER65 – ER69]
  - Cancer [ER70 – ER76]
  - Diabetes [ER77 – ER83]
- Concepts related with NCDs (*game)* [LO84 – LO85]
- Template for system mapping by students (*ppt file*)

The system map as a tool to support understanding of the dynamics of science and social aspects surrounding the prevalence of *non-communicable diseases* from a system thinking perspective. The tool makes visible the connections between risk factors (e.g., high sugar intake), diseases (e.g., diabetes) and long-term conditions related with NCDs (e.g., vision loss).

- Template for students to describe facts about NCDs
- Template for students to design the scientific poster

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- Primary prevention (*infographic*) [ER86-87]
- Secundary prevention *(infographic)* [ER88]
- Terciary prevention (*infographic*) [ER89]

From other sources/high-quality platforms:

- Determinants of health

Life expectancy 2002-2019 Europe - EUROSTAT dynamic map [LO15]
Life expectancy at birth 2019 Europe, regions, cities- EUROSTAT dynamic map [LO16-18]

- Health and disease burden [ER 47]

Eurostat (europa.eu)
Diabetes prevalence
Cancer incidence, 2017
Eurostat (europa.eu)
WHO GLOBAL HEALTH ESTIMATES 2019
Noncommunicable diseases (who.int)

Link for the resources (*under development*):
Session 1 and 2: https://www.canva.com/design/DAE1uXuidgU/xrIbZb3qQFNayVF6LNcKSQ/edit
Session 3: https://www.canva.com/design/DAE8eFZ0_Jw/y3C8AmhA5bH1GYsDtWEt7A/edit
Session 4 and 5: https://www.canva.com/design/DAE8eYgMIVQ/VBiMXKzqbpf4HxNdysS9GA/edit

Supplementary learning objects and educational resources:

- Risk factors for NCDs

Risk factors summary OMS [ER]
Risk factors preventable OMS [ER]
Tobacco How Smoking Kills - YouTube [ER]

- Non-communicable diseases incidence

NCDs cases by cause (cardiovascular disease, diabetes, cancer) EUROSTAT: Population [LO]
Europe distribution Cancer incidence - interactive map [LO]
Europe distribution Diabetes (% population)- interactive map [LO]
Europe distribution Cardiovascular disease - interactive map [LO]

- Non-communicable diseases burden

Global health estimates Deaths 2019 World Bank database [LO]
Global health estimates DALYs 2019 World Bank database [LO]
World distribution NCD global mortality - interactive map [LO]
World distribution NCDs global premature deaths OMS - table [LO]
World distribution NCDs deaths by cause OMS - table [LO]
World distribution Major causes of death - interactive map [LO]
World distribution Cancer deaths by type - interactive map [LO]
World distribution Stroke deaths rates [LO]

- Urbanisation

European project Lisbon case studyUrban environment and health in Lisbon, Portugal, 2017 - YouTube [ER]
Project for public spaces Healthy places [ER]
Project for public spaces Placemaking guidelines and initiatives [ER]

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Project for public spaces Questions healthy places [ER]
Tool for Place Standard [LO]

- Heart disease

Ataque cardíaco – Astrazeneca video [ER]
Insuficiência Cardíaca – SPC video [ER]
O que é a insuficiência cardíaca – Astrazeneca article [ER]
WHO: animated video on heart disease 1 (risk factors) [ER]
WHO: animated video on heart disease 2 (who should I ask for health advice) [ER]
WHO: animated video on heart disease 3 (How can I help my family get healthy?) [ER]
Move with heart - NIH video (healthy behaviours) [ER]
Heart and sleep - NIH video (Get Enough Sleep) [ER]
Exercise (Testimonial of a Youth)- NIH video [ER]
Exercise (Fact sheet youths) - NIH infograph [ER]
Heart failure clinical overview and management (video) [ER]
Heart Failure causes (video) [ER]

- Chronic respiratory disease

O que é a Doença Pulmonar Obstrutiva Crónica – Astrazeneca article [ER]
COPD - Nucleus Health video-[ER]

- Cancer

What Is Cancer? - video FuseSchool [ER]
What causes cancer - video [ER]
What causes cancer - video [ER]
How does cancer spread through the body - video [ER]

- Tobacco

EUROSTAT: Smoking of tobacco products by sex, age and country of citizenship [LO]
EUROSTAT: Frequency of alcohol consumption by sex, age and country of birth [LO]
EUROSTAT: Health-enhancing physical activity by sex, age and country of citizenship [LO]
WHO: Ban tobacco advertising, promotion, and sponsorship [ER]
WHO: Commit to quit tobacco [ER]
WHO: infographic tobacco 1 [ER]
WHO: infographic tobacco 2 [ER]
How smoking kills - video American Lung Cancer Screening Initiative [ER]

- Diabetes

What is type 1 diabetes - video Diabetes UK [ER]
What is type 2 diabetes - video Diabetes UK [ER]
Calculadora risco diabetes - APDP [LO]
Diabetes - fatores de risco - infografia DGS [ER]
Diabetes na adolescência - video DGS [ER]
Diabetes - avaliação de risco - folheto DGS [ER]
Diabetes infographic 1 - WHO [ER]
Diabetes infographic 2 - WHO [ER]
Diabetes type 1 and 2 - text - WHO Europe [ER]

Teaching -learning activities (lesson plan/ learning trajectory)

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Principal target:
Science classes
9^{th} grade (+/- 15 years old students)
4-6 sessions/classes of 40-45 minutes
Science teachers integrate other colleagues in the enactment of the scenario (e.g., ICT, visual education, mathematics and english teachers), as the implementation of scenario aims to be interdisciplinary.

Prerequisite knowledge and skills
Use of internet, use of web search engines, tools of Microsoft Office software (basic level), English (basic level).

Lesson 1: Health, quality of life, and wellbeing
At the end of lesson 1 students should be able to:
- Define health and quality of life and explain how they are related.
- Identify the general components of health and quality of life.
- Explain the general factors that influence humans' health.
- Identify general actions that can benefit the health and quality of life of the community.

➢ **brainstorming on the concept of health.**
This initial activity aims to assess general preconceptions and misconceptions of the students on the topic of health. Students are asked to pick 1 to 3 post-its and complete the phrase "A youth is healthy when...". Each student should produce between 1 to 3 phrases, write them in post-its and fix them on the white board or flip chart.
The teacher organizes their ideas in the three components of health: physical, mental and social.
Photos are taken and information is kept for next lessons (the teacher uses the information also to solve misconceptions and false claims this point forward).
The following Digital Learning Objects should be used at this stage: **concept and dimensions of health [ER1]**

Students get that health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1948). Is also the ability of every citizen to adapt and manage physical, social, and emotional challenges (Huber, 2011).
Students understand the difference between the three components – physical (absence of disease, illness, to be fit and able to perform daily tasks), mental (realization of one's worth and potential, being able to cope with normal type of stress and to feel good, to work productively and participate in contributing to the collective good), social (being able to create and sustain social relationships, have friends and have a sense of being supported).
Students recognize that health is a fundamental human right and an investment in a democratic and just society: "the extent to which an individual or group is able, on one hand, to realize aspirations and satisfy needs and, on the other hand, to change or cope with the environment; health is therefore seen as a resource for everyday life, not the objective of living: it is a positive concept emphasizing social and personal resources as well as physical capabilities (WHO, 1994).
The following Digital Learning Objects should be used at this stage: **concept and dimensions of health [ER2 – ER3]**

➢ **classroom discussion**
The teacher asks students about the difference between health and quality of life.
The discussion is conducted in a way students recognize that health is an essential component of quality of life. Students understand that quality of life represents the degree to which an individual enjoys important life-long possibilities and feels satisfied overall. In the discussion, becomes clear that quality of life is an

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individual perception of position in life, within the context of the culture and values, and in relation to individual goals, expectations, standards and concerns.
Students understand that health is not only a determinant of life expectancy, but also of the functional capabilities that, in turn, influence quality of life. Students are introduced to the individual dimension (perception about physical or mental health) and the community dimension (availability of community resources, which influences individual perceptions of health and functional status).
The following Digital Learning Objects should be used at this stage: **health as a component of quality of life [ER4-ER7]**

- **classroom discussion**

The teacher asks students about the components of quality of life (*What means having a good quality of life? What aspects mainly contribute to your quality of life?*).
Each student picks one sticky note and writes its major source of quality of life.
Groups are organized (3-4 students) and each student discusses with the other members his/her response. The group members, with the support of the teacher, choose to elect a couple of ideas that are presented in the front of the class, by one representative of each group.
The teacher moderates the discussion and takes photos to the white board (where sticky notes are with the ideas).

Then students are introduced to the factors that influence health and quality of life. The following Digital Learning Objects should be used at this stage: **quality of life wheel [ER8-ER10]**

The teacher proposes students to think about the school community with a particular focus on the environmental and housing conditions, local resources, infrastructures and services.Then students are asked to think about problems, issues and solutions that may benefit the community health and quality of life. Then group work is organized **[ER11]**

- **group work**:
  i. "What are the major sources of health and quality of life in our community?"
  ii. "What are the major issues affecting health and quality of life in our community?"
  ii. "Which proposals do you have to increase health and quality of life of our community?

Students work in groups to answer the questions.
Responses may be written in paper. They should be kept for the students' project.

Assessment task: Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

<u>Lesson 2: determinants of health</u>

At the end of lesson 2 students should be able to:

- ✓ Identify and explain the determinants of health.
- ✓ Explain the major sources of health and quality of life.
- ✓ Explain why SDG3 is related with the other SDGs.
- ✓ Explain the attributes of healthy communities.

The teaching-learning script starts with the following questions:

i. Has the expectancy of life increased or decreased in the past 100 years?
ii. Do people live longer or lesser today than they did at the beginning of the century? Why?

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[ER12-ER13] may be used at this stage. Students communicate their responses to the entire class. Then they are asked to look to **[ER13]** and explain and interpret the title of the article published in the Journal *Washington Post* in november 2019.

This initial activity aims to assess general preconceptions and misconceptions of the students on the topic of expectancy of life, reliable sources of health information and map:

- ✓ their initial perceptions on the need to search for information to base their answers.
- ✓ their initial perceptions on reliable sources of health information.
- ✓ their initial ability to discuss if the source of information is trustfull and if the information is updated or outdated.
- ✓ their initial perceptions on the determinants of health (if they think that expectancy of life is influenced by the country and place of living or born)
- ✓ their initial perceptions on the need of implementing fact checking routines to avoid false ideas and claims.

The notes taked by the teacher during this activity are revisited later (the teacher uses it to address the need of having credible sources of information, implementing fact checking routines to formulate ideas and avoid false claims).

Then the teacher explains that life expectancy has more than doubled since 1900. In 1950 a human being could expect to live 46 years, on average. In 2000, 67 years. The expectancy of life for a baby born today is more than 77 years. In the beginning of the 22nd century, a human born can expect to live up to 82 years. This is explained by a combination of factors, which may be linked with advances in medicine, economic development, individual choices in relation to health and improved living conditions. The following resources should be used at this stage: **life expectancy at birth, 2002- 2019, source Eurostat (map) [ER14]**
The teacher asks students to look at the graph and find if there are differences in the expectancy of life between boys and girls. The following resources should be used at this stage: **life expectancy at birth, 2019, source Eurostat (map) [ER15]**

However, health conditions around the world and in countries belonging to the same continent differ. The teacher shows that in Europe, the actual expectancy of life at birth is superior to 80 years in Portugal, Greece and Cyprus, but is around 75 years in Latvia and Lithuania. The following resources should be used at this stage: **life expectancy at birth, 2019, regions, source Eurostat (map) [ER16]**

The teacher explains that in the North and Center of Portugal, the expectancy of life is superior to Algarve region. Even at the same city, the expectancy of life may differ. According to the Euro-healthy project, over a distance of only eight kilometres across the metro line, Lisbon life expectancy for those born in São Domingos de Benfica is 80.7 years. While a person born in the Santa Maria Maior neighborhood will on average live 74.5 years.

These differences are mainly driven by differences in economic development, social and labour conditions, access to high-quality education, lifestyles, dynamics of local environments, and access to healthcare services. So, all these are determinants of health. The following resources should be used at this stage: **life expectancy at birth, 2019, regions, source Eurostat (map) [ER17-ER19]**

The teacher explains that to improve health, reduce illness, and have great quality of life we need to consider lifestyles - individual choices in relation to health, including choices concerning eating, physical activity, sexual behaviour, tobacco use, substance use, etc. - but also the environment, social relationships and living conditions.

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Students understand their power to make choices that prevent poor health and certain medical conditions, such as non-communicable diseases, and the influence they may have on peers' choices. Living conditions also influence health and quality of life and refer to the contexts in which people live and work; to the influences that surrounding environment and society have on people lives and well-being. These could be the general socioeconomic conditions, working environment, access to house, education, employment, healthcare services, culture, the city policy (urban health perspective), the access to water and fresh food, etc. The following resources are used at this stage: **the main determinants of health [ER20-ER21]**

- **debate:**
  i. Lifestyles (individual choices in relation to health) are influenced by environmental factors? By living environments?

Students are asked to answer if lifestyles and living conditions influence each other and are invited to give some examples. They recognize, for instance, that if someone lives in a community where fruit and vegetables are easy assessable, will probably eat healthier, and this is a protective factor for NCDs. They understand that there are several environmental factors that may encourage or restrict mobility, such as having conditions to walk or cycle to and from school, doing exercise and playing in free time. **[ER22]** may be used at this stage.

Then teacher explains that living conditions relate to Agenda for Sustainable Development of the United Nations. These are influences more difficult, but not impossible, to change, as they ask for concerted action of community members and society as a whole. The following resources should be used at this stage: **social and environmental determinants of health with link to the sustainable development goals [ER23-ER24]**.

[ER24] is printed. 1 copy is provided to each student. Students are invited to link each determinant of health to one sustainable development goal. The teacher collects the responses and asks students to justify the connection.
The teacher summarizes by highlighting that each determinant of health may be linked with multiple sustainable development goals. Example**: housing is strongly connected with SDG 1, SDG3, SDG 8, SDG 9, SDG 10, SDG 11.**

- **Debate:**
  "Is SDG 3 – good health and well-being – connected with the other SDGs?"

[ER25] may be used at this stage.
The teacher explains that the best way to understand how SDGs are interrelated is by mapping the attributes of a healthy community.
The following resources should be used at this stage: **SDG 3 connected with SDG 8, 16 and 11 [ER 26]**.
When we think about a community plenty of health and quality of life, some attributes immediately come up: people are employed and have a good work, business get the money they need to survive and grow, people pay affordable prices for goods and have access to healthcare services. Institutions are effective in their work, accountable, inclusive, buildings and infrastructure are energy efficient, employers and employees are committed to a positive environment that promotes health and well-being. Institutions deliver people-centered services and appropriate social support to those in a vulnerable situation. The houses are affordable, people earn a sustainable living in the place, and are comfortable with living there.
The following resources should be used at this stage: **SDG 3 connected with SDG 11, 13 and 15 [ER27].**
People have access to local, affordable, and nutritious food, and there are public places to play and exercise, that residents use also to connect with each other. A healthy community is also a place where residents are

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connected by the purpose of reducing the ecological footprint and engage public and private initiatives with this aim. Public policy creates opportunities for people to contribute to community gardens, to grow fruits and vegetables, sell in local markets and consume it.
The following resources should be used at this stage: **SDG 3 connected with SDG 11, 9, 7 and 12 [ER28].** Residents use soft transportation modes, such as bicycles, in their routines, and have access to good and affordable public transportation network, that allows them to stay active and independent so they can participate in social life and to access services. It is a place that provides accessible and barrier-free public spaces and buildings. There is no energy poverty because people have access to clean and affordable energy, use it in a sustainable manner and avoid waste, houses indoor temperatures round 18 degrees, according to the recommendations of WHO. Unsustainable modes of production, harmful for life on land and below water, are rejected by the community. Deforestation, food insecurity, abusive use of antibiotics and pesticides is rejected, due to its effects on the planet and consequences in human health.
These resources should be used at this stage: **SDG 3 connected with SDG 4, 6, 1, 2 and 10 [ER29]**. The community moves together towards supporting people in situation of hunger and poverty, stimulates children and youths to go to school and achieve good results, doesn't accept unequal and/or unjust distribution of opportunities among members, has access to high quality water and sanitation, and to information that is fundamental to make choices concerning their health.

The teacher asks students to visualize the images and mentions that they are relative to the features of healthy & eco-friendly neighborhoods. Students are asked to describe what they see. The following resources should be used at this stage: **some features of positive neighborhoods: healthy & eco-friendly [ER 30-32].**
Then que teacher uses **[ER33]** to explain that the configuration of public space influences people health:

- ✓ Promoting mobility, walking, outdoor activities, physical exercise, contact with nature and social relationships.
- ✓ Contribute to low carbon dioxide emissions to the atmosphere, to carbon fixation through photosynthesis, to the supply of oxygen, which improves air quality and prevents respiratory and cardiovascular diseases.
- ✓ Promote people use for walking and the adoption of soft modes of transport (e.g., bicycles, scooters), which influences the functional decline of adults and elderly people.
- ✓ Influence people's exposure to environmental hazards, such as stress and heat, which are risk factors for strokes.
- ✓ Encourage the use of public transport, through providing a transportation network that is ecologic and accessible.
- ✓ Promote the consumption of fresh products through purchasing in local markets.
- ✓ Promote urban gardens, where people can grow food and plants, learn new knowledge and develop skills, meet the neighbors and improve their physical and mental health. Cultivation must be based on the principles of sustainability, using traditional agricultural practices, reuse of generated resources, such as organic fertilizer or wastewater in closed cycles.
- ✓ Encourage participation in awareness-raising initiatives on global risks to public health.
- ✓ Encourage civic participation with a view to contributing to better solutions in terms of public policy.

Assessment task: Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Lesson 3: NCDs burden

At the end of lesson 3 students should be able to:

- Define disease burden
- Identify indicators to measure disease burden
- Understand how the burden of a disease is estimated

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- Select appropriate sources to characterize the burden of diseases in a scientific perspective

The teaching-learning script starts with a discussion of the concept of burden of disease.
The teacher asks students to identify a couple of serious diseases.
Then students are encouraged to complete the sentence "A disease is serious when...". **[ER 34]** may be used at this stage. Each student must produce 2-3 different sentences and read them.
A flipchart or whiteboard is used to distribute the ideas. Then the teacher distributes the ideas in 3 categories: mortality; poor health and quality of life; disability.

The teacher directs the discussion in a way students can understand that a disease is serious not only when it causes many deaths, but also when it affects people's daily lives, independence, abilities, relationships and quality of life.
Road accidents can be given as an example of a serious public health problem that causes many deaths and disability in young people. Diabetes also, due to a frequent complication – retinopathy – that causes vision loss and, in advanced stages, blindness. Mental illness also, due to the impact in relationships, frequent absences at school and work, and loss of quality of life.

Then students are introduced to the concepts and indicators of disease burden and understand that NCDs are leading causes of death and disability adjusted life years (DALYs) worldwide. The following resources should be used at this stage:

- **concept of disease burden [ER35]**
- **indicators of disease burden (DALY, YLD, YLL, premature death) [ER36-38]**
- **global DALYs by cause 2019 [ER39]**

Then the teacher asks students what are the leading causes of deaths, loss of quality of life and disability in the world **[ER39].**
The teacher explains that the burden of non-communicable diseases is increasing worldwide due to changes in lifestyles. The following resources should be used at this stage: **burden of non-communicable diseases [ER40].**
The teacher explains the increasing burden of non-communicable diseases by using **[ER41-42]**.

- **classroom discussion**

The teacher asks the classroom if there are modifiable risk factors for non-communicable diseases connected with people lifestyles. Students are asked to give some examples.
The following resources should be used at this stage: **CVD Burden attributable to modifiable risk factors [ER43].**

The teacher explains that non communicable diseases are on the top causes of death worldwide by using the following Digital learning objects: **ischemic cardiac disease, stroke, cancer, chronic respiratory diseases, diabetes on the top 10 causes of death [ER44].** Then the teacher explains that non communicable diseases are on the top causes of poor health, disability and premature deaths worldwide by using the following Digital learning objects: **ischemic cardiac disease, stroke, cancer, chronic respiratory diseases, diabetes, on the top 10 causes of disease burden [ER45-ER46]**

- **group work (the availability of laptops or tablets for group work is required)**

[LO 47] is used at this stage. Students are organized in groups (1 group – 1 topic). Each group uses a laptop to explore databases (among other relevant links) that retrieve information on NCDs burden.
They describe major NCDs (diabetes, cardiovascular disease, chronic respiratory disease, cancer) according to the available indicators of burden. They are asked to identify the source and reference period of data.
The following questions and sources of evidence may be used for this purpose:

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Question	Topic	Proposed source of evidence
1. How many cases of diabetes were active in Portugal in 2011? The percentage of population with this condition was higher in Portugal or in Spain? And comparing to other countries, such as Switzerland?	Diabetes	Eurostat (europa.eu)
2. Which percentage of diabetics had the Portuguese population, in 2019? And in 2010? Is the prevalence of diabetes growing?	Diabetes	Diabetes prevalence
3. How many new cases of cancer were registered in Portugal in 2017? In 1990 the number of cases was superior, or inferior? Is the incidence growing?	Cancer	Cancer incidence, 2017
4. In 2017 the incidence of cancer was superior in Portugal than in Italy? And comparing to other countries, such as Poland?	Cancer	Cancer incidence, 2017
5. How many cases of heart disease were active in Portugal in 2011? The prevalence of heart disease was higher in Portugal or in France? And comparing to other countries, such as Switzerland?	Heart disease	Eurostat (europa.eu)
6. How many deaths in the world were due to ischemic heart disease, stroke, chronic obstructive pulmonary disease and diabetes, in 2019? Rank them in the leading causes of death.	Heart disease Respiratory disease Diabetes	WHO GLOBAL HEALTH ESTIMATES 2019
7. Which proportion of global deaths in 2019 is attributable to NCDs?	Non communicable diseases	WHO GLOBAL HEALTH ESTIMATES 2019
8. How many disability-adjusted life years (DALYs) were registered due to ischemic heart disease, stroke, chronic obstructive pulmonary disease and diabetes, in 2019? Rank them in the leading causes of disability.	Non communicable diseases	WHO GLOBAL HEALTH ESTIMATES 2019
9. Which proportion of global DALYs was attributable to NCDs, in 2019?	Non communicable diseases	WHO GLOBAL HEALTH ESTIMATES 2019
10. Which proportion of premature death due to major NCDs can be prevented? Identify 5 risk factors for NCDs.	Non communicable diseases	NONCOMMUNICABLE DISEASES (WHO.INT)

Assessment task: Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

<u>Lesson 4: major non-communicable diseases</u>

At the end of lesson 4 students should be able to:

- Identify and characterize the major NCDs
- Select appropriate sources to characterize NCDs in a scientific perspective
- Identify the most common symptoms of each NCD
- Identify the most important risk factors for each NCD
- Identify individual actions that can prevent NCDs
- Identify and explain the major components of a healthy lifestyle
- Propose actions to be implemented at the community level to prevent NCDs

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From the previous lesson, students already recognize the most important non-communicable diseases. This lesson explores each NCD, risk factors and preventive actions at the individual and community level to mitigate their burden.

The teacher starts by presenting the agenda for the lesson by using **[ER 48-49].**

- **Classroom discussion.**

Students are asked to pick 1 to 3 post-its and complete the phrase "We can prevent non-communicable diseases by…" **[ER50].** Each student should produce between 1 to 3 ideas, write them in post-its and fix them on the white board or flip chart. Photos are taken and information is kept for next lessons, particularly for the school project.

The teacher explains that the incidence of non-communicable diseases is influenced by a couple of factors that elevate the risk gradually over the life course and that can be modified through healthy lifestyles. The following resources should be used at this stage: **modifiable risk factors [ER51-53].**

Then the teacher explores in detail the burden of chronic cardiovascular diseases: ischaemic heart disease and stroke. The following resources should be used at this stage: **cardiovascular diseases [ER54-55].**

The teacher explains the pathophysiology of **ischaemic heart disease**, burden, risk factors, consequences and preventive action. The following resources should be used at this stage: **cardiovascular diseases [ER56-58]. After presenting ER 57, the teacher asks students to identify symptoms of heart attack.**

The teacher goes into detail on pathophysiology of **stroke**, burden, risk factors, consequences and preventive action. The following resources should be used at this stage: **cardiovascular diseases [ER59-63]. After presenting ER 61, the teacher asks students to identify the symptoms of a stroke.**
The teacher summarizes preventive actions for cardiovascular diseases in two types: primary prevention (avoids disease) and secondary prevention (limits disease progression and disability in people with the disease). The following resources should be used at this stage: **primary and secondary prevention [ER64].**

The teacher goes into detail on pathophysiology of **chronic pulmonary disease**, burden, risk factors, consequences and preventive action. The following resources should be used at this stage: **chronic pulmonary disease [ER65-68]. After presenting [ER 67], the teacher asks students to identify symptoms of exacerbation of chronic pulmonary disease.**

The teacher summarizes preventive actions for chronic pulmonary disease in two types: primary prevention (avoids disease) and secondary prevention (limits disability in people with the disease). The following resources should be used at this stage: **primary and secondary prevention [ER69].**

The teacher goes into detail on pathophysiology of **cancer**, burden, risk factors, consequences and preventive action. The following resources should be used at this stage: **cancer [ER70-75]. After presenting ER 71, the teacher asks students to identify the most common organ affected by cancer. After presenting [ER 73] the teacher asks students to identify two symptoms of cancer.**

The teacher summarizes preventive actions for cancer in two types: primary prevention (avoids disease) and secondary prevention (limits disability in people with the disease). The following resources should be used at this stage: **primary and secondary prevention [ER76].**

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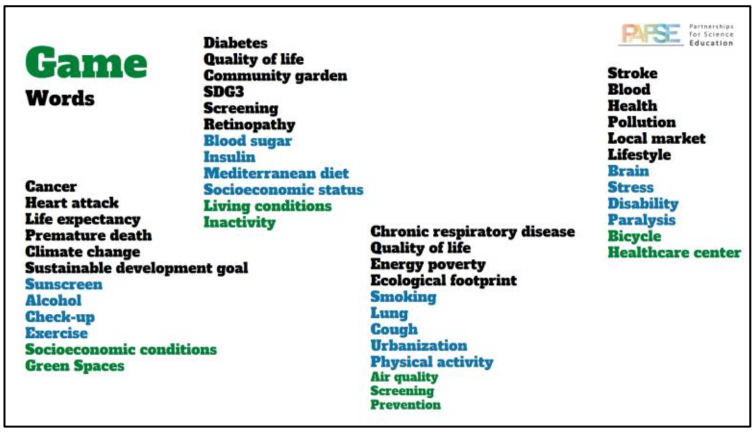
The teacher goes into detail on pathophysiology of **diabetes**, burden, risk factors, consequences and preventive action. The following resources should be used at this stage: **diabetes [ER77-82].**
The teacher summarizes preventive actions for diabetes in two types: primary prevention (avoids disease) and secondary prevention (limits disability in people with the disease). The following resources should be used at this stage: **primary and secondary prevention [ER83].**

- **Game competition – to describe and explain relevant concepts [LO 84-85]**

A set of words/concepts related with NCDs are mapped in cards. Students are organized in groups of 5-6. Each group is given a set of words which they distribute randomly between the members without showing the cards to each other (e.g.: 1 group – 10 to 12 cards). Each member is given 60 seconds to explain the word/concept in hand to other members, without showing or using that one particular word. When the time is out, the words that were identified right brings one point to the group.



- **group work** (the availability of paper is required)

[LO 86] may be used at this stage. Students are organized in 2 groups. In 5 minutes, they should propose at least 5 actions for primary and secondary prevention of non-communicable diseases. The teacher attributes one topic to each group:

Group 1: primary prevention **[ER87]**
Group 2: secondary prevention **[ER88]**
At the end, the teacher explains that when primary and secondary prevention fail is fundamental to invest in terciary prevention to limit the complications of the disease. The following resources should be used at this stage: **terciary prevention [ER89].**

Assessment task 1: build a systems map (qualitative assessment)

The availability of laptop is required.
Students come back to their initial groups (4-5 members) to build a systems map (using a provided online template). Each group is asked to:
- identify and represent the relationships between risk factors, lifestyles, urban and modern living, and medical conditions related to a specific major NCD (e.g., diabetes).
- use their system map to build argumentation about the interrelationships between lifestyles, living conditions and a specific NCD (e.g., diabetes).
- justify the system map with evidence and use their representation to reason about the key behavioral and environmental factors linked with the burden of NCDs.

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After building and presenting the systems map students are challenged to build a scientific poster about NCDs (group work). This is the school project described down, in autonomous section.

Tip1: using ppt file or canva file to design the systems map
Tip2: photos are taken to be used as learning objects for students' projects.

- **Suggested homework**

Students perform research work with the purpose of identifying more scientific evidence about diabetes, cardiovascular diseases, chronic respiratory diseases, cancer, with a particular focus on the risk factors (e.g.: high sugar intake, smoking) and actions to fight them at the individual and community level. They are asked to identify the source of the evidence.

Assessment task 2: Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior (quantitative assessment)

Supplementary learning resources and educational activities

During lesson 5 (or in the sessions devoted to the development of the research project) is organized:

1. Conference with STEM professionals

The conference may be organized at the school or stakeholder location and promotes an interaction between students and STEM professionals, such as medical experts, policy makers, public health authorities, officer of the municipality working on urban and environmental health, data scientists, technology developers, researchers of PAFSE consortium.
Students are oriented by the teacher to pose questions to the experts with a particular focus on:
a) academic choices and career paths;
b) reasons to adopt a career that contributes for better public health;
b) identifying actions to fight NCDs in their community. for better expectancy and quality of life for all.

2. Visits to organizations interested in STEM and public health education:
a. INSA (national public health laboratory - department of non-communicable diseases)

https://www.insa.min-saude.pt/

b. IBET

https://www.ibet.pt

c. Sporting Clube Portugal

https://www.sporting.pt
d. Lean Health Portugal
https://leanhealth.education

d. Roche

https://www.roche.com

A couple of programmes defined in the scope of the action of science education clusters built by PAFSE will be presented to schools. These can be 1/2 or 1-day joyful programmes that PAFSE stakeholders organize for schools. The principal aim of these visits is to connect students with STEM professionals that

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can act as role models for students in terms of healthy lifestyles and professional choices in the STEM field. With these interactions, is also expected that students understand the vast huge of professionals working (or contributing indirectly with their work) for the health market (ahead of healthcare professionals).

The teacher instructs students towards making questions to professionals with a particular focus on:
a) business of the organization and their role;
b) academic choices and career paths;
b) reasons to adopt a career that contributes for better public health.

School Research Project

Overview. The project is based on guided research about social and environmental issues around NCDs, with a particular focus on the contribute of the school for a healthy community and on the general attributes of healthy communities. Students will be developing digital skills (e.g. finding, reviewing, organising and sharing information effectively, handling data appropriately, using different online resources and tools to study), acquire socio-scientific argumentation skills and improve communication and collaboration skills while understanding the multiplicity of factors leading to non-communicable diseases and mapping solutions for reducing or mitigating their impact at the school community with the support of stakeholders. At the end of the teaching-learning sequence, students will have developed the ability to explain how scientific knowledge and processes may contribute to the resolution of a socioscientific issue related to public health and to recognize dimensions of the issue that cannot be addressed by science.

In a first stage, students will be elaborating with the teacher on the principal research question, goals, data collection methods and instruments. They will be improving inquiry-based investigation skills to answer the questions of a socioscientific issue related to non-communicable diseases and their environmental determinants.

What are the **major determinants** of non-communicable diseases incidence?

Which **environmental factors** influence the incidence of non-communicable diseases in the school community?

Then students perform inquiry-based activities, administer the data collection instruments, analyse results, extract conclusions, and propose priorities for action. In the end, they will have created a poster that identifies strengths of the school and their surrounding area in a public health perspective, as well as identified areas for improvement that may be addressed by community stakeholders (students, residents, organisations, policy makers).

Relevance. Scientific evidence shows that the way public place functions, looks and feels influences health, wellbeing and incidence of diseases. With the project students will be contributing to tackle inequalities by identifying potential strengths and weaknesses of spaces located at the school and in the neighbourhood, with a particular attention to the access of vulnerable groups. Based on the collected evidence, they will suggest actions and efforts for different stakeholders, according to the fields where they are needed most.

Estimated duration. The school research project starts after lesson 5 and has an estimated duration of 5-6 sessions of 45 minutes.

Session 1-2: research administration

The teacher organizes groups, each group addresses 1 topic connected with the environmental influences of non-communicable diseases in the school community:

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A. Accessibility, transportation options and security
B. Public green and social spaces
C. School environment

The teacher discusses with students' possible questions to assess the attributes of the communities in the subjects and possible methods to get the answers. The application of an online questionnaire is suggested but other data collection methods (e.g.: observations, interviews) may be considered. The advantages and limitations of the alternatives are discussed.

A brainstorming of possible questions to address the topics is promoted by the teacher.
Then the following may be presented to complete the task:

- **Accessibility, transportation options and security (Group 1)**

Can you walk from home to school?
Are there enough routes for walking and cycling to go to school?
The streets are flat and accessible for everyone?
Is easy for people with physical disabilities to use the streets?
Are there bike paths to go to school?
Are walking and cycling given priority over cars and other traffic as much as possible?
Are routes good quality, attractive and pleasant to use?
Do routes meet the needs of everyone, whatever their age or mobility, and is there seating for those who need it?
Is the nearest public transport closer to school?
Is public transport to go to school good?
Is public transport to go to school affordable?
Are bus stops and stations in convenient places?
Is public transport safe and easy to access, whatever people age or mobility ?
Are there many cars at the roads surrounding school?
Is there too much traffic surrounding school? Why?

- **Public green and social spaces (Group 2)**

Is the nearest park closer? What is the distance from the school to the park?
Is the park a place where you would choose to meet your friends?
Is the park accessible for people with special needs?
There are conditions in the park for playing and exercising?
There are facilities in the park to exercise?
There are facilities in the park to play and have joy with your family and friends?
There are enough places in the park to sit?
There are places to seat that are clean, comfortable, conveniently located?
Do people have a choice of places to sit, either in the sun or shade?
Do vehicles dominate or block space dedicated to pedestrians or bicycles?
Do you feel secure in public space around school, during the day? And at night?
Is the area free of violence and antisocial behaviour?
Is the area safe for everyone, whatever their age, sex, ethnic group, religious beliefs, sexuality or disability?
Do people feel safe both at school and when out and about?
Are there any social activities organized at the public space surrounding school?
Is easy for people with special needs to join those activities?
How many different types of activities are occurring in public space surrounding school- people walking, eating, playing baseball, chess, relaxing, reading?
Are there organized activities/initiatives ongoing in public space surrounding school?
Are there any local initiatives that encourage social interaction?

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Are there any recreative events like art displays and performances occurring to celebrate local artists and cultures?
Are there any natural features into the urban space, such as street trees or plantings in plazas?
Is there any market with fresh products (e.g., vegetables, fruit, fish, etc.)?
Are there regular farmers markets at already existing properties, like building plazas, parking lots or streets?
Is there any community garden?
Is there any discussion ongoing about the design of public space?

- **School environment (Group 3)**

Are there facilities to park the bicycle at school?
Are there any bins at school to deposit paper and plastic, for recycling purposes?
Are there facilities to repair objects near school, such as bicycles?
Are there facilities to leave used clothes and toys?
Are there solar panels at school?
Is there any strategy ongoing to avoid waste of water and energy at school?
During meals at school is usual to throw away food?
Is there a range of spaces (indoor, outdoor, purpose-built and more informal) where students can meet?
Is there a range of spaces to enjoy leisure and sporting activities?
Is there too much noise at school?
Is there any community garden at the school? Are you interested in contributing to it?
Do organisations such as local authorities and health services actively work with the school to understand needs?
Is there any initiative or channel connecting students and teachers with municipalities, such as “school parliament”?

After finishing the list of questions, students prepare the data collection instrument.
Is suggested that they work in groups and use a laptop to build an online questionnaire in Google forms. To conclude the preparation of the survey the teacher supports students in:

- ✓ writing the introductory text (HEADER)
    - Project title/Project acronym
    - Summary description of the project
    - Why is the project relevant/project goals
    - Who is implementing the project and where.
- ✓ configure the questions (WHAT)
    - turning questions into sentences
    - defining a scale for responses options
- ✓ identifying the target group(WHO)
- ✓ defining a strategy and activities to achieve the target (HOW)
- ✓ defining the minimum number of responses from the target (EXPECTED RESULTS)
- ✓ stablish a timeline for collecting the responses (WHEN)
- ✓ which events may constraint data collection (RISKS)
- ✓ which strategy to track results (CONTROL procedures)

Examples of scale:

1- strongly disagree; 2 – disagree; 3- not disagree, not agree 4- agree; 5 – strongly agree
2- definitely false; 2 – false; 3 – not false, not true; 4 – true; 5-definitely true
3- extremely unlikely; 2 – unlikely; 3 – not unlikely, not likely; 4 – likely; 5-extremely likely.
1 – yes; 2 – no

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Example 1:
Can you walk from home to school?
Is possible to walk from home to school.
Response options: 1-strongly disagree; 2 – disagree; 3- not disagree, not agree 4- agree; 5 – fully agree

Example 2:
Is the nearest public transport closer to school?
The nearest public transport is closer to school.
Response options: 1-strongly disagree; 2 – disagree; 3- not disagree, not agree 4- agree; 5 – fully agree

Example 3:
Is there any local market with fresh products (e.g., vegetables, fruit, fish, etc.)?
There is a local market with fresh products (e.g., vegetables, fruit, fish, etc.)?
Response options: 1-yes; 2 – no;

Example 4:
Are there regular farmers markets at already existing and centrally located properties, like building plazas, parking lots or streets?
There are regular farmers markets at already existing properties, like building plazas, parking lots or streets?
3- extremely unlikely; 2 – unlikely; 3 – not unlikely, not likely; 4 – likely; 5-extremely likely.

Session 3: data analysis

After administering the survey and collecting the minimum number of responses, an Excel file may be downloaded from google forms. Alternatively, if the questionnaire is administered in paper, students prepare a file with the questions and distribution of responses. The teacher reminds students about the relevance of the project and supports each group of students in preparing tables, graphics and then promotes a debate around the results.

Session 4-5: presentation of evidence

Session 4 starts with the discussion of the best presentation format of the project results.
The output is produced and should describe the research question, methodology, results, conclusions and recommendations arising from the inquiry-based project. A poster is suggested, it can be built in paper or Canva software.
Then students discuss with the teacher the organisation of a forum for presentation and discussion of the output that invites students, teachers, parents, social partners of the local community to participate and engage in a debate.

Session 6: open schooling event

During session 6 students will be holding a community event to share the results of their research with the participation of students, teachers, parents, social partners of the local community.
Each group will be presenting their evidence and informing the public about the questions they have addressed in the project while improving communication skills and developing responsible citizenship.

- Each project output (e.g.: poster) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair).
- Students will communicate policy measures using science-based argumentation. Students appeal to action of all in the health of the community, providing great understanding that health literacy and health promotion is a responsibility of all, not only of the ministry of health or healthcare providers.
- Students, parents, school community and relevant local stakeholders attend the event and understand how the prevalence of NCDs is influenced by a set of common behavioral factors related with lifestyles

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but also social and environmental factors. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community).

Suggested printing (to be available at the wall where the project is developed): “You choose, ONE Life, TWO Directions” [LO 92].

Suggested complementary readings for teachers:

1. Watch this video

Lisbon case study Urban environment and health, 2017 - YouTube

2. Take a look at these infographics and texts!

Healthy places

Placemaking guidelines and initiatives

3. Perform this assessment

Place Standard

Teaching-learning process for school project (summary):

1. Collection of evidence.
2. Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
3. Identify effective presentation formats.
4. Produce the output (e.g.: scientific poster**)**
5. Present the output in open schooling event.

Expected outcomes of the teaching-learning process (summary):

- Students will be able to incorporate evidence coming from trustful data sources to support their ideas and arguments.
- Students will be able to communicate the merits and limitations of various data and data collection processes considered in the work process.
- Students will be able to identify and communicate factors that inhibit or promote healthy behaviors in their community.
- Students will be able to identify and communicate evidence-based policy measures to prevent and manage NCDs in their community.
- Students will be able to use non-biased data to justify policy choices.

Target Audience for Recommendations

School community and local stakeholders: students, parents, municipalities, healthcare providers, local enterprises.

Public Debate and Recommendations (based on research results)

Presentation of the project results by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

Scenario topic: Non-Communicable Diseases

Knowledge	
1. Recognizes and characterizes the major NCDs.	**Question 1.1:** What are the most prevalent non communicable diseases? A) gastrointestinal diseases, cancer, diabetes, road traffic accidents. B) cancer, cardiovascular diseases, chronic obstructive pulmonary diseases, diabetes. C) diabetes, oral diseases, urinary diseases, cancer.

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	Question 1.2: Identify the most frequent symptoms of heart attack: A) chest pain, lightheadness, breathleness. B) blurred vision, confusion, paralysis of 1 side of the body. C) lightheadness, breathleness, cough. **Question 1.3:** Identify the most frequent symptoms of cancer: A) fever, fatigue, weight loss B) blurred vision, paralysis of 1 side of the body. C) lightheadness, cough, increased appetite. **Question 1.4:** Identify the most frequent symptoms of stroke: A) fever, chest pain, cough B) blurred vision, fever, paralysis of 1 side of the body. C) pain, swelling, cough, increased appetite. **Question 1.5:** Identify the most frequent symptoms of ischemic heart disease: A) chest pain, heart palpitations, breathlessness. B) fever, cough, increased appetite. C) blurred vision, confusion, paralysis of 1 side of the body.
2. Identifies the most important risk factors for each NCD.	**Question 2.1:** Identify the most important risk factors for ischaemic heart disease: A) pollution, smoking, alcohol consumption, fat diet. B) exposition to dusts and chemicals at work, inactivity, low-fat diet C) Exposition to ultraviolet radiation, exposition to solid fuels, chronic infections. **Question 2.2:** Identify the most important risk factors for cancer: A) inactivity, high sugar intake, stress. B) Exposition to ultraviolet radiation, air pollution, smoking, alcohol consumption. C) stress, diet rich in vegetables, exposition to dusts and chemicals at work. **Question 2.3:** Identify the most important risk factors for diabetes: A) overweight, inactivity, abdominal fat. B) Exposition to ultraviolet radiation, chronic infections, stress. C) pollution, smoking, diet full of vegetables.
3. Identifies measures and proposes general action to fight NCDs.	**Question 3.1:** Identify appropriate actions to have a healthy lifestyle and prevent the major non-communicable diseases: A) avoid pollution, alcohol, tobacco and drugs consumption, adopt fat diet, avoid stress and physical exercise. B) adopt a meat-free diet, consume food supplements and practice exercise. C) avoid the sun and plant-based foods, drink soda and travel mainly by public transport. D) adopt the Mediterranean diet, travel on foot or by bicycle and enjoy green spaces. **Question 3.2:** As a citizen, what can you do to fight non-communicable diseases? Please identify the most important actions: A) Commit to SDG 11 (sustainable cities and communities), to SDG 13 (climate action) and to Mediterranean diet. B) Commit to SDG 17 (partnerships for the goals), to the use of car as principal transportation mode and to vegan diet. C) Commit to SDG 3 (Health and Well-Being), to recycle and to the use of car as principal transportation mode.
4. Defines burden of disease and identifies indicators to measure it.	**Question 4.1:** What is disease burden? A) the impact of the problem in terms of public health. B) the impact of the problem in an economic perspective. C) the impact of the problem in an environmental perspective. **Question 4.2:** Which indicator is used to measure disease burden? A) DALYs (disability adjusted life years). B) Number of deaths. C) Costs incurred by the health system.

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5. Identifies the determinants of health and understands their relationship with NCDs and SDGs.	**Question 5.1:** The major determinants of health are: A) genetics, access to healthcare, family history of disease. B) unhealthy diet, inactivity, stress. C) energy poverty, unaffordable prices, access to healthcare. **Question 5.2:** SDG 3 (Health and Well-being) is connected with SDG 11 (Sustainable Cities and Communities) because: A) in a healthy community "people have access to local, affordable and nutritious food, live in a sustainable, inclusive, and climate-friendly environment that promotes well-being". B) in a healthy community "access to justice for all is assured". C) in a healthy community "infrastructure for the use of car as transportation mode is promoted".
Skills	
1. Selects concepts, indicators, and evidence to characterize disease burden.	**Question 1.1:** You aim the characterize the burden of diabetes. Which indicator would you choose: A) number of deaths/100.000 people. B) number of citizens with the disease. C) premature mortality and years lived with poor health.
2. Can anticipate the consequences of unhealthy lifestyles and risky behavior (e.g., smoking).	**Question 2.1:** Urbanization, pollution, smoking, alcohol consumption and unhealthy diet and inactivity are risk factors for non-communicable diseases. Considering that factors that elevate disease risk accumulate gradually over the life course, anticipate the most important consequences for the future of having these conditions in your lifestyle: A) Abdominal fat, overweight, hypertension. B) Mental disease, hypertension, overweight. C) Fatigue, weight loss, hypertension.
3. Can adopt a healthy lifestyle.	**Question 3.1:** I will try to adopt a healthy lifestyle (avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months: 1) definitely true... 5) definitively false. **Question 3.2:** I feel able to resist peer pressure regarding unhealthy options (e.g., smoking, drinking, not practicing physical exercise, foods full of fat): 1) definitely true... 5) definitively false. **Question 3.3:** I feel capable of identifying the attributes of healthy lifestyles and act based on it. 1) definitely true... 5) definitively false. **Question 3.4:** If I want, I can adopt a healthy lifestyle during the next three months. 1) definitely true... 5) definitely false. **Question 3.5:** For me, avoiding smoking, consuming alcohol, not practicing physical exercise, and having a diet full of fat, during the next three months, is: 1) definitely possible ... 5) definitely impossible. **Question 3.6:** For me adopting a healthy lifestyle during the next three months, would be: 1) very important... 5) very insignificant. **Question 3.7:** I will be able to find the necessary strategies and resources for adopting a healthy lifestyle in the next three months: 1) very probable... 5) very improbable.
4. Feels able to propose concrete action towards adopting healthy lifestyles in his/her routine.	**Question 4.1:** I feel able to identify relevant actions for adopting a healthy lifestyle in my routine: 1) definitively true… 5) definitively false. **Question 4.2:** I feel able to change my routine in order to adopt a healthier lifestyle. 1) definitely true... 5) definitively false.

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5. Feels able to influence the adoption of healthy lifestyles by others (e.g., family, peers, friends).	**Question 5.1:** I feel able to propose actions to be taken at home environment for healthy lifestyle adoption: 1) definitely true... 5) definitively false. **Question 5.2:** I will try to influence the adoption of healthy lifestyles by others (family, friends): 1) definitely true... 5) definitively false.
6. Selects appropriate sources to characterize NCDs in a scientific perspective.	**Question 6.1:** I believe that to find valid information, based on science, about diseases, I should consult the following sources: A) scientists, scientific publications, WHO database. B) newspapers, google, youtube. C) friends, journalists, facebook.
7. Can identify the problems and challenges of the community in relation to NCDs, relate them with SDG 3 (health and well-being) and find the relevant resources to address them.	**Question 7.1:** I feel able to identify the attributes of healthy communities: 1) definitely true... 5) definitively false. **Question 7.2:** I feel able to identify the problems and challenges of my community in relation to health and well-being: 1) definitely true... 5) definitively false. **Question 7.3:** I feel capable of proposing actions that benefit the health and well-being of my community. 1) definitely true... 5) definitively false. **Question 7.4:** To address the problems and challenges of my community in relation to health and well-being (SDG 3) I should understand the attributes of sustainable communities (SDG 11) and targets of climate action (SDG 13): 1) strongly agree... 5) strongly disagree.
Beliefs, attitudes and behavior	Instructions: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that health is a fundamental component of quality of life.	**Question 1.1:** Health is a fundamental component of quality of life: 1) strongly agree… 5) strongly disagree. **Question 1.2:** I am capable of adopting a healthy lifestyle that benefits quality of life: 1) Strongly agree… 5) Strongly disagree.
2. Believes that lifestyles influence the incidence of NCDs.	**Question 2.1:** Lifestyles and living environments influence the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree. **Question 2.2:** Alcohol abuse influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree. **Question 2.3:** Diet influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases). 1) strongly disagree… 5) strongly agree. **Question 2.4:** Smoking influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree. **Question 2.5:** Inactivity influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree. **Question 2.6:** Access to fresh products (fish, vegetables, fruits) influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree.

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	Question 2.7: Pollution influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree.
3. Believes that is important to adopt a healthy lifestyle to prevent NCDs and stay healthy.	**Question 3.1:** Youths should adopt healthy lifestyles to prevent non-communicable diseases and stay healthy in older ages: 1) strongly disagree… 5) strongly agree. **Question 3.2:** The adoption of a healthy lifestyle will reduce my risk of having a non-communicable disease and dying prematurely from it: 1) strongly disagree… 5) strongly agree.
4. Reproves patterns of risky and unhealthy behavior in his/her living environment.	**Question 4.1:** The adoption of a healthy lifestyle will ruin my image: 1) strongly disagree… 5) strongly agree. **Question 4.2:** For me the adoption of a healthy lifestyle (e.g.: avoid stress, polluted environments, consume alcohol, tobacco, drugs, fat diets, inactivity) in the next three months, would be: 1) Bad... 5) Good. **Question 4.3:** For me to adopt a healthy lifestyle, in the next three months, would be: 1) useless... 5) useful. **Question 4.4:** I don't accept patterns of risk and unhealthy behavior in my living environments (e.g., sedentary lifestyle, smoking, drugs consumption): 1) definitely true... 5) definitively false.
5. Adopts a healthy lifestyle.	**Question 5.1:** I plan to not smoke in the next three months: 1) definitely true... 5) definitively false. **Question 5.2:** I plan to not consume alcohol, drugs and other substance use in the next three months: 1) definitely true... 5) definitively false. **Question 5.3:** I plan to do physical exercise at least 60 minutes every day in the next three months: 1) definitely true... 5) definitively false. **Question 5.4:** I plan to follow low-fat and low-sugar diet, or Mediterranean Diet, in the next three months: 1) definitely true... 5) definitively false. **Question 5.5:** I plan to avoid stress and polluted environments in the next three months: 1) definitely true... 5) definitively false. **Question 5.6:** Among the following statements, choose the one that best describes what you currently think: 1) I do not have a healthy lifestyle, and I also have no intention of doing so. 2) I do not have a healthy lifestyle, but I have been thinking about the possibility of starting to do so. 3) I never or rarely have a healthy lifestyle, but soon I will start doing it on a regular basis. 4) I adopt a healthy lifestyle regularly. 5) For more than six months I have always or almost always followed a healthy lifestyle. 6) For several years now, I have adopted a healthy lifestyle, and I will continue to do so.

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6. Is committed to communicate and address the problems and challenges of the community in relation to the determinants of health and to contribute to the SDGs.	**Question 6.1:** I intend to identify and address the problems of the community in relation to the environmental determinants of health: 1) Strongly disagree… 5) Strongly agree. **Question 6.2:** Among the following statements, choose the one that best describes what you currently think: 1) I am not contributing to my community health, and I also have no intention of doing so. 2) I am not contributing to my community health, but I have been thinking about the possibility of starting to do so. 3) I am never or rarely have been contributing to my community health, but soon I will start doing it on a regular basis. 4) I am contributing to my community health regularly. 5) For more than six months I have always or almost always been contributing to my community health. 6) For several years now, I have been contributing to my community health, and I will continue to do so.
7. Attitude towards NCDs and a healthy lifestyle.	**Question 7.1** For me, non-communicable diseases are : Very harmful: _____:_____:_____:_____:_____: beneficial **Question 7.2:** For me, to adopt a healthy lifestyle is: harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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24. Specifications for an educational scenario on the topic of "Sustainable Development Goals"

Main Partner responsible: UNL (School of Public Health)

Context

The Sustainable Development Goals (SDGs) provide a framework to address challenges faced worldwide. The United Nations Sustainable Development Agenda, created in 2015, includes 17 SDGs to be achieved by 2030. It was adopted by 193 members and is a result of the joint work of Governments and Citizens to meet an extended set of goals, such as making energy clean and affordable, stopping global warming, ending hunger and poverty, promoting healthy lives and creating sustainable cities and communities. Teaching the SDGs in schools promotes awareness on the global challenges and individual responsibility for actions while committing students to build a better and more sustainable future for everyone. Therefore, learning about the SDGs, reporting performance and actions, participating and/or developing campaigns, are dimensions of competence important for students' citizenship. The scenario supports teachers in encouraging students to be active participants in their local and global communities to solve the biggest challenges the world faces today while exploring how schools can help advancing the Global Goals and preparing them to capture evidence and communicate progresses. The final project engages students in community discourse on measures they can adopt to introduce positive changes, with big or small actions, thus creating a connection between students, the school, the community and local stakeholders.

Scientific content and its relevance to public health education

The SDGs aim to boost citizens quality of life globally, without hindering the ability of future generations to meet their own needs, and promoting the integration of environmental, social, and economic factors into decision making. Public health is both a precondition for sustainable development and a significant outcome of it. Health and SDGs are intimatery interconnected, as sustainable development does not occur in societies with persistent socio-economic inequalities, poverty, large scale enviromental degradation, or widespread diseases. Health itself is one of the SDGs: Goal 3 aims to ensure healthy lives and promote well-being for all at all ages. Other goals address the main determinants of health. SDGs are so interconnected and progress requires integrated actions from different groups to address the social, economic and environmental dimensions of health and health-related SDGs. Students are particularly estimulated to be active participants in their local and global communities when engaged in real-life challenges, practical goals and problem-solving activities that connect global challenges with their living environments, and particularly with issues related to their health and well-being. School curriculums in the field of geography, science and citizenship promote, at different levels, fundamental learnings regarding the SDGs, their importance and pathways for action. The scientific and pedagogical content of the scenario allows teachers and students to explore sustainable development in its relationship with public health, and prepares them to take action in their community. The scenario contains inquiry based activities, learning objects, and updated evidence on SDGs implementation. It also challenges others to have a contribution for their community health and well-being, by engaging families in educational activities, and reaching people with a local community project and a set of open schooling events, organized by the school and leaded by students.

Estimated duration

5 sessions of 40-45 minutes
5-6 sessions of 40-45 minutes for students projects

Classroom organization requirements

From lessons 1 to 5, students work both alone and in groups. The use of computer is necessary in lessons 1 to 4 for the teacher to explore the learning objects in lessons. The use of computer is necessary in lesson 3

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for the students to explore the learning objects. From lesson 6 onwards, students form four- or five-member groups for the development of the school project. The use of computer may be necessary.

Prerequisite knowledge and skills

Use of internet, use of web search engines, tools of Microsoft Office software (basic level), English (basic level).

Content glossary

Biodiversity. The different kinds of life found in one area—the variety of animals, plants, fungi, and microorganisms that make up our natural world.

Clean energy. Energy generated from recyclable sources and without emitting greenhouse gases.

Climate change. Long-term shifts in temperatures and weather patterns (regarding temperature, precipitation, and wind) that are especially caused by human activities.

Food security. People have, at all times, physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life.

Gases. A state of matter consisting of particles that have neither a defined volume nor defined shape

GDP. Total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period. The gross domestic product (GDP) serves to measure the economic evolution of a country and is composed of the set of all goods and services, which produces value by national or foreign companies, in a given country.

Gender equality. The state in which access to rights or opportunities is not affected by gender.

Inequality. Unequal and/or unjust distribution of resources and opportunities among members of a given society

Material footprint. The total amount of raw materials extracted to meet final consumption demands.

Poverty. The state of one who lacks financial resources or material possessions to fulfill his/her basic needs.

SDG Indicators. Statistical/mathematical value used to monitor the progress of the SDGs.

Sustainable cities. An urban center engineered to improve its environmental impact through urban planning and management.

Sustainable Development Goals. Collection of 17 interlinked global goals designed to be a blueprint to achieve a better and more sustainable future for all.

Sustainable development. Development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.

Universal health coverage. All people have access to the health services they need, when and where they need them, without financial hardship.

Virus. Infectious agent of small dimension and simple composition that can multiply only in living cells of animals, plants, or bacteria.

Water, sanitation and hygiene. Essential liquid for survival of human, animals and plants. Conditions related to clean drinking water and adequate treatment and disposal of human excreta and sewage. Conditions or practices conducive to maintaining health and preventing disease, especially through cleanliness

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Pedagogical glossary

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills.

Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. Inquiry-based learning refers to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organization, variable handling, data driven conclusion making and communicating over scientific issues.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Sources: Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

Indicative literature

Pradhan, P., Costa, L., Rybski, D., Lucht, W., & Kropp, J. P. (2017). A systematic study of sustainable development goal (SDG) interactions. Earth's Future, 5(11), 1169-1179.

United Nations (2018). The Lazy Person's Guide to Saving the World. Available at: https://www.un.org/sustainabledevelopment/takeaction/

United Nations (2021). Progress towards the Sustainable Development Goals. Report of the Secretary-General. E/2021/58. 2021 session. Available at: https://sustainabledevelopment.un.org/content/documents/28467E_2021_58_EN.pdf

Other relevant references include:

Sachs, J., Kroll, C., Lafortune, G., Fuller, G., & Woelm, F. (2021). Sustainable development report 2021. Cambridge University Press. DOI 10.1017/ 9781009106559

United Nations (2015). Transforming Our World: The 2030 Agenda For Sustainable Development. Available at: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

Competences / Learning Goals

Key Competences

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STEM / Personal, social and learning to learn, citizenship

Knowledge
Social and global concepts: sustainable development; sustainable development goals (SDGs); poverty; food security; universal health coverage; gender equality; water, sanitation and hygiene; clean energy; gases; viruses; inequality; sustainable cities; material footprint; climate change; biodiversity.
Knowledge – impact assessment:
1. Explains the history of the development of SDGs.
2. Recognizes the importance of the SDGs.
3. Characterizes the goals and defines relevant concepts regarding the SDGs.
4. Identifies quantitative measures to track the progress of the SDGs.
5. Characterizes the association between the different SDGs.

Skills (abilities/competences):
General: Critical thinking; teamwork; communication; science-informed decision-making; analytical competency; problem solving, interpreting scientific data and scientific arguments; public speaking and debate; understanding how to use scientific data and texts.

Specific:
- understanding the background of the SDGs and their importance to achieve a better and more sustainable future for all;
- identifying what are the SDGs, their targets and indicators;
- understanding how the SDGs can be addressed at the school/community setting;
- finding, analyzing and interpreting scientific data, graphical elements and tools to track and visualize progress towards the goals
- understanding appropriate strategies and interventions at the local, national and international level to achieve the SDGs.

Skills – impact assessment:
1. Selects appropriate sources to characterize performance on the SDGs.
2. Proposes concrete actions towards promoting sustainability in his/her lifestyle.
3. Influences the adoption of choices aligned to the SDGs by others (e.g., family, peers, friends).
4. Is able to demonstrate values and to adopt individual attitudes that lead to more sustainable societies.
5. Selects appropriate scientific data and information to describe the progress of the SDGs.
6. Identifies the problems and challenges of the community in relation to SDGs, connect them with SDG 3 (health and well-being) and find the relevant resources to address them.

Affective /Attitudes/Behaviour *(beliefs)*

- ✓ Adopting actions that can help towards achieving the SDGs (e.g., eat a healthy diet and drink a lot of water, donate non-perishable foods to charities, donate books, recycle, save water and electricity).
- ✓ Adopting attitudes supporting intellectual curiosity and evidence-based thinking (e.g., understanding how to interpret data and identify inaccurate findings and conclusions).
- ✓ Getting involved in the promotion of measures to address inequalities and vulnerabilities, environmental protection attitudes, concern for ethical issues.

Attitudes and behavior - impact assessment:
1. Believes that is important to contribute to the Global Goals.
2. Believes that working on the Global Goals can lead to positive outcomes at the community level.
3. Believes that it is crucial to identify obstacles and problems faced by communities regarding the SDGs.
4. Believes that efforts must be employed to achieve the SDGs.

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5. Is committed to adopt sustainable behaviors in his/her lifestyle.
6. Is committed to communicate and address the problems and challenges of the community in relation to sustainable development.

Learning goals and outcomes

- Describes the SDGs and understands the importance of sustainable development.
- Explains how SDGs are interrelated.
- Uses argumentation to connect SDG3 with other SDGs.
- Obtains and analyzes data and scientific information regarding SDGs tracking.
- Proposes evidence-based actions, at different levels, that help advancing the SDGs.
- Finds evidence, compiles data and information to help progressing the SDGs at the local level.
- Uses evidence to propose measures that contribute for the sustainability agenda at the community level and communicates them to the community leadership.

Assessment methods

✓ Outcome assessment
  - Quantitative - questionnaire (in paper) - Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
  - Qualitative – students project: scientific poster and presentation.

✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid*:* reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better)

Content

STEM content (relevant to learning goals & research topics)
STEM knowledge applied to sustainability: climate action, ecosystem preservation, health, mobility, digitalization, urban design, energy, water, sanitation and hygiene.

Non-STEM content
Environmental and social changes, sustainability. Education for citizenship.

Digital learning objects and educational resources

- *Interactive dashboards*

Interactive dashboards of countries' progress regarding SDGs: developed by the United Nations, the European Commission, and Our World in Data, provide quantitative goals, and SDGs indicators, allowing analysis of trends and inter-country comparisons.
Interactive dashboard of countries' total progress towards achieving all 17 SDGs **[LO1]**: https://dashboards.sdgindex.org/map
Interactive website of European countries' progress towards SDGs **[LO2]**: https://ec.europa.eu/eurostat/cache/digpub/sdgs/
Interactive website of countries' progress for each SDGs indicator available **[LO3]**:
https://sdg-tracker.org/

- The origins of the SDGs, challenges and opportunities (*infographic*) **[ER1]**

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https://www.canva.com/design/DAE9rgTFfsg/EtHkkNj0fx2srp1OQ96TGg/view?utm_content=DAE9rgTFfsg&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

- The SDGs and their targets (*infographic*) **[ER2]**

https://www.canva.com/design/DAE3D37Ty_U/SMHVhveh2NXPwiZCsYlO9w/view?utm_content=DAE3D37Ty_U&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

- Actions to support the SDGs (*infographic*) **[ER3]**

https://www.canva.com/design/DAE-VA5kfHY/els1YF6ONfi-aieeCpslaA/view?utm_content=DAE-VA5kfHY&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

- SDGs targets and indicators- concepts (*infographic*) **[ER4]**

https://www.canva.com/design/DAE5xAZWDrs/-lihVLvt_HWvrz9hk90yAg/view?utm_content=DAE5xAZWDrs&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

- COVID-19 and the SDGs (*infographic*) **[ER5]**

https://www.canva.com/design/DAE5xGfrEsY/64mYacaO4fSHe4sEO_VvnA/view?utm_content=DAE5xGfrEsY&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

- Questionnaire- quantitative assessment of learning (*in paper*) **[ER6]**

From other sources/open access selected platforms:

- SDGs Booklet: Booklets developed by the United Nations, in which each SDG is described, and their importance described [**ER7]**

Booklet on the 17 SDGs (In Portuguese): https://unric.org/pt/wp-content/uploads/sites/9/2019/01/SDG_brochure_PT-web.pdf
Booklet the 17 SDGs (In English):
https://www.undp.org/content/dam/undp/library/corporate/brochure/SDGs_Booklet_Web_En.pdf

- SDGs Targets and Indicators **[ER8]**

https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202021%20refinement_English.xlsx

- 170 actions to transform the world: Book developed by the United Nations, containing 10 daily suggestions for each SDG; it focuses on how individuals can make a difference in the world around them **[ER9]**

170 Actions : https ://drive.google.com/file/d/1iMdE6DLLuCqwq3K9U-DaTUWB6KyMa8QG/view

- SDGs data matrix: developed by "Our World in Data", indicates for which of the 230 SDGs indicators there is data available **[ER10]**

https://ourworldindata.org/uploads/2018/06/SDG-Data-Matrix-01.png

Videos **[ER11]**

Call to Learning for Climate Education (03:11)
A video to inspire learning about climate change, with actions taken by youth around the world.
https://www.youtube.com/watch?v=2oGKKAMjRfQ&t=12s&ab_channel=TheGlobalGoals (In English)

Changemakers- One Step Greener (01:02)

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A video about a project created in India aimed at recycling and better waste management.
https://www.youtube.com/watch?v=riK1lfT1xUM&t=59s&ab_channel=TheGlobalGoals (In English)

Fashion Avengers (01:00)
A video about individual actions to lead to more ethical and sustainable practices in how we dress.
https://www.youtube.com/watch?v=Iknb7lJHrEQ&ab_channel=TheGlobalGoals (In English)
Can Children Really Make a Difference? (01:40)

A video of children advocating for different global challenges.
https://www.youtube.com/watch?v=hR8hgBfZJcs&ab_channel=TheGlobalGoals (In English)
Leave No One Behind: Tracy´s story (03:00)

A video telling the story of Tracy, and how she is a vocal advocate for girl's education
https://www.youtube.com/watch?v=_qwG8UdQpII&ab_channel=TheGlobalGoals (In English)

Sustainability in everyday life (01:38)

A video showing small changes in our day to day that can lead to a big impact in sustainability
https://www.youtube.com/watch?v=kZIrIQDf1nQ&ab_channel=ACCIONA (In English)

Repensar, Reduzir, Reutilizar, Reciclar (02:30)

A video discussing how we can take actions in our day-to-day life regarding sustainable consumption

https://www.youtube.com/watch?v=PckAgY6stqU&ab_channel=institutoakatu (In Portuguese, with English subtitles)

Campanha Igualdade de Genero (01:56)
A video discussing actions that can be taken to tackle gender inequalities
https://www.youtube.com/watch?v=sR9ooS8EYO8&ab_channel=CanalCNTC (In Portuguese)

Complementary
- Education for Sustainable Development (ESD). Developed by UNESCO, A resource bank, developed by UNESCO, that offers hundreds of pedagogical ideas for classroom activities and multimedia resources detailing how best to integrate ESD into teaching and learning **[ER12]**:
https://en.unesco.org/themes/education/sdgs/material

- The World's Largest Lesson, an initiative by UNESCO and UNICEF, with hundreds of free materials for students aged 4-18 **[ER13]**.
In English: https://worldslargestlesson.globalgoals.org/resources/?_sft_language=english
In Portuguese, promoted by the Portuguese UNICEF Committee and by the Directorate-General of Education:
https://drive.google.com/drive/folders/0B79QWkVg54k_flZBekxOUFRlSGpDUWs2QmlOa1JyMmJHTjlTWENpcllNM2llV09rRU9haUk?resourcekey=0-vvNBnQK5OOYy4VSMseF3Xg

Teaching -learning activities

Principal target:
Sciences and Geography classes and Science clubs
8^{th} grade (+/- 14 years old students)
5 sessions of 40-45 minutes

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Geography and science teachers integrate other colleagues in the enactment of the scenario (e.g., mathematics, english and visual education teachers), as the implementation of the scenario aims to be interdisciplinary.

Lesson 1: Introduction to Sustainable Development Goals

➢ Learning objective: at the end of lesson 1 students should be able to identify the pillars of Sustainable Development, the origins of the SDGs and their meaning, recognize their importance, and to express that the different SDGs are related.

➢ Discussion on the main challenges the world/our country/the community faces now.
The teacher introduces the question "which are the main problems the world/our country/the community faces now?". Students are separated in groups for discussion, and each group must come up with a specific number of problems (to be defined according to number of students). Then a representative of the group is elected and write the ideas of the group on the board or flipchart.
Students identify environmental, political and economic problems our world/country/community faces at different levels. The ideas should be kept for another activity at the end of lesson 1.

➢ Presentation on the SDGs and their origins.
Teacher questions students about initiatives that could be taken to tackle these issues that affect us all. Following this discussion, the teacher asks if they know the term SDGs; if yes, the teacher asks students to express their ideas about SDGs. If not, the teacher asks students to explain the meaning of the word "Sustainable". Following this discussion, the teacher explains that the Agenda for Sustainable Development addresses the major problems that the world faces today and explore the movements that triggered the SDGs. The SDGs were introduced in 2015 and are related to the Millennium Development Goals (MDGs), which established measurable, universally agreed objectives for tackling extreme poverty and hunger, preventing deadly diseases, and expanding primary education to all children, among other development priorities. The teacher presents the SDGs and gives an overview of targets and indicators applied to track the SDGs' progress. The following resources should be used at this stage:
- The origins of the SDGs, challenges and opportunities **[ER1]**
- SDGs Booklet **[ER7]**
- The SDGs and their targets **[ER2]**

➢ Connecting real challenges to the SDGs.
Students are stimulated to connect the problems previously identified to the SDGs, with teacher moderating the class discussion. Some problems will be related to more than one SDG, therefore, in this activity, students realize that only integrated action at the level of several SDGs can effectively tackle the problems.

Suggested homework: students are encouraged to explore the SDGs and actions that support the Agenda for Sustainable Development. Following this class, they may also explore their targets and indicators, and their associations, after this lesson. The School Research Project consists in identifying actions, that have a relevant contribution to the SDGs, to be implemented at the school setting. Students can then start gathering ideas that contribute for the project since the first lesson.

Lesson 2: Individual actions towards the SDGs

➢ Learning objective: at the end of lesson 2 students should be able to propose concrete actions towards promoting sustainability in their lifestyle, able to demonstrate values and to adopt individual attitudes that lead to more sustainable societies, recognize the importance of contributing to the Global Goals and be committed to actions that support SDGs achievement.

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➢ Discussion on possible actions, of individual nature, tham contribute to the SDGs
Students discuss, in groups, with the moderation of the teacher, which individual actions they can adopt towards supporting the SDGs achievement. Students should suggest actions they can take from their homes and in their communities. These actions can include saving electricity and water; reducing carbon emissions; recycling; biking, walking or taking public transport; donating what it is not used anymore; being vocal about inequality; to name a few. The discussion of actions will be supported by the following resource:

- 170 actions to transform the world **[ER9]**

The teacher may decide to present actions that the students didn't map during the exercise. For that the teacher can use the following resource:

- Actions to support the SDGs **[ER3]**

➢ Incorporating actions and practices in their lifestyle.

Based on the previous list of potential actions, students are estimulated to think about their routines and to identify 5 actions that they aim to incorporate in their daily lives, and explain how they will do it. The students work individually and write their answers on paper. This lesson is aligned with the School Research Project, and students can start getting insights and preparing for it. Students then present their findings to the class. The teacher promotes a discussion on strategies to address them in everybody lives. The ideas that emerge during the discussion between students, moderated by the teacher, should be kept, as this knowledge will be useful for the School Research Project.

Lesson 3: The progress to achieve the SDGs

➢ Learning objective: at the end of lesson 3 students should be able to identify data sources to characterize SDGs in a scientific perspective, select scientific data and information to describe the progress of the SDGs, define relevant concepts associated to the SDGs, and be able to interpret results regarding SDGs' targets and indicators.

➢ Assessing progress on the SDGs using global indicators
Teacher reviews the SDGs, the targets and the indicators presented in Lesson 1. Students understand that the achievement of the SDGs depend on an effective process of monitoring, reviewing, and following up. Students also understand that tracking the SDGs can be used to hold policy makers accountable to develop, implement, conduct and promote actions to achieve the agreed goals.

Teacher and students explore together the progress made towards achieving the SDGs in a global perspective, through inter-country comparisons. Students understand that there are countries in which major challenges remain. (e.g., for SDG1 (No poverty), many European countries have achieved the SDG, while in most African countries major challenges remain; for SDG13 (Climate action), many African countries have achieved the SDG, while in most European countries major challenges remain). The following resource should be used at this stage:

- Interactive dashboard of countries' total progress towards achieving all 17 SDGs **[LO1]**

➢ Assessing the progress of SDGs using national indicators
Teacher and students explore together the national progress regarding the SDGs. It is suggested they explore varied SDGs and their respective indicators. Teachers must assist students in the interpretation of graphs that show varied indicators trends, as well as in understanding the concepts behind them (e.g., Healthy life years at birth; GDP per capita). Teachers also discuss with students the challenges in tracking the SDGs, either due to data shortcoming (incomplete or outdated data), or because global monitoring is not currently possible. Students understand the importance of tracking progress and how to interpret and compare data.

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Given that there are too many targets and SDGs to explore, below there are some examples of questions that can be explored regarding different SDGs. These serve as guidance for the discussion in class, but students are encouraged to explore other SDGs, indicators, data and countries after the class.
Students are organized in 2 groups and invited to explore trustful data sources regarding SDGs tracking. They report performance on the SDGs according to the available indicators for each SDG. Is suggested that students answer the following questions:

Question	Proposed data source
1. Which European country had the highest percentage of people facing severe housing deprivation/poor housing conditions in 2020? (SDG1)	LO2
2. What was the share of the population living in extreme poverty in Italy in 2019? Was it higher or lower than the share in Spain? (SDG1)	LO3
3. What was the percentage of the population aged 18 years or over who were obese in Portugal in 2017? (SGD2)	LO2
4. What was the death rate due to tuberculosis, HIV and hepatitis (per 100 000 persons) in the European Union in 2017? (SDG3)	LO2
5. How many people have died in the world from road traffic accidents in 2019, including vehicle drivers or passengers, motorcyclists, cyclists and pedestrians? (SDG3)	LO3
6. What was the mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease in France in 2019? Has it increased or decreased since 2010? (SDG3)	LO3
7. Was the gender pay gap in the European Union higher than 10% in 2019? Has the gender pay gap increased or decreased since 2012? (SDG5)	LO2
8. Which of the following countries had the lowest percentage of population connected to at least secondary waste water treatment systems in 2019? Belgium, Bulgaria, Finland, Slovenia? (SDG6)	LO2
9. Has the share of renewable energy as % of gross final energy consumption been increasing in Portugal since 2004? (SDG7)	LO2
10. Which country had the highest GDP per capita in 2019? France, Germany, Spain, Sweden? (SDG8)	LO2
11. Has the material footprint in the world increased or decreased since 2010? (SDG12)	LO3

The following resources should be used at this stage:
- SDGs targets and indicators- Concepts **[ER4]**
- Interactive website of European countries' progress towards SDGs **[LO2]**
- Interactive website of countries' progress for each SDGs indicator available **[LO3]**

The teacher explains the challenges in tracking the SDGs, either due to data shortcoming (incomplete or outdated data), or because global monitoring is not currently possible. The limitations of the collected evidence are discussed and students should be able to distinguish different types of uncertainty related to the SDGs.

The following Resource should be used at this stage:

- SDGs data matrix **[ER10]**

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Lesson 4: COVID-19 and SDGs

➢ Learning objective: at the end of lesson 4 students should be able to characterize the impact of the COVID-19 pandemic on the SDGs, identify data sources to map trends and performance on the SDGs

➢ COVID-19 and the SDGs

The teacher explains that the COVID-19 pandemic has been an unprecedented event for our generation, and the extent to which the achievement regarding the SDGs has been derailed is not fully comprehended yet. The teacher asks students if they can infer what happened during the pandemic regarding performance on the SDGs. Then, students are organized in groups for answering this question. They define questions and generate hypothesis about the impact of the pandemic on the SDGs. They can use the resources presented in the previous lesson to empirically base their findings. Finally, students return to their initial questions and hypothesis and explain if they were answered of validated by their research. Finally, students present and discuss their results in the classroom.

Some SDGs have a less strong relationship with public health and so the impact of the pandemic is less pronounced, and assessing their progress involves less STEM content. For these reasons it is suggested that the groups focus their attention on the following goals: SDG 1; SDG3; SDG4; SDG8. The following questions can be used to serve as guidance for the students to explore the progress of the SDGs during the pandemic period:

Question	Proposed data source
1. Was the percentage of people at risk of poverty or social exclusion in the European Union in 2020 higher than the percentage in 2019? (SDG1)	LO2
2. In Italy, what was the percentage of people facing with severe housing deprivation between 2015 and 2019? And what happened in 2020? (SDG1)	LO2
3. In India, what was « percentage of people living in extreme poverty between 2010 and 2019? And what happened in 2020? (SDG1)	LO1
4. Which year had the highest share of the population living in extreme poverty in Brazil in the period between 2015 and 2021? (SDG1)	LO1
5. Was the percentage of the population reporting unmet need for medical examination and care higher in 2020 than in 2019 in France? And in Spain? (SDG3)	LO2
6. What happened to the percentage of adults participating in learning between 2019 and 2020 in Portugal? And Italy? And France? (SDG4)	LO2
7. What was the trend for the GDP per capita in Portugal between 2014 and 2019? Has it increased or decreased in 2020? And in Italy? (SDG8)	LO2 and LO3
8. Was the share of the population employed in 2020 higher or lower than the share in 2019? (SDG8)	LO2
9. What happened to the unemployment rate in 2020 in India? And in Peru? And in Ethiopia? (SDG8)	LO1

Then the teacher also presents official data published by UNESCO, using the following resource:

- COVID-19 and SDGs **[ER5]**

Students understand the impact that COVID-19 had on the SDGs, and the challenges and opportunities that arise from the pandemic.

Lesson 5: Review of SDGs

➢ Learning objective: at the end of lesson 5 students should explain the origins of the SDGs, the importance of developing consistent actions towards sustainable development, to know sources of

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information to track them, recognize how they are interrelated, and have their doubts and misconceptions addressed, answered, and corrected.

Students answer a questionnaire about the SDGs. Questions encompass the learning goals and themes explored during lessons 1-4 (origins, each SDG, meaning, targets, progress tracking, relevant action). The questionnaire **[ER6]** assesses their knowledge, skills, attitudes and behaviours regarding sustainable development. The teacher reviews the responses and captures students' misconceptions on the topic, the skills that are still underdeveloped and auto-declared behaviour that are not aligned with sustainable development and returns to the classroom to discuss the answers. Special materials are prepared to come back to the classroom in the project phase to address the absence of fundamental learnings and skills.

At this phase of the teaching-learning sequence, students have been exposed to SDG topics that are meaningful for them (e.g., poverty, hunger, diseases, inequalities, loss of biodiversity) and also have understood the unique challenges communities face all over the world, many of which that they may not have been conscious about before the classes. This understanding creates and fosters a sense of global empathy, solidarity, and connection with the planet as a whole. By transforming this empathy into affective behaviour, students are ready to start designing projects that contribute to the community and to organize or get involved in local initiatives that create positive change.

Supplementary learning resources and educational activities

During any session of the school research project (described down, in autonomous section) is organized at least one of the following activities:

1. **Discussion with school representatives.** The school is a transformative environment, and the representatives can discuss with students how sustainable development is promoted at the school setting. Students can identify actions and interventions promoted at the school level that may contribute to the SDGs.
2. **Discussion with private or third sector organizations regarding sustainable development.** Many organizations incorporate practices that promote sustainable development, and students can discuss with experts how these practices are introduced and monitored, as well as positive results they are bringing to society.
3. **Discussion with governmental actors regarding Sustainable Development.** Many countries and governments have agencies and departments dedicated to the promotion and monitoring of SDGs, and students can discuss with experts how SDGs are promoted and monitored at a national level..

These educational activities can be in the form of teleconference, classroom visits by experts, or students visiting organizations.

School Research Project

Topics

Global Agenda for Sustainable Development
Scientific evidence and monitoring indicators
Actions to achieve the SDGs
Translation of the SDGs to the local level

Research management, design and administration

Overview. The project is based on guided research about measures that can be adopted at the school level to support the Agenda for Sustainable Development 2030, with a focus on questions related with SDG3-Good Health and Well-being. Students will be contributing to a healthy school and to the sustainability of their community by developing inquiry-based activities and presenting their results in a schooling event

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open for community participation. The students perform inquiry-based activities, collect data, analyse results, extract conclusions, and propose priorities for action. In the end of the project, students will present a scientific poster that identifies strengths of the school and the community in a public health and sustainability perspective, as well as areas for improvement that may be addressed by community stakeholders (e.g., students, residents, organisations, policy makers). During the process, they will be developing research skills, the capacity to navigate in digital environment, improve their skills to develop and communicate ideas, and teamwork skills, while investigating and discussing important actions that can be taken by the school regarding the requirements of sustainability.

Relevance. The agenda for Sustainable Development 2030 brings attention to the main challenges our world faces in different levels and defines ways to contribute for SDGs advancement from an individual to a global perspective. By learning about the SDGs, students get greater knowledge on solutions for problems they face in their own lives (e.g., energy poverty), as well as how to impact positively the lives of others. Students address the socioscientific issues brought by the project by collecting evidence and translating the research findings into concrete actions and efforts, to be taken at the school level, that contribute the sustainability agenda, while promoting equality, health, well-being and sustainability in their community.

Estimated duration. The school research project starts after lesson 5 and has an estimated duration of 5-6 sessions of 45 minutes.

Resources. The following Digital Educational Resources can assist at this stage:
- Education for Sustainable Development (ESD) **[ER12]**
- The World's Largest Lesson **[ER13]**
- Videos **[ER11]**

Phases of the School Research Project:

The School Research Project structure follows the typical phases of an inquiry-based project:

1. Orientation – discovering a problem: students are introduced to a problem, which is the effects of humans lives on the planet and the unsustainability of maintaining lifestyles and behaviours that destroy the capacity of sustainable living on earth. Teacher uses **[ER2]** to show some impacting images.

2. Conceptualization – finding a research/starting question: the teacher asks students if they believe they may have a relevant contribution for the sustainability of the planet and if the school can help in this mission. After discussion around potential starting questions, students elect one that drives the school research project.
E.g.
- how may the school help advancing the SDGs?
- what are the challenges of the school community regarding sustainable development?
- what are the challenges of the school community regarding SDG3?
- what are the elements present at the school community that don't contribute to the UN Agenda for Sustainable Development?

Students are separated in groups and each group addresses one category, mostly related to a group of SDGs and systematically associated to SDG3- Good Health and Well-being. The three categories are:

A. Social progress (SDG1, SDG2, SDG3, SDG8, SDG10, SDG11)
B. Environmental protection (SDG 3, SDG6, SDG7, SDG 11, SDG 12,SDG13, SDG 14, SDG 15)
C. Sustainable lifestyle (SDG 3, SDG11, SDG12, SDG13, SDG14, SDG15)

The teacher discusses with students' possible questions to assess the attributes of the school community in the categories and possible methods to get the answers. It is suggested the application of an online

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questionnaire and to conduct observations, but other data collection methods (e.g.: interviews) may be included. The advantages and limitations of the alternatives are discussed.

For each category it is suggested below a couple of questions and a method to collect evidence. Given that the SDGs are related, some questions or attributes may be associated to more than one of the categories. At the end of the project, students must express on how these attributes in their school/community are related to Good Health and Well-being (SDG3).

- Social progress: Decent work, food security and reduced inequalities (SDG1, SDG2, SDG3, SDG8, SDG11)

Main SDGs	Questions	Suggested data collection instrument
1,3	There are humans in a situation of poverty in the community?	Survey
8	Is access to employment and decent income for all assured?	Survey
1,2,3	There are humans in situation of hunger or malnutrition in the community?	Survey
2, 3, 8	Are the price of the meals affordable?	Survey
2,3	Are the meals healthy? (With the key nutrients)	Survey
2, 3,11,12	Is it usual to throw away food? Is there food waste?	Survey or Observation
2, 3, 11, 12, 13	There is a community garden?	Observation
3, 8, 11, 13	Is public transport to go to school good and cheap?	Survey
3, 10, 11, 13	Is public transport accessible for everyone regardless of their mobility?	Survey
3, 4, 10, 11	Is the school accessible for everyone regardless of their mobility?	Survey
1, 2, 3, 10, 11	Are there activities organized in the school/around the school/by the community to address needs of social nature? (e.g. food donation, charity events, social fairs, exhibitions, informative campaigns)	Survey/Observation/Interview

Note: different scales for responses may be applied (e.g. 1- strongly disagree; 2 – disagree; 3- not disagree, not agree 4- agree; 5 – strongly agree; 2- definitely false; 2 – false; 3 – not false, not true; 4 – true; 5-definitely true; 1- extremely unlikely; 2 – unlikely; 3 – not unlikely, not likely; 4 – likely; 5-extremely likely; 1 – yes; 2 – no).

- Environmental protection: Sanitation, clean energy and climate action (SDG3, SDG6, SDG7, SDG11, SDG 12, SDG13, SDG 14, SDG 15)

Main SDG	Questions	Suggested data collection instrument
3, 6, 11, 12	Is there any waste of water at the school?	Survey or Observation
3, 8, 11, 13	Is the school accessible by public transport?	Survey
3, 11, 13	Is the school accessible by walking?	Survey

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3, 11, 13	Is the school accessible by bicycle?	Survey
3, 11, 13	Is car the preferred mode of transportation in your community? (to go to school, supermarket, visit friends)	Survey
3, 11, 12, 13	Is there any waste of energy in the school?	Survey or Observation
3, 7, 11, 13	Are there clean sources of energy at the school?	Survey or Observation
3, 11, 13, 15	Are there green public spaces in the school/around the school?	Survey
3, 11, 13, 14, 15	Are there social activities organized in the school/around the school/by the community to address environmental protection? (e.g. clean the beach/park campaign, car-free day, bicycle day, informative campaigns)	Survey/Observation/Interview

Note: different scales for responses may be applied (e.g. 1- strongly disagree; 2 – disagree; 3- not disagree, not agree 4- agree; 5 – strongly agree; 2- definitely false; 2 – false; 3 – not false, not true; 4 – true; 5-definitely true; 3- extremely unlikely; 2 – unlikely; 3 – not unlikely, not likely; 4 – likely; 5-extremely likely; 1 – yes; 2 – no).
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- Sustainable Lifestyle: Sustainable communities and responsible consumption (SDG3, SDG11, SDG12, SDG13, SDE14, SDG15)

Main SDG	Questions	Suggested data collection instrument
12, 13, 15	Is the paper usage in the school excessive?	Survey
12, 14	Is single-use plastic common in the school?	Survey
11, 12	Are school supplies (pencils, markers, crayons) re-used or used until they are unusable?	Survey
11, 12	Are there recycling bins for paper, glass, metal and plastic in the school/around the school?	Observation
11, 12	Are there donation bins in the school/around the school (e.g. for clothing items)?	Observation
12	Are there facilities in the school/around the school to repair objects?	Observation
11,13	Are there green spaces in the school/around the school?	Survey
3, 11	Are there public spaces in the school/around the school for people to do physical exercises and to be physically active?	Survey

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3, 11, 12, 13, 14, 15	Are there social activities organized in the school or by the community to promote healthy and sustainable lifestyles? (e.g. clothes swap events, donation days, group walks/exercises)	Survey/Observation/Interview

Note: different scales for responses may be applied (e.g. 1- strongly disagree; 2 – disagree; 3- not disagree, not agree 4- agree; 5 – strongly agree; 2- definitely false; 2 – false; 3 – not false, not true; 4 – true; 5-definitely true; 1- extremely unlikely; 2 – unlikely; 3 – not unlikely, not likely; 4 – likely; 5-extremely likely; 1 – yes; 2 – no).

In summary, a problem statement and a starting question are defined that stimulates students' interest and curiosity on the theme. Students, with the guidance of the teacher, decide on the data collection methods to answer the question and test their hypothesis, administer surveys, observations, interviews with community members/stakeholders (being the first two methods preferred). The advantages and limitations of the alternatives are discussed, and the data collection instruments are prepared. It is suggested that they work in groups using a laptop to build an online questionnaire in Google forms. At this phase, students must write the following crucial aspects of their scientific project.

- ✓ Problem
- ✓ Research question
- ✓ Research objectives
- ✓ Data collection method and instruments
- ✓ Define study participants/target group (WHO)
- ✓ Defining a strategy and activities to achieve the target group (HOW)
- ✓ Defining the minimum number of responses from the target (EXPECTED RESULTS)
- ✓ Set a timeframe for data collection (WHEN)
- ✓ Identify events that may limit data collection, and define mitigation strategies (RISKS)
- ✓ Define how to monitor results (CONTROL procedures)

<u>3. Investigation</u>- collecting evidence and information of scientific nature: students carry out the investigation, design and implement the inquiry–based activities (exploration, observation, experimentation, data interpretation). After reaching a minimum number of responses, they can use Microsoft Office programs (e.g., excel, word) to organize their data, either it is quantitative or qualitative. Different methods of investigation can be employed, and the strategies to achieve the target group and the minimum number of responses/observations are defined, as well as alternative strategies if unexpected events that may limit data collection occur.

<u>4. Conclusion</u>- –analyzing the collected evidence:

Students analyse the data collected and draw conclusions. The teacher discusses with the students the obtained results andm based on the evidence, they discuss actions to be implemented in the school context that contribute to the SDGs and to promote public health. The teacher discusses with students what is the best method to present the results and software tools to produce the scientific poster may be used (the poster can also be produced on paper if the access on the computer is limited). The teacher supervises the work of students in preparing tables, graphs, texts, images and the production of the final output –the scientific poster. The poster must include the research question, methodology, results, conclusions and recommendations from the inquiry project.

<u>5. Discussion –</u> exploring the implications of the new knowledge: students present the conclusions of their research to the teacher and receive feedback, comments and improvement suggestions. Then the organization of the open schooling event is discussed to present and discuss the findings of the projects. Each group of students will present the evidence of their scientific poster and inform the public about the

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challenges of the project. At this phase, students will be improving their communication skills and developing responsible citizenship. Students will be capable to explain how scientific knowledge may contribute to the resolution of a socioscientific issue related to sustainable development, and to recognize dimensions of the issue that cannot be addressed by science. The scientific poster, that identifies the strengths of the school and their surrounding area in terms of sustainable development, is presented and discussed. Within this scope, improvement areas that may be addressed by community stakeholders are identified (students, residents, organisations, policy makers).

In summary:

- Each project output (e.g.: scientific poster) is presented by the students in a community setting (e.g., exposition center, municipality, garden, museum, science fair).
- Students will communicate measures that contribute to the SDGs, using science-based data and argumentation. Students appeal to action that promotes health of the community and sustainable development.
- Students, parents, school community and relevant local stakeholders attend the event; understand strategies relevant for sustainable development and how each of them may be an agent of influence on the relevant settings (e.g., home, school, workplace, public space at the community).

Additional information

- Students and teachers should use the resources introduced in the lessons, as well at the complementary resources *Education for Sustainable Development* **[ER12]**, and *The World's Largest Lesson* **[ER13]**. These resources Objects contain one section for each SDG, and these contain a great variety of materials including videos, reports, infographics, case studies, booklets. It is also suggested that teachers and students watch the videos **[ER11]**.

- In collaboration with the disciplines of Information and Communication Technologies and Visual Education, students can select the best software to prepare their scientific poster and subsequentially work on it with the support of the teacher (e.g., Canva, MS Power Point).

The project is based on guided research about the Global Goals and how schools can support this Agenda. To address the challenge proposed in this project, students bring the ideas from the first lessons and supplementary educational activities. Students understand the importance of progressing on the SDGs and of searching for reliable data to propose measures. Students propose actions for the school community that supports sustainable development.

Teaching-learning process milestones:

1. Students are able to incorporate evidence in their scientific poster coming from reliable data sources to support their ideas and show media literacy.
2. Students are able to identify and communicate measures based on the data collected by them to help progressing the SDGs and producing positive impacts in the school and community settings.
3. Students are able to suggest and advocate for actions by different stakeholders, based on scientific-based data and information.

Organization of the open schooling event:

- Each poster is presented by the students in a community setting (e.g., exposition center, garden, museum, science fair).
- In the public presentation, students must be prepared to communicate relevant evidence-based recommendations that help to support progress on the SDGs, and that bring consequently bringing positive impacts for the local level.

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Students, parents, school community and relevant local stakeholders attend the event and understand how the progress regarding the SDGs is associated to positive outcomes for the community health and well-being. In this context, they discuss with students the project results and strategies to support the progress of the SDGs at school and community level.

Public Debate and Recommendations (based on research results)
Presentation of posters, and discussion of recommendations based on data collected with the community leadership and stakeholders, dissemination via social communication (national, local, and specific networks).

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
Scenario topic: Sustainable Development Goals

Knowledge	
1. Explains the history of the development of SDGs.	**Question 1.1:** What are the three pillars of Sustainable Development? A) Society, Economy, Environment. B) Equality, Freedom, Justice. C) Altruism, Joy, Optimism. **Question 1.2:** Which of the following statements regarding the Sustainable Development Goals is NOT true? A) The Sustainable Development Goals represent mandatory and international set of rules for development. B) The Sustainable Development Agenda was unanimously approved by 193 members of the United Nations. C) The Sustainable Development Goals are universal, and applicable to all countries while respecting their own national contexts. **Question 1.3:** The SDGs were adopted in 2015 by the United Nations General Assembly and should be achieved by:. T? A) 2030. B) 2040. C) There is no year specified.
2. Recognizes the importance of the SDGs.	**Question 2.1:** Which of the following is NOT a goal of the United Nations Agenda for Sustainable Development 2030? A) To legally oblige countries to develop and adopt policies towards sustainability. B) To address the urgent environmental, political and economic challenges the world faces. C) To promote peace and inclusive societies, reduce inequalities and contribute to the prosperity of economies. **Question 2.2:** Which of the following actions are NOT crucial for getting the SDGs on track? A) Reduce the number of SDGs in Agenda 2030. B) Recommitment by government, cities, business, and industries regarding the SDGs. C) Improvement of the availability of high-quality data for tracking and decision-making.
3. Characterizes the goals and defines relevant concepts regarding the SDGs.	**Question 3.1:** Identify how many SDGs and targets were defined. A) 17 goals and 169 targets. B) 17 goals and 201 targets. C) 15 goals and 21 targets. **Question 3.2:** SGD 3 is to ensure healthy lives and promote well-being for all at all ages, and Target 3.3 aims to end the epidemic of communicable diseases. Please identify which of the following diseases IS NOT included in Target 3.3. A) Diabetes. B) HIV. C) Tuberculosis.

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4. Identifies quantitative measures to track the progress of the SDGs.	**Question 4.1**: Which indicator is used to control Target 1.1 (to eradicate extreme poverty for all people everywhere by 2030). A) Proportion of population living on less than $1.90 a day. B) Prevalence of undernourishment. C) Annual growth rate of real GDP per capita. **Question 4.2**: Target 8.1 is tracked through the indicator "Annual growth rate of real Gross Domestic Product per capita". Which of the following options is NOT integrated in the calculations of the Gross Domestic Product? A) Unemployment Rate. B) Investments. C) Imports and Exports.
5. Characterizes the association between the different SDGs.	**Question 5.1**: SDG 3 (Health and Well-being) is connected with SDG 1 (No Poverty) because: A) Poor socioeconomic conditions, such as poverty, contribute to health inequalities. B) Easy access to adequate sanitation is recommended to human health and well-being. C) The Mediterranean Diet is essential to reduce preventable NCDs. **Question 5.2:** Which of the following actions greater contributes to the achievement of decent work, economic growth and reduced inequalities? A) Enact policies to raise minimum wages and other wages. B) Encourage boys at school age to pursue social studies and girls at school age to pursue technical studies. C) Limit carbon footprint by consuming local and seasonal products. **Question 5.3**: Which impact does climate change may produce on health? A) Negative Impact: Increased respiratory, cardiovascular, and infectious diseases due to negative influences in air and water quality, changes in the prevalence and geographical distribution of food. B) Negative Impact: The higher energy costs associated to droughts and higher temperatures will lead to less financial investments in health promotion activities. C) Positive Impact: The rise in temperature will make cold areas easier to live, making common winter diseases such as cold, flu and pneumonia less frequent.
Skills	
1. Selects appropriate sources to characterize performance on the SDGs.	**Question 1.1:** Which data sources may are preferred to track performance on the SDGs? A) United Nations SDGs tracker. B) National Statistics on Economic Development. C) Data retrieved by google searches.
2. Proposes concrete actions towards promoting sustainability in his/her lifestyle.	**Question 2.1:** Which individual actions can be taken to promote responsible consumption and production? A) Repair house appliances that no longer work. B) Throw away things that are no longer needed. C) Take a bath instead of using the shower. **Question 2.2**: Which individual actions can be taken to promote good health and well-being? A) Do not smoke and be more active. B) Visit a health provider at least once per month. C) Do not consume over 2,500 calories a day.
3. Influences the adoption of choices by others (e.g., family, peers, friends).	**Question 3.1:** I feel able to influence the adoption of actions that help achieving the SDGs by others (family, friends). 1) definitely true... 5) definitively false. **Question 3.2:** I will try to influence the adoption of actions that help achieving the SDGs by others (family, friends). 1) definitely true... 5) definitively false.

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4. Is able to demonstrate values and to adopt individual attitudes that lead to more sustainable societies.	**Question 4.1:** I feel able to adopt individual attitudes in my day-to-day life that lead to more sustainable societies. 1) definitely false… 5) definitely true. **Question 4.2:** I feel able to identify different actions that lead to more sustainable societies. 1) definitely false… 5) definitely true.
5. Selects scientific data and information to describe the progress of the SDGs.	**Question 5.2:** I know the sources I have to consult to assess the progress of the SDGs. 1) strongly disagree… 5) strongly agree. **Question 6.1:** To find reliable information about the SDGs I should consult the following sources. A) researchers, scientific publications, United Nations SDG tracker. B) newspapers, google, youtube. C) friends, journalists, facebook.
7. Identify the problems and challenges of the community in relation to SDGs, connect them with SDG 3 (health and well-being) and find the relevant resources to address them.	**Question 7.1:** I feel able to identify the main problems my community faces in relation to SDGs. 1) definitely false… 5) definitely true. **Question 7.2:** I can understand how the challenges my community faces are related to health and well-being outcomes. 1) definitely false... 5) definitely true. **Question 7.3:** I feel capable of proposing actions that address the SDGs on my community. 1) definitely true... 5) definitively false.
Beliefs, attitudes and behavior	Instructions: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that is important to contribute to the Global Goals.	**Question 1.1:** My individual actions and participation in society life have an impact on the Global Goals. 1) strongly disagree… 5) strongly agree. **Question 1.2:** I am physically and financially capable of adopting actions that contribute to the Global Goals (. 1) Extremely unlikely... 5) Extremely likely. **Question 1.3:** My family and friends think that I should adopt actions that contribute to the Global Goals. 1) Extremely unlikely... 5) Extremely likely.
2. Believes that working on the Global Goals can lead to positive outcomes at the community level	**Question 2.1: If I** contribute to the Global Goals I will bring positive outcomes to my community. 1) strongly disagree… 5) strongly agree. **Question 2.2:** I believe the issues tackled by the Global Goals have *1) No influence... 5) Complete influence* over the most important challenges that my community faces. **Question 2.3:** My community thinks that the success of the Global Goals will bring positive outcomes for all 1) Extremely unlikely... 5) Extremely likely.
3. Believes that it is crucial to identify obstacles and problems faced by communities regarding the SDGs.	**Question 3.1:** The identification of obstacles and problems that my community faces regarding the SDGs is crucial for solving them. 1) strongly disagree… 5) strongly agree. **Question 3.2:** It is possibleto identify obstacles and problems that by community faces regarding the SDGs 1) strongly disagree… 5) strongly agree. **Question 3.3:** It is common knowledge that it is necessary to identify obstacles and problems that the community faces for solving them. 1) strongly disagree… 5) strongly agree.

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4. Believes that efforts must be employed to achieve the SDGs.	**Question 4.1:** It is important to employ efforts to achieve the SDGs. 1) strongly disagree… 5) strongly agree. **Question 4.2:** It is possible to employ efforts to achieve the SDGs. 1) strongly disagree… 5) strongly agree. **Question 4.3:** It is common knowledge that it is necessary to employ efforts to achieve the SDGs. 1) strongly disagree… 5) strongly agree.
5. Has intention to adopt sustainable behaviours in his/her lifestyle.	**Question 5.1:** I will plan eat a healthy diet and drink a lot of water in my day-to-day life. 1) Extremely unlikely... 5) Extremely likely. **Question 5.2:** I plan to incorporate recycling in my day-to-day life. 1) Strongly disagree... 5) Strongly agree. **Question 5.3:** I plan to donate non-perishable foods and things that I no longer use in the next three months. 1) Strongly disagree... 5) Strongly agree. **Question 5.4:** I plan to save water and electricity in the next three months. 1) Strongly disagree... 5) Strongly agree. **Question 5.5:** I will walk, cycle or take public transport instead of using car or motorcycle as much as possible in the next three months. 1) Strongly disagree... 5) Strongly agree. **Question 5.6:** Among the following statements, choose the one that best describes what you currently think. 1) I do not promote sustainability in my day-to-day life, and I also have no intention of doing so. 2) I do not promote sustainability in my day-to-day life, but I have been thinking about the possibility of starting to do so. 3) I never or rarely promote sustainability in my day-to-day life, but soon I will start doing it on a regular basis. 4) I do promote sustainability in my day-to-day life regularly but I have only begun to do so in the last 6 months. 5) I do promote sustainability in my day-to-day life regularly I have been doing so for longer than 6 months.
6. Is committed to communicate and address the problems and challenges of the community in relation to sustainable development.	**Question 6.1:** I intend to communicate and address the problems and challenges of the community in relation to sustainable development. 1) Extremely unlikely... 5) Extremely likely. **Question 6.2:** I have the physical and financial means to communicate and address the problems and challenges of the community in relation to sustainable development. 1) Strongly disagree... 5) Strongly agree. **Question 6.3:** It is expected from me that I communicate and address the problems and challenges of the community in relation to sustainable development. 1) Strongly disagree... 5) Strongly agree. **Question 6.4:** Among the following statements, choose the one that best describes what you currently think. 1) I am not contributing to sustainability in my community, and I also have no intention of doing so. 2) I am not contributing to my community health, but I have been thinking about the possibility of starting to do so. 3) I am never or rarely have been contributing to my community health, but soon I will start doing it on a regular basis. 4) I am contributing to my community health regularly. 5) For more than six months I have always or almost always been contributing to my community health. 6) For several years now, I have been contributing to my community health, and I will continue to do so.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

7. Attitude Toward SDGs.	**Question 7.1:** For me to achieve SDGs is: harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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25. Specifications for an educational scenario on the topic of "Artificial Intelligence responses when clinical symptoms appear"

Main Partner responsible: UNL (Information Management School)

Context

The pandemic brought severe social and economic impacts and healthcare systems were disrupted by the need to diagnose, trace patients in isolation at home, assure in-home and inpatient care, according to the severity of the cases. At the moment, more than 6 million deaths had been attributed to COVID-19 around the globe. Creating awareness on the symptoms and actions to be taken in their presence is very important, not only to increase personal protection but also to help containing the spread of communicable diseases in the community. This can be supported by artificial intelligence (AI) systems, which have been successfully employed for healthcare purposes during the pandemic and many positive outcomes have been documented (e.g., improved COVID-19 screening, diagnostics, follow-up, timely response, most reliable response, efficient outcomes, etc.). In this context, is important to explore ideas and develop students thinking computing around the use of AI systems, and produce creative digital artifacts, using digital strategies and tools to support students' creativity in educational environments: know and explore the concept of AI, the steps for creating and developing an AI system, and promote understanding and classroom debate around its use as an emerging technology.

Scientific content and its relevance to public health education

Students should adopt a critical, thoughtful, and responsible attitude in the use of digital technologies, environments and services. In fact, the goal of creating awareness on the impact of emerging technologies such as AI in society and in everyday life is stablished in the formal curriculum of Information and Communication Technologies (ICT). Therefore, the scenario supports 9th grade ICT teachers in exploring societal concerns around the use of AI. The learning experience supports youths in reaching high-level comprehension on how STEM (science, technology, engineering, mathematics) may contribute to address public health challenges, and ethical concerns around its use, contribute to evidence-based personal decision-making, and encourage the adoption of academic curriculums and professions in the STEM field.

Estimated duration
6 classes of 40-45 minutes
Up to 12 sessions of 40-45 minutes for students projects

Classroom organization requirements

From lesson 1 to lesson 2 students work alone or occasionally in groups. The use of computer may be required. During lessons 3, 4 ,5 and 6 they are asked to work in groups and the use of computer is required. In the Project Activity the students form four- or five-member groups which carry out the school project. The use of computer is required.

Grade
9th grade (+/- 15 years old students)

Content glossary

Artificial General Intelligence (AGI) – AGI is a computational system that can perform any intellectual task a human can. Also called "Strong AI." At this point, AGI is fictional.

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Artificial Intelligence (or Weak AI) – A computational system that simulates parts of human intelligence but focuses on one narrow task. Also called narrow AI, in contrast to AGI.

Artificial Neural Network – A model for AI and machine learning inspired by the neural network configurations of the human central nervous system, especially the brain.

Data Mining – The process by which patterns are discovered within large sets of data with the goal of extracting useful information from it.

Deep Learning – The general term for to machine learning using layered (or deep) algorithms to learn patterns in data. It is most often used for supervised learning problems. In parsing a photo, layers might respond first to edges, then paws, then dogs.

Expert System - A form of AI that attempts to replicate a human's expertise in an area, such as medical diagnosis. It combines a knowledge base with a set of hand-coded rules for applying that knowledge. Machine-learning techniques are increasingly replacing hand coding.

Machine Learning (ML) – A general term for algorithms that can learn patterns from existing data and use these patterns to make predictions or decisions with new data.

Natural Language Processing - A computer's attempt to "understand" spoken or written language. It must parse vocabulary, grammar, and intent, and allow for variation in language use. The process often involves machine learning.

Perceptron - An early type of neural network, developed in the 1950s. It received great hype but was then shown to have limitations, suppressing interest in neural nets for years.

Supervised Learning - A type of machine learning in which the algorithm compares its outputs with the correct outputs during training. In unsupervised learning, the algorithm merely looks for patterns in a set of data.

Turing Test - A test of AI's ability to pass as human. In Alan Turing's original conception, an AI would be judged by its ability to converse through written text

Unsupervised Learning – A class of machine learning algorithms that learns patterns in data without knowing outcomes. Here, the machine is presented with totally unlabelled data, then asked to find the intrinsic patterns in or draw its own conclusions from the data.

Source:https://www.analyticsinsight.net/understanding-artificial-intelligence-a-comprehensive-glossary-of-terms-and-definitions/

Pedagogical glossary

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas or concepts which are relevant to a given guiding question or central term. Criticism on the ideas is absent during brainstorming and its aim is the production of a lot and divergent ideas.

Collaborative learning. Collaborative learning is a didactic model that involves a set of instructional techniques, during which students cooperate and/or collaborate during the learning process, instead of the atomistic, and often rival, view of students by the traditional school. Collaborative learning can boost the learning outcomes, students' interests and participations and their collaboration and communication skills

Data – Any collection of information converted into a digital form**.**

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Information. Facts, ideas, concepts and data that have been recorded, analyzed, and organized in a way that facilitates interpretation and subsequent action.

Inquiry based learning. By the term inquiry-based learning we refer to the engagement of students in learning activities during which they practice several scientific inquiry skills. Students make use of these skills in order to answer to scientific questions either posed by the students themselves or by the teacher, by the handling of authentic data, either experimentally collected by themselves or given already collected. Some common inquiry skills include constructing and using models, carrying out experiments, data collection and organisation, variable handling, data driven conclusion making and communicating over scientific issues.

Lifelong learning. A broad concept where education that is flexible, diverse and available at different times and places is pursued throughout life. It takes place at all levels—formal, non-formal and informal—utilizing various modalities such as distance learning and conventional learning.

Project based learning. Project based learning is an instructional model of active learning. It has several forms, during which students work in groups on the development of projects, which often refer to authentic problems or situations approaching real life conditions. Project based learning includes the phases of project initiation, project development and project presentation.

Indicative literature

Russell, Stuart, and Norvig, Peter. Artificial Intelligence: a Modern Approach, 4th. Edition, Prentice Hall, 2020.

Elaine Rich, Kevin Knight; Artificial intelligence. ISBN: 0-07-100894-2

Hands-On Chatbots and Conversational UI Development: Build chatbots and voice user interfaces with Chatfuel, Dialogflow, Microsoft Bot Framework, Twilio, and Alexa Skills (book ISBN-13: 978-1788294669 ISBN-10: 1788294661)

Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, citizenship

Knowledge
Computer science, software engineering and technology concepts:
- Artificial Intelligence (AI) - what AI is and the different ways to build intelligent Systems
- Machine Learning (ML)
- AI applications in healthcare systems

Social concepts and global concerns:
- Role of AI and ML in society (in particular in epidemic outbreaks)

Knowledge - outcome assessment:
1. Defines relevant concepts of artificial intelligence.
2. Recognizes the limits of AI
3. Recognizes the importance of AI in Healthcare
4. Characterizes Intelligence Interfaces
5. Characterize chatbots and understand its role in the healthcare sector

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Skills (abilities/competences)
General: curiosity; collaboration; critical thinking; self-awareness, citizenship
Specific:

- Obtaining, assessing, and communicating evidence related to Artificial Intelligence Systems
- Applying the main approaches used in building Virtual Agents to build a system that serves public health
- Understanding the appropriate strategies and techniques to build a bot for healthcare
- Analyzing possible consequences of not investing in technology in a situation of pandemic outbreak
- Understanding the advantages and concerns of using AI systems in public health

Skills – outcome assessment:
1. Selects appropriate sources to characterize AI systems in a STEM perspective
2. Selects appropriate techniques and methods to develop a simple AI System.
3. Can develop a simple AI system to fight epidemic outbreaks
4. Can propose concrete AI-based software development actions to fight epidemic outbreaks
5. Can anticipate the consequences of inappropriate use of AI systems in epidemic outbreaks.

Affective /Attitudes/Behaviour (*beliefs)*
General:

- Intellectual curiosity (simulators are adequate to nowadays students and they are keen to use them).
- Respect for plurality of viewpoints (there is no bad idea or stupid observation).
- Collaboration (the collaborative work is critical).
- Teamwork (the project involves students and brings complicity that will be reflected in the rest of the school activities).
- Team support (the project "runs as fast as the lowest mate": in the different stages there will be the need to backing someone.
- Return to basic (the need to explain to others concepts that are basic for some).

Specific:
- Adopting attitudes supporting the use of AI in public health.
- Engaging discourse on the risks and opportunities of using AI systems in public health.
- Engaging public speaking and debating of measures to boost the use of AI in public. health, particularly in the emergence of epidemic outbreaks.
- Engaging public speaking and debating of the role of software in the development of advanced responses for public health, with a particular focus on AI systems.

Attitudes and behavior - outcome assessment:
1. Believes that AI systems are important in healthcare and is committed to contribute for it.Believes that working on computer science and AI is relevant for healthcare.Believes that the collaborative work is critical to overcome obstacles and problems.
2. Believes that efforts should be made to have the best technologies in healthcare.
3. Considers that respect for the plurality of points of view is crucial to obtain good and lasting solutions.
4. Attitudes towards AI

<u>Learning goals and outcomes</u>

- Applies appropriate methods and techniques to develop simple AI systems for public health.
- Incorporates Artificial Intelligence strategies in web applications.
- Identifies philosophic questions than can emerge from the use of AI.

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- Identifies possible applications of AI in public health.
- Uses evidence-based argumentation to promote the use of AI in public health.
- Analyzes possible consequences of inappropriate use of AI in public health.
- Uses evidence-based argumentation to discuss concerns around the use of AI in public health.

Assessment methods

- ✓ Outcome assessment
    - Quantitative - questionnaire in paper - Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
    - Qualitative - students project: development of a bot, its integration in a mini website

- ✓ Process assessment - *assessment of the teaching-learning sequence* – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content

- Importance and general consequences of epidemic outbreaks for society
- Artificial Intelligence
- Concepts of Human Computing Interface (HCI)
- Innovative computer science
- Emerging AI in healthcare settings
- Quality and reliability of information systems

Non-STEM content

- Digital literacy
- Societal concerns around the development of AI systems

Digital Learning Objects (LO) and Digital Educational Resources (DER)

New:

Resources for teachers to support theoretical and practical AI subjects, including smart bot construction

- Learning object: What is Artificial Intelligence? (infographic) (ppt file) [LO1]
- Learning object: AI in healthcare (infographic) (ppt file) [LO2]
- Learning object: Intelligence User Interfaces concepts (infographic) [LO3]
- Learning object: Implementation Manual (how to build a bot integrated in a mini web site) [LO4]
- Learning object: Chatbot Ai source code [LO5]
- Learning object: Mini website template - Template for building a mini web site (HTML and CSS) [LO6]

From other sources/high-quality selected platforms:

Artificial Intelligence
What is artificial intelligence (AI)?
Introduction to AI

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Turing Test – Stanford
Chinese Room
Azure Health Bot
Podcast - Building The Future - AI Portugal - Spotify
AI News

Intelligence User Interfaces
Siri
Alexa
Cortana

Websites
10 Best Website Builders
Wix

Chatbots
Top 6 Use Cases & Examples of Chatbots in Healthcare in 2022
Patient Satisfaction for COVID-19 Chatbots Comes With Conditions
Using AI, Chatbots to Drive Seamless Patient Experiences, Access
Example 1: Healthcare Chatbots
Example 2: Symptomate - symptom checker. Medical app for online self-diagnosis.
How to Make a Chatbot in Python Step By Step
DialogFlow
How to Integrate Dialogflow with Website

2019 Novel Coronavirus (2019-nCoV),
COVID-19 Symptoms - LabXchange
Get Tested for COVID-19 - Providance
Coronavirus (COVID-19) Information - Virginia Mason Health System

Complementary resources:

- Hands-On Chatbots and Conversational UI Development: Build chatbots and voice user interfaces with Chatfuel, Dialogflow, Microsoft Bot Framework, Twilio, and Alexa Skills (book ISBN-13: 978-1788294669 ISBN-10: 1788294661)
- Building Chatbots with Python: Using Natural Language Processing and Machine Learning 1st ed. Edition (book ISBN-13: 978-1484240953 ISBN-10: 1484240952)
- Other multimedia content (e.g.: videos, photos) taking by the project team in the working environment, during the professor workshops, classroom and outside classroom enactments.

Teaching -learning activities

Principal target:
ICT classes
9th grade (+/- 15 years old students)
6 sessions/classes of 40-45 minutes
ICT teachers integrate other colleagues in the enactment of the scenario (e.g, science, visual education, mathematics and english teachers), as it aims to be interdisciplinary and innovative.

A variety of instructional strategies will be applied, including exposure and demonstration with step-by-step examples (with and without software), questions and answers. The sessions include presentation of concepts and methodologies, examples, discussion and interpretation of results. The practical component is geared towards building a mini web site and a bot, including discussion and interpretation of results.

Lesson 1: Artificial Intelligence

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The teaching-learning script starts with a question “what is Artificial Intelligence (AI)”?
After posing the question, three or four students are asked for their opinion on what they think AI is.
Next, the teacher shows an image of robot sitting on a rock that seems to be thinking about something and poise a new question “The machines can think”?

- brainstorming on the question “The machine can think?”

Students are asked to make a justified vote (yes or no) on the question "if the machine can think".
The teacher records the vote on a board and then summarizes the arguments for and against.
After, the teacher explains:

- The Turing test, - the most famous test related to Artificial Intelligence capabilities. Its purpose is to test the machine's ability to express intelligent behavior indistinguishable from that of a human. The test can be summarized as follows: a remote human interrogator, within a fixed time frame, must distinguish between a computer and a human subject based on their replies to various questions posed by the interrogator. By means of a series of such tests, a computer’s success at “thinking” can be measured by its probability of being misidentified as the human subject.
  https://plato.stanford.edu/entries/turing-test/

- “Chinese room” argument - a powerful rejoinder to the idea that the Turing test can show that a machine could think. Suppose a human who knows no Chinese is locked in a room with a large set of Chinese characters and a manual that shows how to match questions in Chinese with appropriate responses from the set of Chinese characters. The room has a slot through which Chinese speakers can insert questions in Chinese and another slot through which the human can push out the appropriate responses from the manual. To the Chinese speakers outside, the room has passed the Turing test. However, since the human does not know Chinese and is just following the manual, no actual thinking is happening.
  https://plato.stanford.edu/entries/chinese-room/

- The following Digital Learning Object should be used at this stage: What is Artificial Intelligence? (infographic) **[LO1]**

The professor presents some areas of health where knowledge, reasoning and the ability to process information are very relevant. E.g., diagnosis, treatment protocol development, drug development, personalized medicine and patient monitoring and care.
AI technologies have the potential to transform many aspects of patient care, as well as administrative processes within provider, payer and pharmaceutical organisations. There are already several research studies suggesting that AI may perform as well or better than humans on key health tasks such as diagnosing disease. Today, algorithms are already outperforming radiologists in detecting malignant tumors and advising researchers on how best to build clinical trials. However, there are several barriers to the rapid implementation of AI in healthcare, for example ethics.

- The following Digital Learning Object should be used at this stage: AI in healthcare (infographic) **[LO2]**

- Debate on the question “How can AI benefit the healthcare industry?”

- Complementary Resources:
  Podcast - Medical Diagnosis Assisted by Artificial Intelligence
  https://popcasts.pt/diagnosticos-medicos-assistidos-por-ia-convidada-joana-rocha/

Lesson 2: Intelligence Interfaces

- Intelligence Interfaces concepts

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

The teacher starts by introduction Intelligence Interfaces as an Intelligent personal support tools that are one of the main applications of artificial intelligence. Usually, they are software agents capable of performing tasks or services based on commands or questions, which can be provided by text or voice. Then, the teacher presents some famous examples: Siri, Alexa and Cortana.

- debate on the question “Are these Intelligence Interfaces useful? How & Why?”

One type of Intelligence Interfaces is a chatbot. Generally, the literature uses several terms as synonyms for "chatbots". These terms include "virtual assistants", "digital assistants", "conversation agents", "chatterbots" or "natural dialogue systems" among others, although they are all used interchangeably to describe conversation systems using natural language.

- debate on the question “What does a chatbot do?”

- It is a system that just answers simple questions to exclude people about symptoms (for instance, of COVID-19), care they should have, procedures to follow… or is more than this?
- It can be a way to free human helplines for cases of medical diagnosis?
- It can be a form of screening and act as the first line of clarification?
- Could it be a powerful tool to combat miss-information and manage the panic generated by the chains of shares on social networks?
- “*Bot, you are not a doctor, but could you be*?”

- The following Digital Learning Object should be used at this stage: Intelligence User Interfaces concepts (infographic) **[LO3]**

- Complementary Resources on Chatbots examples

Siri
Alexa
Cortana

- Complementary Resources on Healthcare Chatbots

AI News – Four major impacts of artificial intelligence on healthcare
Top 6 Use Cases & Examples of Chatbots in Healthcare in 2022
Patient Satisfaction for COVID-19 Chatbots Comes With Conditions
Using AI, Chatbots to Drive Seamless Patient Experiences, Access
Example 1: Healthcare Chatbots
Example 2: Symptomate - symptom checker. Medical app for online self-diagnosis.

Lesson 3-6: Building Chatbot

Students have an overview the main steps to build a Chatbot
1 - Planning the Purpose of Chatbot (Collect inquiries and FAQs, Group the intentions and Provide responses)
2- Setup
3- Building Chatbot
4 -Deploying Chatbot

Then, by doing a step by step tutorial will learn how to build a Basic Dialogflow Chatbot.

Learning objects on Building Chatbot

- The following Digital Learning Objects should be used at this stage: AI in healthcare (infographic) **[LO4, LO5, LO6]**

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By following the step by step instructions of the implementation Manual [**LO4]** students will learn how to build a Dialogflow Chatbot and integrate it in a website.
Then, students creatively customize a website template that incorporate the chatbot.

➢ Complementary Resources on Building Chatbot (video and tutorial)
Video
Tutorial
How to Make a Chatbot in Python Step By Step
DialogFlow
How to Integrate Dialogflow with Website

➢ Complementary Resources on building websites (Website templates)

10 Best Website Builders
Wix

➢ Complementary Resources on on how to integrate the Chatbot in the website (tutorial)
How to Integrate Dialogflow with Website

➢ Quantitative assessment – questionnaire **-** Knowledge, Skills, Beliefs, attitudes and behavior

➢ Presentation and Activity in groups (also works as qualitative assessment):
Students must present their chatbots and for each presentation, in groups, the other students need to identify which information, dialogs were used or which other solutions maybe used to improve to object presented.

After building and presenting the bot students are challenged to build other chatbot in groupwork. This is the **School Project** described down, in autonomous section.

Supplementary learning resources and educational activities

The most important supplementary educational activities is the School Research Project, that has the challenge to build a Chatbot to address the actions to be taken when symptoms appear.

The interaction between students and STEM organizations can be achieved through activities to be carried out in parallel with the execution of the School Research Project. Namely: Classroom visits by IT professionals, healthcare professionals, project managers, software developers or Teleconferences and the organization of a chatbot evaluation competition with rewards attribution where the judges belong to STEM organizations

School Research Project

Topics
- Major communicable diseases. H2019 Novel Coronavirus (2019-nCoV), Measles, Mumps, Zika Virus, Pertussis, Influenza
- CDs Symptoms
- Artificial Intelligence
- Building Chatbot
- Quality and reliability of Information Systems
- Scientific literacy, fact-checking techniques, quality of information sources

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Estimated duration. The school research project starts after lesson 5 and has an estimated duration of 5-6 sessions of 45 minutes.

Research management, design and administration

Students are organized in groups. The project challenges each group of students to create and present a website that contains a chatbot that helps people decide what to do when they have symptoms. They must integrate the knowledge obtained during the teaching-learning sequence and ideas emerged during the meetings with experts.

Connections with possible STEM curriculums and careers

During the development of the Research Project is relevant to organize:

1. **Classroom visits** by IT professionals, healthcare professionals, project managers, software developers, or **Teleconferences** with data scientists or technology developers, researchers of PAFSE consortium, among others. Students make questions to experts with a particular focus on: a) future academic choices and career paths in the STEM field; b) identifying how AI technologies benefit the healthcare industry
2. **Production of multimedia content** (photos, videos)
3. **Competition and reward** of best website and chatbot

Teaching-learning process milestones:
1. Students will be able to propose solutions based on chatbots for healthcare contexts
2. Students will be able to identify and communicate the importance of the role of AI in society and, in particular, in healthcare.
3. Students will be able to use technical argumentation to justify policy choices.

Teaching-learning process for school project (summary):
1. Development of materials (videos, tutorials, pictures).
2. Website and chatbot.
3. Presentation of the Website and chatbot in open schooling event.

Organization of the open schooling event:
1. Each project output (website and bot) is presented by the students in a community setting (e.g., local server or through computers placed in exposition center, garden, museum, science fair).
2. Students will prepare a pitch on how AI and chatbots can address public health challenges. Technical speeches to motivate peers to new technologies and environments.
3. Students, parents, school community and relevant local stakeholders attend the event and are introduced on the topic on how AI can be used to address challenges.

Data Analysis and Reporting
Content Analysis; Descriptive statistics; Data presentation formats; Report writing; Development of presentation.

Target Audience for Recommendations
School community and local stakeholders: students, parents, municipalities, healthcare providers, local enterprises

Public Debate and Recommendations (based on research results)

Public presentation of the website and chatbot and dissemination of evidence-based recommendations via social, community and mainstream media. Release report and recommendations for public consultation.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

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Scenario topic: "Artificial Intelligence responses when clinical symptoms appear"

Knowledge	
1. Defines relevant concepts of artificial intelligence.	**Question 1.1:** What is Artificial Intelligence? A) A type of films of action. B) An extension of the brain. C) An area of Computer Science. D) Does not exist. **Question 1.2:** Which of the following options regarding Artificial Intelligence (AI) is true? A) The object of study of AI is the functioning of the brain. B) The AI is a patent of an American company. C) The object of study of AI is to understand and build intelligent entities. D) AI is a fiction promoted by the media. **Question 1.3:** The concept of Artificial Intelligence was born in: A) 1956. B) 1980. C) 2016. D) There is no specified year.
2. Recognizes the limits of AI	**Question 2.1:** What can NOT be said about the Turing test: A) Its purpose is to test the machine's ability to express intelligent behavior. B) The test can include a remote human interrogator. C) The test includes a remote computer interrogator. D) The human interrogator must distinguish between a computer and a human based on their replies to various posed questions. **Question 2.2:** The "Chinese room" argument is related to: A) A Chinese who wanted to learn AI. B) Chinese life in cities. C) Reject to the idea that the Turing test can show that a machine could think. D) Learning to speak Chinese.
3. Recognizes the importance of AI in Healthcare	**Question 3.1:** Today Artificial Intelligence (AI) technologies DO NOT: A) Help diagnosis. B) Help treatment protocol development. C) Replace doctors. D) Help personalized medicine and patient monitoring and care. **Question 3.2:** There are several barriers to the rapid implementation of Artificial Intelligence (AI) in healthcare. A good example is: A) Poor quality of algorithms. B) Lack of computers in hospitals. C) Ethical problems. D) Doctors strike against AI.

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4. Characterizes Intelligence Interfaces	**Question 4.1**: What can NOT be said about Intelligence Interfaces: A) They use applications of artificial intelligence. B) They are capable of performing tasks or services based on commands or questions. C) They can use text, images or voice. D) They can´t be used in chatbots. **Question 4.2**: A good example of an Intelligence Interface is: A) Alexa. B) Google. C) MS Excel. D) Internet Explorer.
5. Characterizes chatbots and understands its role in the healthcare sector.	**Question 5.1:** A Chatbot is: A) A system that only answers simple questions. B) A type of robot. C) A website functionality. D) A computer program designed to simulate conversations with human users, especially over the internet. **Question 5.2:** Generally, the literature uses several terms as synonyms for "chatbots". These terms DO NOT include: A) Virtual assistants. B) Virtual Reality. C) Digital assistants. D) Conversation agents. **Question 5.3:** The use of chatbots in the health sector DOES NOT allow: A) a form of free humanized care for medical diagnosis cases. B) totally replacing doctors. C) combating the lack of information and managing the panic generated by the chains of shares on social networks. D) a form of rapid triage and act as a first line of clarification.
SKILLS	
1. Selects appropriate sources to characterize AI systems in a STEM perspective	**Question 1.1**: Which data sources should we use to characterize Artificial Intelligence systems? A) Newspapers. B) Scientific databases. C) Data retrieved by google searches.

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2. Selects appropriate techniques and methods to develop a simple AI System.	**Question 2.1:** What are the most important techniques to develop an Artificial Intelligence system? A) Drawing Techniques. B) Programming Techniques. C) Writing Techniques. D) Database Techniques. **Question 2.2**: Which individual actions can be taken to become an Artificial Intelligence expert? (select all that are appropriate) A) Learn Mathematics. B) Learn to program computers. C) Read science fiction books. D) Learn Robotics.
3. Can develop a simple AI system to fight epidemic outbreaks	**Question 3.1:** I´m able to plan a simple Artificial Intelligence system to fight epidemic outbreaks: 1) definitely true... 5) definitely false. **Question 3.2** I´m able to develop a simple Artificial Intelligence system to fight epidemic outbreaks: 1) definitely true... 5) definitively false.
4. Can propose concrete AI-based software development actions to fight epidemic outbreaks	**Question 4.1** It **CANNOT** be said that AI-based software development can help fighting epidemic outbreaks in the following case: A) Helping to predict contagions. B) Healing the sick. C) Helping to build more effective vaccines. D) Helping to make better diagnoses. **Question 4.2** I feel able to identify areas of use of Artificial Intelligence that support the improvement of healthcare services: 1) definitely false… 5) definitely true.
5. Can anticipate the consequences of inappropriate use of AI systems in epidemic outbreaks.	**Question 5.1** A good example of misuse of AI systems in epidemic outbreaks is: A) Help predict infections. B) Help build more effective vaccines. C) Use of AI for surveillance purposes (such as detecting new Covid-19 cases and gathering data from healthy and ill individuals) D) Help make better diagnoses. **Question 5.2** Misuse of Artificial Intelligence systems in epidemic outbreaks can threaten individual privac**y:** 1) strongly disagree… 5) strongly agree.

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Beliefs, attitudes and behavior	Include: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1.Believes that AI systems are important in healthcare and is committed to contribute for it.	**Question 1.1** I believe that Artificial Intelligence systems are important in healthcare: 1) strongly disagree… 5) strongly agree. **Question 1.2** I am interested in imagining and designing Artificial Intelligence systems for healthcare: 1) Extremely unlikely... 5) Extremely likely. **Question 1.3:** For me working on an Artificial Intelligence system, in the next three months, would be: 1) Bad... 5) Good. **Question 1.4:** For me working on an Artificial Intelligence system, in the next three months, would be: 1) useless... 5) useful. **Question 1.5** I plan to work on an Artificial Intelligence project in the next three months: 1) definitely true... 5) definitively false.
2. Believes that working on computer science and AI is relevant for healthcare.	**Question 2.1** I believe that work in the field of Artificial Intelligence has: *1) No influence... 5) Complete influence* over the most important challenges that society faces in healthcare. **Question 2.2** My community thinks that developing Artificial Intelligence systems is relevant for healthcare: 1) Extremely unlikely... 5) Extremely likely.
3. Believes that the collaborative work is critical to overcome obstacles and problems	**Question 3.1** I believe that teamwork is important to overcome obstacles and solve problems: 1) strongly disagree… 5) strongly agree. **Question 3.2** I believe that is easier to identify obstacles and solve problems through team discussions: 1) I totally disagree... 5) I totally agree.
4. Believes that efforts should be made to have the best technologies in healthcare	**Question 4.1** I believe that is important to develop and use the best Artificial Intelligence (AI) technologies in healthcare: 1) strongly disagree… 5) strongly agree. **Question 4.2** It is possible to employ efforts in developing AI technologies for healthcare services.

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	1) strongly disagree… 5) strongly agree. **Question 4.3** It is common knowledge that it is necessary to invest money in AI technology for healthcare services. 1) strongly disagree… 5) strongly agree.
5. - Considers that respect for the plurality of points of view is crucial to obtain good and lasting solutions.	**Question 5.1** I respect my colleagues' views because it helps me to develop a better work: 1) Strongly disagree... 5) Strongly agree. **Question 5.2** In the process of developing a solution, I hear opinions different from mine without interrupting: 1) Strongly disagree... 5) Strongly agree. **Question 5.3** I listen to many different points of view because is important to obtain good and lasting solutions: 1) Strongly disagree... 5) Strongly agree.
6. Attitudes towards AI	**Question 6.1** For me to use AI is harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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26. Specifications for an educational scenario on the topic of "Low-code development environments – Level 1 (Basic)"

Main partner responsible: UM (University of Minho)

Title of Educational Scenario: Connecting students to IT using low-code development environments to promote public health and digital literacy – Level 1 (Basic)

Topic in School Curriculum: Block programming / Hygiene habits

School Subject: ICT classes/Biology/F.Q classes/Health Education classes (Interdisciplinarity[1])

Main resource: MIT App Inventor

Grade level: 7th grade (+/- 12-13 years old students)

Context and relevance to public health education

In a world of immediacy, anything less than digital handiness results in lost opportunities and innovation disregard. In fact, technology is enriching humans' lives, improving access to information, and revolutionizing how people teach, learn and work in the 21st century. Thus, learning how to code is a contribute to the process of developing problem-solving skills central to success in STEM (Science, Technology, Engineering, Mathematics) curricula and careers. It can also aid students in the development of innovative solutions that benefit the health of their community.

Block-based coding or programming is based on a drag-and-drop learning environment, where programmers use coding instruction, called "blocks", to construct animated stories, games and other types of multimedia content. It's an entry-level activity, where students can gain a foundation in computational thinking through visuals as opposed to coding that is based in text, making it more interesting and viable to use as an educational resource.

The educational scenario assists (mainly) ICT teachers in exploring how low-code environments can positively impact education and increase digital and public health literacy. The learning experience supports youths in understanding how STEM may contribute to create new and revolutionizing solutions to the healthcare market, as well as stimulate their creativity, decision-making and problem-solving competences and enhance their technological and communication skills. In the teaching-learning sequence, hygiene habits (e.g.: oral health, sleeping habits) are explored in connection with appropriate tools for multimodal content creation (quizzes, infographics, presentations, etc.) that promote appropriate exposition of this relevant public health topic to other members of the society.

Estimated Duration

5 classes of 40-60 minutes (lesson 1 – lesson 5)

5-6 sessions of 40-45 minutes for supplementary learning activities and school project (session 6 – session 12)

Classroom organization requirements

Classroom ergonomics:

- Create a space that is adaptable to the learning experience instead of having the learning experience adapted to the space (Bayse, 2015).
- Focused on the training of required skills and collaborative work.
- Teachers are required to provide high support to students.

[1] Integrating knowledge and methods from different disciplines, using a real synthesis of approaches.

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For the learning-through-teacher lessons, students will work alone/in groups and should have access to:

- An ICT classroom with regular functioning computers;
  - Setup - MIT App Inventor;
    - System Requirements - MIT App Inventor;
    - App tester - MIT App Inventor;
    - Pre-setup (Tech and Networking Specialists) - MIT App Inventor.
- An internet connection;
- A gmail account (to log in in MIT App Inventor);
  - Accounts and devices - MIT App Inventor.
- Any android device.

To carry out the research project, students will work in groups and the same equipment is required, as well as an open, curious, and creative mind.

Observations:

- No prior downloading of software is required;
- Students are welcome to use their own computers;
- Each student should have their own email account;
- App Inventor offers the ability to develop using the Android emulator that shows up in a window on the computer screen if the students don't have an android device. However, using the emulator isn't as good as a physical device, because students can't carry their apps around with them and some features might not be present;
- The navigator "Internet Explorer" is not supported;
- MIT App Inventor works as a cloud, therefore everything is stored online.

Prerequisite knowledge and skills

- Basic IT and ICT notions.

Content glossary

IT. IT (Information Technology) is the study, design, development, application, implementation, support, or management of computer-based information systems. (Source: Code Academy)

ICT. Information and communication technologies (ICT) is defined as a diverse set of technological tools and resources used to transmit, store, create, share or exchange information. These technological tools and resources include computers, the Internet (websites, blogs and emails), live broadcasting technologies (radio, television and webcasting), recorded broadcasting technologies (podcasting, audio and video players, and storage devices) and telephony (fixed or mobile, satellite, visio/videoconferencing, etc.). (Source: UNESCO)

Low-code. A low-code platform allows app development through the use of a graphical user interface (GUI) rather than traditional hand-coding. In other words, it is a type of visual software development environment that allows developers to drag and drop application components, connect them together and create mobile or web apps with little to no code. (Source: Techtarget)

Block coding. Block coding is a process used in computer programming where text-based software codes change to a visual block format to create animated games, characters, and even stories. With block coding, kids can learn the basics and foundational concepts through visuals instead of text-based coding. (Source: Codingal)

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Algorithm. An algorithm is a detailed step-by-step instruction set or formula for solving a problem or completing a task. In computing, programmers write algorithms that instruct the computer how to perform a task. When you think of an algorithm in the most general way (not just in regards to computing), algorithms are everywhere. A recipe for making food is an algorithm, the method you use to solve addition or long division problems is an algorithm, and the process of folding a shirt or a pair of pants is an algorithm. (Source: Tynker - Coding for Kids)

Programming language. A **programming language** is a set of commands, instructions, and other syntax use to create a software program. In other words, it is a language that allows a programmer to tell the computer what to do in a variety of circumstances. Languages that programmers use to write code are called "high-level languages." This code can be compiled into a "low-level language," which is recognized directly by the computer hardware. (Source: Techterms; Ageuk)

Event-driven programming. ***Event-driven programming*** is a programming paradigm in which the flow of program execution is determined by *events* - for example a user action such as a mouse click, key press, or a message from the operating system or another program. An event-driven application is designed to detect events as they occur, and then deal with them using an appropriate *event-handling procedure*. (Source: Technologyuk)

MIT App Inventor. **MIT App Inventor** is an intuitive, visual programming environment that allows everyone – even children – to build fully functional apps for Android phones, iPhones, and Android/iOS tablets. It is an open-source tool that aims to make programming and app building accessible to a wide variety of audiences (educators; researchers; government; etc.) Initially developed by Professor Hal Abelson and his team, App Inventor is managed by members of MIT's Center for Mobile Learning. (Source: MIT App Inventor)

IDE. An **IDE**, or Integrated Development Environment, enables programmers to consolidate the different aspects of writing a computer program and develop programs more efficiently. IDEs increase programmer productivity by combining common activities of writing software into a single application: editing source code, building executables, and debugging. (Source: Code Academy)

User Interface. The **user interface** (UI) is the look and feel of an operating system. A good interface puts the user first, making commands and access to apps easy to discover. For the programmer, understanding how the interface works and what impact it has on application design is extremely useful. (Source: O'Reilly)

Conditional blocks. Conditionals refer to expressions or statements that evaluate to true or false. If the condition is "true", a particular section of text will be inserted into the message. If the condition is "false", the text will not be inserted. An "ELSE" clause can be included as part of the conditional statement so that a different section of text will be inserted into the message when the condition is "false". (Source: Isoft)

Loops are a way to tell a computer to do something many times in a row. Computers are really good at doing things over and over again, and doing them fast. (Source: technovationchallenge)

Lists - a way to organize multiple pieces of data in App Inventor (Source: technovationchallenge)

Index - a number that tells you where a piece of data is in a list (Source: technovationchallenge)

Array - common name for lists in programming languages other than App Inventor (Source: technovationchallenge)

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Pedagogical glossary

Constructivism. Jean Piaget presented the theory of **constructivism**, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed in the mind of the learner. Learners don't receive ideas; rather they create them from their own base of knowledge. Some characteristics of constructivist learning are that it:

⇒ fosters critical thinking;
⇒ creates motivated and independent learners;
⇒ has lessons that include guided discovery, whereby the teachers acts as a guide to the learner, helping to point out inconsistencies in students' thinking. Students build their understanding by resolving these conflicts;
⇒ includes a minimal amount of direct instruction. (Source: MIT App Inventor)

Constructionism. Building from the idea of **constructivism**, Seymour Papert presented his theory of constructionism which suggests that new ideas are most likely to be created when learners are actively engaged in building some type of external artifact that they can reflect upon and share with others. Elements of a constructionist learning environment include:

⇒ a teacher who acts as a facilitator;
⇒ learners who investigate, create, and solve problems;
⇒ learner collaboration;
⇒ learners engaging in authentic tasks;
⇒ opportunity for feedback and multiple opportunities for revision. (Source: MIT App Inventor)

Problem-Based Learning. Problem-based learning is one type of constructivist learning theory that can be applied in a classroom setting. It is a method which allows students to learn about a subject by exposing them to multiple problems, so they will be able to construct their understanding of the subject through these problems. Problem-based learning typically:

⇒ begins with problem for students to solve or learn about;
⇒ includes problems that are somewhat ambiguous to mirror the complexity of real life;
⇒ uses an inquiry model;
⇒ requires students to present a conclusion of the problem solving process, but does not necessarily require them to create a product as a result;
⇒ is driven by defined problems. (Source: MIT App Inventor)

Project-Based Learning. Project-based learning encompasses Papert's theory of constructionism where students build an artifact as part of the learning process. Project-based learning typically:

⇒ begins with an end product in mind;
⇒ includes production of an artifact, which typically raises one or more problems for students to solve;
⇒ asks students to use or present the product they have created;
⇒ is driven by the end product;
⇒ stresses that content knowledge and skills acquired during the production process are critical to success. (Source: MIT App Inventor)

Computational thinking. The term Computational Thinking (CT), coined by Jeannette Wing in 2006, describes solving problems, designing systems, and understanding human behavior based on the principles of computer science. CT includes analyzing and organizing data, automated problem solving and using it to solve similar problems. Nowadays, it has become necessary to solve complex technological problems. If sufficient background knowledge is available and the necessary new knowledge is acquired through

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critical thinking, CT may help to solve the problem. It is actually a hybrid of several other modes of thinking, like abstract, logical, algorithmic, constructive and modelling thinking, which summarizes all previous modes for solving the corresponding problem. (Source: IGI)

Brainstorming. Brainstorming is a group problem-solving technique that involves the spontaneous contribution of ideas from all members of the group. (Source: Merriam-Webster)

Collaborative learning. A **collaborative** (or cooperative) **learning** approach involves students working together on activities or learning tasks in a group small enough to ensure that everyone participates. Students in the group may work on separate tasks contributing to a common overall outcome or work together on a shared task. This is distinct from unstructured group work. Some collaborative learning approaches put mixed ability pairs, groups or teams together to work in competition with each other in order to drive more effective collaboration. (Source: Evidence For Learning)
Gamification. Gamification of education is a developing approach for increasing learners' motivation and engagement by incorporating game design elements in educational environments. It is often described as the use of game design elements in non-game contexts" (Deterding, Dixon, Khaled, & Nacke, 2011), "the phenomenon of creating gameful experiences" (Hamari, Koivisto, & Sarsa, 2014), or "the process of making activities more game-like" (Werbach, 2014). (Source: Springer)

Learning through Storytelling. **Storytelling** is the vivid description of ideas, beliefs, personal experiences, and life-lessons through stories or narratives that evoke powerful emotions and insights. It represents the use of stories or narratives as a communication tool to value, share, and capitalize on the knowledge of individuals. (Source: Springer)

STEM. **STEM** (Science, Technology, Engineering, and Math) is an integrated, interdisciplinary, and student-centered approach to learning that encourages critical thinking, creativity, collaboration, and design thinking across multiple disciplines. An important role of STEM education is to help students develop skills that will empower them later on in the workplace. This includes helping students develop skills that foster:

- Critical thinking;
- Flexible thinking;
- Data-driven analytical inquiry;
- Design (interdisciplinary) thinking;
- Social responsibility;
- Productivity;
- Leadership;
- Teamwork;
- Collaboration;
- Communication. (Source: Techopedia)

Multimodality. To understand multimodal learning, you first have to know the different modalities and their characteristics.

- Modes are channels of information. They include:
- Speech
- Audio
- Written and print
- Illustrations

An example is that people learn from images by reacting to visual cues such as photos and graphs. People can also learn from kinesthetics by reacting to tactile cues such as actions and movement. Multimodal learning is teaching a concept using more than one mode (visual, auditory, reading, writing, and kinaesthetic methods). By engaging the mind in multiple learning styles at the same time, learners experience a diverse learning style that collectively suits all of them. Thus it is meant to improve the quality of teaching by matching content delivery with the best mode of learning from the student. (Source: eLearning Industry)

Other connected terms (pedagogical eclecticism):
- Adaptative teaching.
- Personal inquiry.
- Dynamic assessment.
- Crossover learning.
- Navigating knowledge.
- Learning through argumentation.
- Learning from animations.
- Learning to learn.
- Event-based learning.
- Learning for the future.
- Immersive learning.
- Open pedagogy.

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Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, literacy, citizenship, responsability

Knowledge
Main concept: The role of low-code programming in public health issues

Programming concepts:
- Basic programming expressions and statements.

ICT concepts:
- Programming solutions development and application; low-code development environments; low-code development in public health *(topic: hygiene habits)*.

Knowledge - outcome assessment:
1. Understands basic concepts of computational thinking/science.
2. Identifies the principles of low code and block-programming.
3. Recognizes the importance of content creation-involved concepts.
4. Recognizes the meaning and basic use of common statements and expressions common in programming languages.
5. Identifies basic MIT App inventor notions.
6. Justifies why low code is crucial to the future.

Skills (abilities/competences)
General:
- "Creactical skills" (Ohler, 2013) / 21st century key skills:
  - Communication: digital communication; digital literacy; traditional literacy; health literacy; public speaking; argue capability; learn to learn.
  - Collaboration: working in groups towards a goal/to solve a problem/answer a question; collaboration.
  - Critical thinking: perform reasoning and analysis to draw conclusions based on simple systems; decision-making process; problem-solving process; project-based thinking.
  - Creativity: involves initiative, entrepreneurship, taking risks and learning from risks.

Specific:
- Developing, enhancing, and practicing computational thinking and technology-based projects.
- Finding, analyzing, and interpreting multimodal content to map the principles of low-code programming.
- Smoothly expanding the 21st century competences.

Skills – outcome assessment:
1. Recognizes basic and appropriate proficiencies necessary for block programming.
2. Can explain pros of adopting multimodal and gamification strategies in education and health.
3. Can partially transform creative ideas into programmable concepts.
4. Uses creativity to explore several basic programming statements and expressions.
5. Feels able to explain the benefits of using low-code development environments for real life problems connected with lifestyles.

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Affective/Attitudes/ Behaviour (*beliefs)*
- Adopting a citizen developer role in society, as well as having social and personal responsibility.
- Pursuing the adoption of critical thinking and problem-solving attitude as an individual.
- Engaging in other basic programming challenges/courses to further develop his/her interest in STEM.
- Adopting attitudes that mitigate public health risks.

Attitudes and behavior - outcome assessment:
1. Believes that technological competence is essential for citizenship and can lead to positive outcomes in the community.
2. Believes that low-code development environments can be vital to solve real-life problems connected with public health and contribute for innovative solutions (since they are fast, cheap, adaptable, and flexible).
3. Believes that health is the most important constituent of life.
4. Believes that digital literacy is vital for any profession in the future.
5. Is committed to improve his/her digital literacy and programming knowledge, as well as influence "STEM adoption" in his/her living environments.
6. Intends to use technology in his/her routine and has a positive attitude towards it.

Learning goals and outcomes
- Uses low-code environments and content creation tools as a creative extension to express ideas and knowledge.
- Correctly uses online tools to create multimodal content.
- Understands the core components of programming and uses them to apply on other block-structured programming applications.
- Clearly exposes the main principles of good hygiene habits, how they influence daily routines and health outcomes.

Assessment methods
- ✓ Outcome assessment
  - Quantitative – A questionnaire (in paper or in digital format)
  - Qualitative - students project: a. basic app/quizz building activity b. additional multimodal resources regarding public health and technological principles.
- ✓ Process assessment – *assessment of the teaching-learning sequence sequence* – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

Content (relevant to learning goals & research topics)

STEM content
- Technical literacy.
- Basic programming expressions.
- Programming oriented math.
- Digital Literacy.
- Communicating science: Healthy lifestyles – hygiene habits.

Non-STEM content
- Teamwork
- Metacognition

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- Proactivity
- Multimodality
- Autonomy

Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)

New (*developed by PAFSE team*):

In order to provide simple and easy-to-use resources for teachers/students, only one DER is presented, in which all DLOs will be inserted.

1. Animated, intuitive, and interactive *Nooc*[2] (*Nano Open Online Course*) using genially[3] concerning MIT App Inventor (Basic) and concepts to communicate science through technological content.
    - Informational multimodal resources (images, videos, sound, etc.) with content, challenges and solutions regarding basic low-code programming.
2. MIT AppInventor app(s) created by the team.
3. Questionnaires – quantitative and qualitative assessment of learnings - Student Interest and Choice in Science, Technology, Engineering and Mathematics (STEM) Survey (adapted from Roller et al. 2018 and Faber et al, 2013); Informed Consent – Students; Informed Consent – Legal Representatives; Process Assessment – Teachers; Scenarios Impact Assessment In Terms Of Students Knowledge, Skills, Attitudes And Behaviour.

Available resources (link):

Low-code universe 1 - Nooc

From other sources/high-quality platforms[4]:

Tutorials and examples to aid teachers prepare and train the students:

- MIT AppInventor:
    - Teach your students
    - Setting up your classroom for teaching App Inventor 2
    - Teaching an app inventor course
    - Hello Codi! (*app example*)
    - The MIT App Inventor library: documentation & support
    - MIT App Inventor - tutorials
    - MIT App Inventor - Beginner videos
    - MIT App Inventor - Nooc
- Block-Programming:
    - Block-based Programming in Computer Science Education
    - Block coding 101
- Hygiene habits (personal, environmental, regarding food, mental, COVID-19 related, etc.):
    - Programa escolar da Colgate
    - Hygiene for teens: why good habits are important
    - The importance of teen hygiene
    - Adolescent hygiene basics

[2] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[3] Genially is the world-leader in interactive visual communication using low/no-code. It is an all-in-one online tool to create stunning presentations, interactive images, infographics, gamification, quizzes, breakouts, portfolios, etc. and enrich them with interactivity and animation effects in seconds.

[4] The majority will be included in the developed DER.

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- Food hygiene
- Show me the science - why wash your hands?
- Several types of hygiene
- Children's oral health
- Sleeping hygiene
- Types of hygiene
- Mental hygiene
- COVID-19 hygiene
- How to protect yourself from COVID-19

Observation:

- The PAFSE team provides examples of high-quality platforms that can be used by students to develop their app in the research project. However, teachers are encouraged to choose the resources they see fit, or even leave it up to the students, instigating their creativity and research capacity, since it is such a "mundane" topic. In case of the schools that have science/health teachers involved (in addition to/instead of ICT teachers), this is even more encouraged.
- Given that there are several types of hygiene, students can choose the topic that is more interesting to them.

Teaching-learning activities

Principal target:
ICT classes /Biology classes /F.Q classes/Health Education classes (depending on the institution)
7h grade (+/- 12-13 years old students)
4-6 sessions/classes of 40-45 minutes
ICT teachers integrate other colleagues in the enactment of the scenario, as it aims to be interdisciplinary. The scenario provides the necessary tools for students to explore desirable behavior in an individual and public health perspective.

General note:

- Even if students stumble into some moderate-advanced programming, this educational scenario focuses on the applicability, on learning by doing. Thus, as the education provider, do not worry if they struggle for a bit and you have to step in from time to time, let them explore and learn as much from the platform as possible.
- All the activities/theoretical aspects used in lessons will be available in the DER so you can all any information there.
- The lessons will have “Bloom’s taxonomy” as a background, which pillars are the following:

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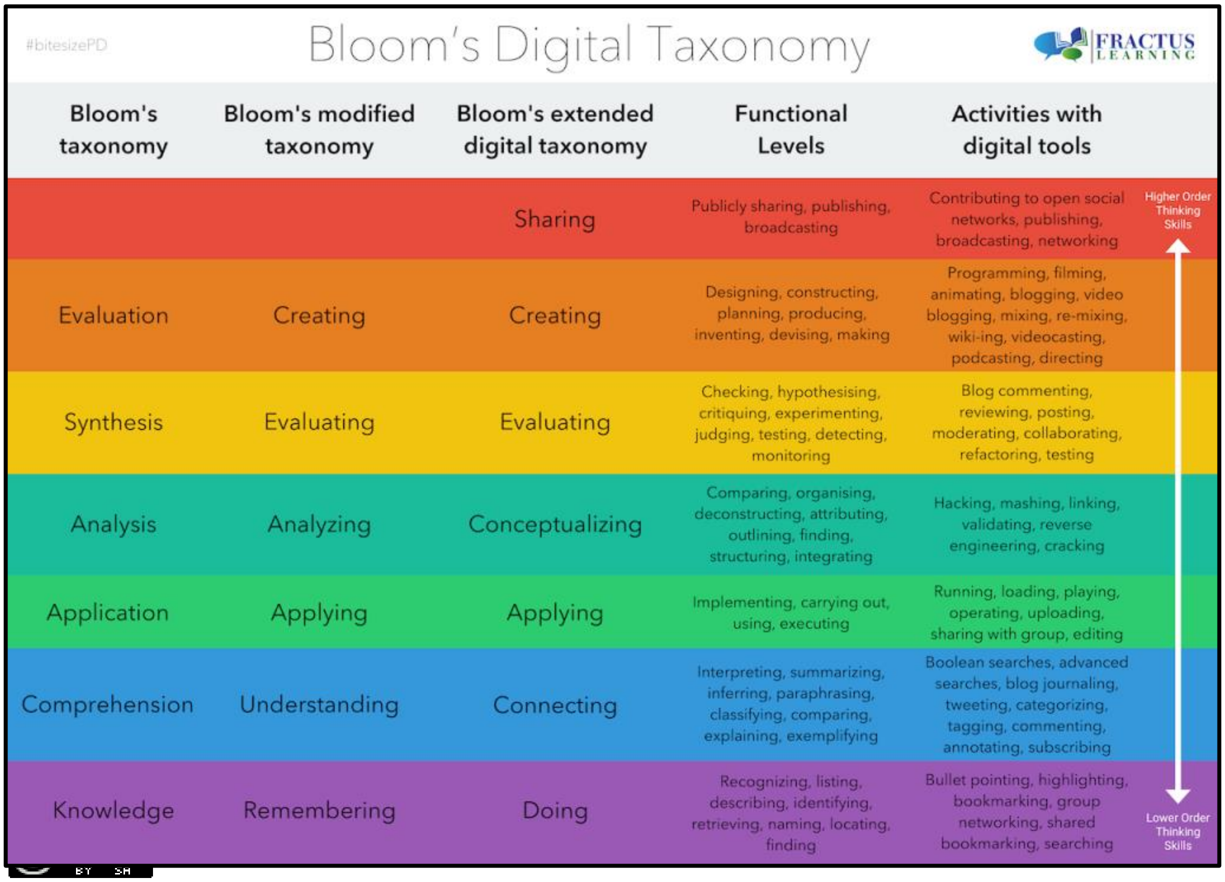

#bitesizePD

Bloom's Digital Taxonomy

Bloom's taxonomy	Bloom's modified taxonomy	Bloom's extended digital taxonomy	Functional Levels	Activities with digital tools
		Sharing	Publicly sharing, publishing, broadcasting	Contributing to open social networks, publishing, broadcasting, networking
Evaluation	Creating	Creating	Designing, constructing, planning, producing, inventing, devising, making	Programming, filming, animating, blogging, video blogging, mixing, re-mixing, wiki-ing, videocasting, podcasting, directing
Synthesis	Evaluating	Evaluating	Checking, hypothesising, critiquing, experimenting, judging, testing, detecting, monitoring	Blog commenting, reviewing, posting, moderating, collaborating, refactoring, testing
Analysis	Analyzing	Conceptualizing	Comparing, organising, deconstructing, attributing, outlining, finding, structuring, integrating	Hacking, mashing, linking, validating, reverse engineering, cracking
Application	Applying	Applying	Implementing, carrying out, using, executing	Running, loading, playing, operating, uploading, sharing with group, editing
Comprehension	Understanding	Connecting	Interpreting, summarizing, inferring, paraphrasing, classifying, comparing, explaining, exemplifying	Boolean searches, advanced searches, blog journaling, tweeting, categorizing, tagging, commenting, annotating, subscribing
Knowledge	Remembering	Doing	Recognizing, listing, describing, identifying, retrieving, naming, locating, finding	Bullet pointing, highlighting, bookmarking, group networking, shared bookmarking, searching

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Lesson 1: Introduction to key concepts

Learning objective: In the starting session, students will be exposed to various theoretical concepts (discussed in the workshop) they will need to use MIT App Inventor successfully and attain the scenario goals. The activities performed during this first lesson aim to engage students in these topics and explore some preliminary ideas.

Topics to be explored: Content Creation; Storytelling; Gamification; Programming; Computational science.

The teaching-learning script starts with the division of the class in small groups (4-5 people or as the teacher sees fit), in order to stimulate collaboration and capacity of exposing and discussing ideas, which will lead to an icebreaking moment, assessing the preconceptions and misconceptions of the students on the topic of "technology".

⇒ Brainstorming on the questions (No research)
- How important is technology?
- What can we use the computer for?
- Do you use a lot of apps? Do they help you daily?

The group organizes the main ideas to present to the class. In parallel, the teacher writes, on the board, the main ideas of each group concerning each question.

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⇒ Taking as a starting point the answers obtained during the icebreaker moment, students will be guided through three questions:
  - What is an app?
  - What are the key programming/computing principles?
  - What do we need to create an app?

⇒ At this point, teachers will discuss these questions in a manner students understand:
  - The importance of technology and digital literacy to learn about specific topics.
    - Show different and simple examples of technology outcomes.
    - Give examples of fun digital resources they use daily in all mundane activities.
  - The core concepts of programming and programming languages. E.g:
    - Coding means to write code, or to write instructions for a computer.
    - Programming, similarly, means to write code or instructions.
    - Debugging means to check code for mistakes and try to fix errors.
  - The main principle of gamification: storytelling (how to make a storyboard).
    - Activity 1: Propose to students the elaboration of a simple storyboard of their weekly morning routine (it doesn't have to be real, let them be creative!) using this simple template (print it).
      - Pair them up and have them swap the papers and telling the story to their colleague.
  - What is MIT App inventor and what will they use it for.
    - Simple run-trough the platform.
    - How to acess it.
    - Quick setup.
      - The teacher should write simple steps on the board and provide students with a tutorial that they consult at any time.
      - Activity: Each student should successfully access their account in the computer.
    - Explain on what they will work on and attribute and elaborate on the topic "hygiene habits".

Lesson 2: Discovering coding

Learning objective: In less than an hour, they will have become familiar with block sequences, conditional connections and loops. They may forget them afterwards, but they will have seen and used these three basic concepts in solving a concrete problem.

Topics to be explored: Block-programming principles.

Lesson 2 starts by asking, once again, for students to divide into groups. Collaborative work is highly appreciated since they will play with code, it's way more fun with friends. They can help each other, as well as discuss what they are about to see.

⇒ Activity 1: Ask students to open this website, watch the video and complete the tasks (phases of a game).

These games work very well to animate a workshop. Each group is focused on the game, and the passage of levels.
  - Help them in the beginning with instructions, clues, triggering and show – along the way – that the blocks are highlighted at the time of execution.
  - Tell them to setup the page to PT-PT since it's available, both video and game.

In case there are some fast and very curious minds, you can give them another example, while the group awaits for the others.

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- ⇒ Facilitate a "Turn and Talk" Ask students to share their game, app or final product with other group for feedback. Ask a few groups to share out their experience:
  - What did you learn about how apps and games work today?
  - How do you feel having had the opportunity to study computer science?
- ⇒ By the end of the exercise, participants will have seen the three essential control structures of any program. Discuss with them what a script or program is: an ordered sequence of instructions, some of which allow you to control what will happen next: loops and conditional connections.
  - You can also point out: that each script begins with an event: Which one? When they pressed the start button. That the progress of the program may depend on the environment, for example the presence of a wall in a labyrinth or lava in Minecraft.
- ⇒ Celebrate! Give them some certificates to keep it fun and make them proud of their work.
- ⇒ Ask them to summarize what they learned today, how they felt, or what they experienced.
- ⇒ Challenge students to share some aspect of their Hour of Code experience on social media using #hourofcode as a way to lend their voices to this world wide movement. Students can share their game, images, videos or just their thoughts.
- ⇒ Give them the used website in case they got interested and want to explore at home.

Lesson 3: Digging into MIT App Inventor

Learning objective: Students should be able to get familiarized with the MIT App Inventor User Interface and basic components.

Topics to be explored: Consolidate the previously experimented concepts - how the components and blocks work and interact; events and a definition of event-based programming – and learn new ones trace existing code to understand functionality; utilize MIT App Inventor interface to modify existing code; demonstrate ability to include conditionals, lists and iteration.

- ⇒ The teacher will rapidly explore the User interface of the app in front of the students, hand them this quick guide and ask if they remember the conclusions from last lesson, then explaining that:
  - The implementation of a program is done in two parts:
  - The creation of the user interface and the choice of resources that will be used in the application,
  - then block programming that uses the components (events, properties, procedures) associated with the components defined in the first part.
  - App Inventor is often called events-based programming. What this means is that the apps run and function based on reactions to events, like on the Minecraft game. When they click a button, start the app, shake the phone, swipe the phone, enter into a textbox. These are all events. Apps and App Inventor are event driven which means that events need to happen to cause something else to happen. Shaking the phone will cause the phone to play a sound and getting a text message will cause the phone to vibrate. Events cause or drive actions.
  - App Architecture includes events but also includes components, event handlers, event types, behavior, and object-oriented programming. App Architecture is extremely important to understanding what an app needs to be built and run.
  -
- ⇒ Activity 1: Let's keep them learning by doing – Creating the "Making Magic" app, a simple app where a rabbit magically comes out of a top hat.
  - Get every student to log onto their account, as they were taught before, and teach them how to make the app (All the info you need is in this simple 6 minute video, give it a try!)
    - Pdf version
    - Media library

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Note: Do not do part 2 as it contains advanced components.
- Get this opportunity to succinctly discuss how to export/Test apps
- Assessment activity so they ponder on what they learned so far.

⇒ Now that that is settled, let's step up a little bit more and start introducing conditionals, lists and iterations.
- Talk about Programming Your App to Make Decisions: Using Conditional Blocks
  - Conditionals refer to expressions or statements that evaluate to true or false.
  - App Inventor provides two types of conditional blocks: if and ifelse, both of which are found in the Control drawer of the Built-In palette.
  - You can plug any Boolean expression into the test slot of these blocks. A Boolean expression is a mathematical equation that returns a result of either true or false. The expression tests the value of properties and variables using relational and logical operators such as the ones shown in the figure below:
  - For both if and ifelse, the blocks you put within the then-do slot will only be executed if the test is true. For an if block, if the test is false, the app moves on to the blocks below it. If the ifelse test is false, the blocks within the else-do slot are performed.
- Talk about lists
  - Apps contain data or information. Data is raw facts, information is data processed into usable items. This data can be anything from your location to a high score. All apps need to have ways to store this data. One of these ways is by using lists.
  - A list in Computer Science is essentially what you think it would be: a number of connected items or names written consecutively. You may have a list of names of the contacts in your phone, a list of email addresses from a conference, a list of homework assignments for the week. Apps also use lists and App Inventor makes it easy to do so.
- Talk about iteration
  - Think about a screensaver that shows a collection of images. These images are stored in a list. To display all of them one at a time, one after the other, this process is called iteration.

⇒ Activity 2: Get every student to complete these tasks to practice the concepts.
- Have a quick group discussion about the results.

⇒ Activity 3: The source code, HelloAnimal, displays a random image and plays a corresponding animal noise for every time the button is clicked. Currently, there are only two images in this app.
- The assignment is to add two additional images and sounds to the app.
- They will also need to modify the blocks in the Blocks Editor to work for two additional images and sounds.
- Remember them that if they wanted, they could completely change the theme of the app.
- Have a quick group discussion about the results.

⇒ Assign homework (if possible due to equipment and wi-fi connection, it can be an activity to lesson 4): tell the students to build the app "Magic 8 ball" (only parts 1 and 2, given that part 3 uses sensors and that's way too advanced for now!)

Lesson 4: Practice makes perfect

Learning objective: During this lesson and as wrap-up moment on the "app creation" world, students are invited to challenge themselves and take it to the next level. Basic concepts where explored. This is the moment to explore.

Topics to be explored: Intermediate block-programming principles.

⇒ Homework of lesson 3: Students present the results of their homework and the entire class discuss the findings.

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⇒ Activity 1: You will tell the students that, in groups, they will create an app, called Paintpot ,(only part 1) in 5 steps:
   - **Step 1:** When user touches, draw a circle. When user drags, draw a line.
   - **Step 2:** Add menu items that let user draw in different colors
   - **Step 3:** Add menu items that let user draw different size circles.
   - **Step 4:** Let the user use camera to set background picture
   - **Step 5:** Add feedback for the user interface

Let them be as independent as possible but provide high support when needed.
The first group to get it moving has an advantage in the final research project and can leave the class early. That will motivate them to do best.

Lesson 5: The final countdown

Learning objective: In this final session, a recap regarding the major practiced concepts concerning block programming is made, as well as of the used methodologies. In addition, students are prepared to the students research project.

Topics to be explored: Mental mapping, Pitch skills
⇒ Present the concept of a mental map by showing one representing the lessons.
⇒ Activity 1: Ask students to elaborate one, on paper, describing what they learnt.
⇒ Aiming to prepare the students for their final project, a presentation called "O meu Pitch em 5 p's" (My pitch in 5 p's) will be given, teaching students how to publicly present projects.
   - How to communicate science/health using these 5 pillars:
      - "Priorizar" (Prioritize).
      - "Pesquisar" (Research).
      - "Planificar" (Plan)
      - Personalizar (Personalize)
      - Produzir (Produce)
   - Provision of storyboard templates to prepare the pitch.
   - Explanation of what will be evaluated.

⇒ Quantitative assessment – questionnaire – impact assessment in terms of student's knowledge, skills, attitudes and behaviour.

Lesson 6-forward:
This is the **School Project** described below.
Final sessions, moments of creative freedom, where students apply the programming concepts learned during previous sessions in a project linked with hygiene habits. There is freedom to work with the MIT AppInventor platform or use paper modeling, with the aim of presenting the project at the end of the sessions, or in another event created for that purpose.
The projects will cover all the tools and themes explored. Students may choose, within the topic of hygiene habits, which sub-topics they want to explore and focus on. Regarding programming skills, they should follow a simple framework to create their own apps, so that they can be as independent as possible.

Supplementary learning resources and educational activities
Regarding the school Research project:
- Production of multimodal content – Students can transfer and use the knowledge acquired to other classes.
- Public health reflection.
- Competition – reward of the best app ideas.

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School Research Project

Topics

Importance of digital literacy and real-life implications.
Basic technical features and principles of programming solutions development.
Possible applications of mobile applications in public health (e.g., in the promotion of hygiene habits).

Research management, design and administration

Challenge: Content exposition creation on one topic involving "hygiene habits", promoting not only technology, but also public health.
Method *(summary)*: Lessons 6 to 11 will be dedicated to the school research project. Students are, as usual, organized in groups and each group addresses the practiced programming and technological concepts and connects them to health.
Development process:
The project is based on the use of technology to create scientific artefacts. The five-six sessions will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.
Groups of students will be instructed to create an interactive game or tool app that explores the topic of hygiene habits in some way, as well as some other resources (of their choice) that they see fit on the same topic:
During session 1, students are presented, not only, with software to use for content creation but also the norms to follow:

1. Each group should have, at least:
    a. 1 sketch of an app (or the app itself) on the theme of healthy habits.
    b. One other multimodal resource on the theme of healthy habits.
        i. It can be a mental/conceptual map, a quizz, a presentation, an interactive resource, an infographic, a story, a video, etc.
    c. A short portfolio with all the created resources.
2. Each group is required to:
    a. brainstorm a project idea, develop drawing(s) of the app/game on paper, creating a storyboard.
    b. meet regularly with the teacher to discuss the feasibility of the app and if necessary make any changes to their plan.
    c. Present a short (5-10 minutes) elevator pitch of your project idea to the class.
3. Create a portfolio (free structure, let the student be creative) write up of your project.
    a. Some useful points:
        i. Names of developers
        ii. Name of your app and why
        iii. Identification and justification of the other resources and
        iv. What problem it solves and/or why it is important or useful
        v. People who would use your app (target audience or market) and why they would use it
        vi. Describe what each person on your team did
        vii. Describe how you made decisions together
        viii. Describe how effectively you worked together as a team

Finishing session 1, the groups are created and ideas start being discussed.
During session 2, the teacher will pass by the groups to collect ideas and topics and, if valid, students can start working on their project. The teacher will provide all the needed help, even if that means that he is an contributor to the project.

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From session 3-forward, the students will actively work on their project and are encouraged to exchange ideas with other groups.

Teaching-learning process milestones:

4. Students will be able to propose basic programming solutions.
5. Students will be able to communicate the findings, motivations and limitations of various solutions considered in the work process.
6. Students will be able to identify and communicate the importance of digital literacy/end-user development in public health and citizenship.

Teaching-learning process for school project (summary):

4. Development of multimodal materials.
5. Basic Mobile Applications Sketches (or real for the most driven).
6. Presentation of all the resources created in the open schooling event, where students will be advocating better conditions for their community and show their relationship with public health and low-code environments.

Organization of the open schooling event:

4. Each project output (portfolio) is presented by the students in a community setting (e.g., exposition center, municipality, science fair) with appropriate/pre-prepared environment (computer and smartphone with the MIT App Inventor installed).
5. Students do a pitch on how mobile solutions can be used to address public health, like the case of good hygiene habits. Technical speeches to motivate peers to new technologies and technological environments. Students will also be advocating better conditions for their community and show their relationship with citizens health.
6. Students, parents, school community and relevant local stakeholders attend the event and recognize that mobile solutions can be used to address real life challenges, public health ones, and others. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, community).

Data Analysis and Reporting

Content Analysis.
Multimodal resources.
Portfolio development.

Target Audience for Recommendations

School community and local stakeholders: students, parents, municipalities, engineers, public health authorities, and local enterprises.

Public Debate and Recommendations (based on research results)

Presentation of the resources produced by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.
Discussion and feedback.
Attribution of the prize of “best app ideas”.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
Scenario topic: “Low-code development environments – Level 1 (Basic)”

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Knowledge	
1. Understands basic concepts of computational science/thinking.	**Question 1.1:** What do we mean by computational thinking? A) Understanding a complex problem and developing possible solutions. B) Using a computer. C) Focusing on what is important, ignoring what is unnecessary. **Question 1.2:** A machine that can perform a task on its own is a: A) Computer. B) Algorithm. C) Program. **Question 1.3:** What every-day activity can be considered an algorithm? • A recipe for making food. • Walking a marathon. • Playing videogames.
1. Identifies the principles of low code and block-programming.	**Question 2.1:** Why is block-programming different from text-based coding? A) Because it is a type of visual software development environment that allows developers to drag and drop application components. B) Because block-programming is based on syntax, therefore making it easier. C) Because it is a programming language specially made to teach kids how to code. **Question 2.2:** Why should one use low-code platforms? A) Low-code platforms are easier to learn, as well as more intuitive and faster. B) “High coding” is becoming useless. C) Because they allow developers to enhance their capabilities.
2. Recognizes the importance of content creation-involved concepts.	**Question 3.1:** The goal of gamification is: A) Maximize enjoyment and engagement by capturing the interest of learners and inspiring them to continue learning. B) Maximize learning by using different tools. C) Maximize engagement and have fun in classes even if you don't learn anything. **Question 3.2:** A storyboard is a detailed guide made up of small, organized frames that contains: A) What will be seen, what will be heard and what will be read. B) Characters, visual and sound effects. C) Details regarding characters surroundings and character lines. **Question 3.3:** Which modes are employed to convey the meaning in an image? A) Visual (and gestures). B) Visual (and gestures) and sound. C) Visual (and gestures) and oral.
3. Recognizes the meaning and basic use of common statements and expressions common in programming languages.	**Question 4.1:** An action that causes something to happen: A) Event. B) Variable. C) Iteration. **Question 4.2:** To identify and remove errors: D) Debug. E) Compile. F) List.

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4. Identifies basic MIT App inventor notions.	**Question 5.1:** On the Palette, under which selection will you find a Button? A) User interface. B) Layout. C) Images. **Question 5.2:** Pieces of app that do actions for you. A) Components. B) Blocks. D) Strings. **Question 5.3:** How do we test the application? A) Emulator. B) Build. C) Interface.
5. Justifies why low code is crucial to the future.	**Question 6.1:** Which of these is **not** a characteristic of low-code environments? A) Special skills (developer skills) are required. B) Cheaper to enterprises. C) Improves productivity and collaboration. **Question 6.2:** In what way could low-code contribute to enhance public health issues? A) Integrate patient and employee information across systems in hospitals. B) Develop cures for diseases. C) Scatter information regarding public health issues.
Skills	
1. Recognizes basic and appropriate proficiencies necessary for block programming.	**Question 1.1:** Which of the following proficiencies is important in a professional programmer? A) Problem-solving B) Entrepreneurial spirit C) Ability to teach and mentor **Question 1.2:** Which of the following proficiencies is **not** required in block-programming? A) Public speaking ability B) Resilience C) Creativity
2. Can explain pros of adopting multimodal and gamification strategies in education and health.	**Question 2.1:** I feel able to enumerate to others some pros of multimodal and gamification strategies in specific curricula. 1) definitely true... 2) definitively false. **Question 2.2:** Public health might be benefited from approaches such as multimodality and gamification in terms of: A) Training of future profissionals B) Enhancement of facilities C) Curing diseases **Question 2.3:** I intend to integrate gamification and multimodality in future school projects.

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	1) definitely true... 2) definitively false. **Question 2.4:** For me, if school used gamification and multimodality in all curricula, it would be: 1) very significant... 2) very insignificant.
3. Can partially transform creative ideas into programmable concepts.	**Question 3.1:** I feel capable of conceiving a simple idea and subsequently turn it into a programable concept. 1) definitely true... 2) definitively false. **Question 3.2:** In the future, I will be able to be more technologically creative. 1) very probable... 2) very improbable.
4. Uses creativity to explore several basic programming statements and expressions.	**Question 4.1:** I feel that programming stimulates my creativity skills. 1) strongly agree... 2) strongly disagree **Question 4.2:** I feel comfortable exploring block-programming environments. 1) strongly agree... 2) strongly disagree
5. Feels able to explain the benefits of using low-code development environments for real life problems connected with lifestyles.	**Question 5.1:** I feel capable of proposing low-code actions that benefit real life problems. 1) definitely true... 2) definitively false. **Question 5.2:** To aid tackling public health issues, people should rely on programming more. 1) strongly agree... 2) strongly disagree
Beliefs, attitudes and behavior	Instructions: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that technological competence is essential for citizenship and can lead to positive outcomes in the community.	**Question 1.1:** I intend to identify and address the problems of the community in relation to technological issues. 1) strongly agree... 2) strongly disagree. **Question 1.2:** The development of technological competences of my own can contribute to the global society's awareness about the importance of technology. 1) extremely likely... 2) extremely unlikely. **Question 1.3:** I can explain to my family and friends the importance of technology. 1) strongly agree... 2) strongly disagree. **Question 1.4:** I think society still does not fully understand the importance of technology. 1) strongly agree... 2) strongly disagree. **Question 1.5:** I feel society takes for granted the benefits of technology. 1) strongly agree... 2) strongly disagree.
2. Believes that low-code development environments can be vital to solve real-life problems connected with public health and contribute for innovative solutions (since	**Question 2.1:** Among the following statements, choose the one that best describes what you currently think: 1) Low-code does not contribute to public health enhancement in any way. 2) I can see where low-code could contribute to public health enhancement in some way. 3) I can definitely see potential contributions of low-code to public health issues. 4) Low-code contributes to public health enhancement. **Question 2.2:** I understand the importance of low-code environments for society. 1) strongly agree... 2) strongly disagree.

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they are fast, cheap, adaptable, and flexible).	
3. Believes that health is the most important constituent of life.	**Question 3.1:** Health is a fundamental component of quality of life. 1) strongly agree... 2) strongly disagree. **Question 3.2:** I am capable of adopting a healthy lifestyle that benefits quality of life. 1) strongly agree... 2) strongly disagree.
4. Believes that digital literacy is vital for any profession in the future.	**Question 4.1:** I believe that digital literacy is important / useful in our daily lives. 1) strongly disagree... 2) strongly agree.
5. Is committed to improve his/her digital literacy and programming knowledge, as well as influence "STEM adoption" in his/her living environments.	**Question 5.1:** I plan to keep improving my digital literacy. 1) definitely true... 2) definitively false. **Question 5.2:** I plan to keep improving my programming knowledge. 1) definitely true... 2) definitively false. **Question 5.3:** I feel digital literacy helps me expand my knowledge of any subject. 1) strongly disagree... 2) strongly agree. **Question 5.4:** I feel programming helps me expand my knowledge of any subject. 1) strongly disagree... 2) strongly agree. **Question 5.5:** I feel digital literacy helps me to develop 21st century skills. 1) strongly disagree... 2) strongly agree. **Question 5.6:** I feel programming helps me to develop 21st century skills. 1) strongly disagree... 2) strongly agree. **Question 5.7:** I feel digital literacy helps me with my problem-solving capacities. 1) strongly disagree... 2) strongly agree. **Question 5.8:** I feel programming helps me with my problem-solving capacities. 1) strongly disagree... 2) strongly agree. **Question 5.9:** I commit to promoting STEM adoption. 1) strongly disagree... 2) strongly agree.
6. Intends to use technology and programming in his/her routine and has a positive attitude towards it.	**Question 6.1:** Among the following statements, choose the one that best describes what you currently think: 1) I do not use technology, and I also have no intention of doing so. 2) I do not use technology, but I have been thinking about the possibility of starting to do so. 3) I never or rarely use technology, but soon I will start doing it on a regular basis. 4) I use technology regularly. 5) I use technology regularly and I will keep doing so. **Question 6.2:** Among the following statements, choose the one that best describes what you currently think: 1) I do not program, and I also have no intention of doing so. 2) I do not program, but I have been thinking about the possibility of starting to do so. 3) I never or rarely program, but soon I will start doing it on a regular basis. 4) I program regularly.

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	5) I program regularly and I will keep doing so. **Question 6.3:** For me, programming is: pleasant:_____:_____:_____:_____:_____:unpleasant good:_____:_____:_____:_____:_____:bad worthless:_____:_____:_____:_____:_____:valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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27. Specifications for an educational scenario on the topic of "Low-code development environments – Level 2 (Intermediate)"

Main partner responsible: UM (University of Minho)

Title of Educational Scenario: Connecting students to IT using low-code development environments to promote public health and digital literacy – Level 2 (Intermediate)

Topic in School Curriculum: Block programming / Nutrition habits

School Subject: ICT classes/Biology/F.Q classes/Health Education classes (Interdisciplinarity[5])

Main resource: MIT App Inventor

Grade level: 8th grade (+/- 13-14 years old students)

Context and relevance to public health education

The technological revolution of the last decades has contributed to the consolidation of a new social paradigm known as knowledge society or information society. This paradigm is reflected in a globalized and multilingual world, full of economic, commercial, political, social, and cultural relations, where professional specialization is a necessity. Aiming to help achieve this specialization, the educational scenario supports ICT teachers in expanding students' skills in a way they are not just passive consumers of technology, but active content creators too. Learning how to code can support students' engagement in the development of innovative solutions that benefit the health of their community, while developing general problem-solving skills central to success in STEM (Science, Technology, Engineering, Mathematics) curricula and careers. By learning how to code students go from being passive users of apps, digital content, and web pages to actively participate in their creation with meaningful purpose.
Particularly, block-based coding or programming is an element of programming where text-based computer commands are groups together in pre-programmed blocks that drag and drop together to build computer programs such as animations and games. Block coding is considered "syntax-free" in that a user does not need to be careful about the order and requisite syntax of commands and punctuation, which need to be memorized in text-based programming. This means it has a tremendous potential to take education to the next level.
The scenario aims to familiarize students with public health risks and patterns of protective behavior, as well as making them capable of explaining those ideas to others in low-code environments. Several topics related to a main determinant of health - nutrition habits - will be explored while operating in various multimodal content creation tools. The learning experience supports youths in understanding how STEM may contribute to create new and revolutionizing solutions to public health, as well as stimulate their creativity, decision-making and problem-solving skills, while supporting them in the process of becoming tech producers and public health ambassadors.

Estimated Duration

5-6 classes of 40-45 minutes (lesson 1 – lesson 6)
5-6 sessions of 40-45 minutes for supplementary learning activities and school project (session 6 – session 12)

5 Integrating knowledge and methods from different disciplines, using a real synthesis of approaches.

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Classroom organization requirements

Classroom ergonomics:

- Create a space that is adaptable to the learning experience instead of having the learning experience adapted to the space (Bayse, 2015);
- Focused on the training of required skills and collaborative work;
- Teachers are practically merely content curators and learning facilitators – Students are required to be as autonomous as possible.

For the learning-through-teacher lessons, students will work alone/in groups and should have access to:

- An ICT classroom with regular functioning computers;
    - Setup - MIT App Inventor;
        - System Requirements - MIT App Inventor;
        - App tester - MIT App Inventor;
        - Pre-setup (Tech and Networking Specialists) - MIT App Inventor.
- An internet connection;
- A gmail account (to log in in MIT App Inventor);
    - Accounts and devices - MIT App Inventor.
- Any android device.

To carry out the research project, students will work in groups and the same equipment is required, as well as an open, curious, and creative mind.

Observations:

- No prior downloading of software is required;
- Students are welcome to use their own computers;
- Each student should have their own email account;
- App Inventor offers the ability to develop using the Android emulator that shows up in a window on the computer screen if the students don't have an android device. However, using the emulator isn't as good as a physical device, because students can't carry their apps around with them and some features might not be present;
- The navigator "Internet Explorer" is not supported;
- MIT App Inventor works as a cloud, therefore everything is stored online.

Prerequisite knowledge and skills

- Basic IT and ICT notions.

General content glossary

IT. **IT** (Information Technology) is the study, design, development, application, implementation, support, or management of computer-based information systems. (Source: Code Academy)

ICT. Information and communication technologies (**ICT**) is defined as a diverse set of technological tools and resources used to transmit, store, create, share or exchange information. These technological tools and resources include computers, the Internet (websites, blogs and emails), live broadcasting technologies (radio, television and webcasting), recorded broadcasting technologies (podcasting, audio and video players, and storage devices) and telephony (fixed or mobile, satellite, visio/videoconferencing, etc.). (Source: UNESCO)

Low-code. A **low-code** platform allows app development through the use of a graphical user interface (GUI) rather than traditional hand-coding. In other words, it is a type of visual software development environment that allows developers to drag and drop application components, connect them together and create mobile or web apps with little to no code. (Source: Techtarget)

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Block coding. **Block coding** is a process used in computer programming where text-based software codes change to a visual block format to create animated games, characters, and even stories. With block coding, kids can learn the basics and foundational concepts through visuals instead of text-based coding. (Source: Codingal)

Algorithm. An **algorithm** is a detailed step-by-step instruction set or formula for solving a problem or completing a task. In computing, programmers write algorithms that instruct the computer how to perform a task. When you think of an algorithm in the most general way (not just in regards to computing), algorithms are everywhere. A recipe for making food is an algorithm, the method you use to solve addition or long division problems is an algorithm, and the process of folding a shirt or a pair of pants is an algorithm. (Source: Tynker - Coding for Kids)

Programming language. A **programming language** is a set of commands, instructions, and other syntax use to create a software program. In other words, it is a language that allows a programmer to tell the computer what to do in a variety of circumstances. Languages that programmers use to write code are called "high-level languages." This code can be compiled into a "low-level language," which is recognized directly by the computer hardware. (Source: Techterms; Ageuk)

Event-driven programming. ***Event-driven programming*** is a programming paradigm in which the flow of program execution is determined by *events* - for example a user action such as a mouse click, key press, or a message from the operating system or another program. An event-driven application is designed to detect events as they occur, and then deal with them using an appropriate *event-handling procedure*. (Source: Technologyuk)

MIT App Inventor. **MIT App Inventor** is an intuitive, visual programming environment that allows everyone – even children – to build fully functional apps for Android phones, iPhones, and Android/iOS tablets. It is an open-source tool that aims to make programming and app building accessible to a wide variety of audiences (educators; researchers; government; etc.) Initially developed by Professor Hal Abelson and his team, App Inventor is managed by members of MIT's Center for Mobile Learning. (Source: MIT App Inventor)

IDE. An **IDE**, or Integrated Development Environment, enables programmers to consolidate the different aspects of writing a computer program and develop programs more efficiently. IDEs increase programmer productivity by combining common activities of writing software into a single application: editing source code, building executables, and debugging. (Source: Code Academy)

User Interface. The **user interface** (UI) is the look and feel of an operating system. A good interface puts the user first, making commands and access to apps easy to discover. For the programmer, understanding how the interface works and what impact it has on application design is extremely useful. (Source: O'Reilly)

Conditional blocks. Conditionals refer to expressions or statements that evaluate to true or false. If the condition is “true”, a particular section of text will be inserted into the message. If the condition is “false”, the text will not be inserted. An “ELSE” clause can be included as part of the conditional statement so that a different section of text will be inserted into the message when the condition is “false”. (Source: Isoft)

Loops are a way to tell a computer to do something many times in a row. Computers are really good at doing things over and over again, and doing them fast. (Source: technovationchallenge)

Lists - a way to organize multiple pieces of data in App Inventor (Source: technovationchallenge)

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Index - a number that tells you where a piece of data is in a list (Source: technovationchallenge)
Array - common name for lists in programming languages other than App Inventor (Source: technovationchallenge)

Variable. A **variable** is a container that holds a single number, word, or other information that you can use throughout a program. A variable is like a chest you can fill with different values. Component properties are variables that are built into a component. Event parameters are special variables that give you extra information about an event. Global variables have global scope, meaning that they can be set and read from any blocks in the workspace. Local variables have local scope, meaning that they exist only within their initialization block, which has space to add more blocks. (Source: Idtech; O'Reilly)

Procedure. A **procedure** is a set of instructions that is grouped together, given a name, and made available for later use. This makes your code easier to read, think about, and change. Ultimately, using a procedure is more powerful. The steps for getting started are straightforward. (Source: O'Reilly)

Pedagogical glossary

Constructivism. Jean Piaget presented the theory of **constructivism**, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed in the mind of the learner. Learners don't receive ideas; rather they create them from their own base of knowledge. Some characteristics of constructivist learning are that it:

⇒ fosters critical thinking;
⇒ creates motivated and independent learners;
⇒ has lessons that include guided discovery, whereby the teachers acts as a guide to the learner, helping to point out inconsistencies in students' thinking. Students build their understanding by resolving these conflicts;
⇒ includes a minimal amount of direct instruction. (Source: MIT App Inventor)

Constructionism. Building from the idea of **constructivism**, Seymour Papert presented his theory of constructionism which suggests that new ideas are most likely to be created when learners are actively engaged in building some type of external artifact that they can reflect upon and share with others. Elements of a constructionist learning environment include:

⇒ a teacher who acts as a facilitator;
⇒ learners who investigate, create, and solve problems;
⇒ learner collaboration;
⇒ learners engaging in authentic tasks;
⇒ opportunity for feedback and multiple opportunities for revision. (Source: MIT App Inventor)

Problem-Based Learning. Problem-based learning is one type of constructivist learning theory that can be applied in a classroom setting. It is a method which allows students to learn about a subject by exposing them to multiple problems, so they will be able to construct their understanding of the subject through these problems. Problem-based learning typically:

⇒ begins with problem for students to solve or learn about;
⇒ includes problems that are somewhat ambiguous to mirror the complexity of real life;
⇒ uses an inquiry model;
⇒ requires students to present a conclusion of the problem solving process, but does not necessarily require them to create a product as a result;
⇒ is driven by defined problems. (Source: MIT App Inventor)

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Project-Based Learning. Project-based learning encompasses Papert's theory of constructionism where students build an artifact as part of the learning process. Project-based learning typically:

⇒ begins with an end product in mind;
⇒ includes production of an artifact, which typically raises one or more problems for students to solve;
⇒ asks students to use or present the product they have created;
⇒ is driven by the end product;
⇒ stresses that content knowledge and skills acquired during the production process are critical to success. (Source: MIT App Inventor)

Computational thinking. The term **Computational Thinking** (CT), coined by Jeannette Wing in 2006, describes solving problems, designing systems, and understanding human behavior based on the principles of computer science. CT includes analyzing and organizing data, automated problem solving and using it to solve similar problems. Nowadays, it has become necessary to solve complex technological problems. If sufficient background knowledge is available and the necessary new knowledge is acquired through critical thinking, CT may help to solve the problem. It is actually a hybrid of several other modes of thinking, like abstract, logical, algorithmic, constructive and modelling thinking, which summarizes all previous modes for solving the corresponding problem. (Source: IGI)

Brainstorming. Brainstorming is a group problem-solving technique that involves the spontaneous contribution of ideas from all members of the group. (Source: Merriam-Webster)

Collaborative learning. A **collaborative** (or cooperative) **learning** approach involves students working together on activities or learning tasks in a group small enough to ensure that everyone participates. Students in the group may work on separate tasks contributing to a common overall outcome or work together on a shared task. This is distinct from unstructured group work. Some collaborative learning approaches put mixed ability pairs, groups or teams together to work in competition with each other in order to drive more effective collaboration. (Source: Evidence For Learning)

Gamification. **Gamification** of education is a developing approach for increasing learners' motivation and engagement by incorporating game design elements in educational environments. It is often described as the use of game design elements in non-game contexts" (Deterding, Dixon, Khaled, & Nacke, 2011), "the phenomenon of creating gameful experiences" (Hamari, Koivisto, & Sarsa, 2014), or "the process of making activities more game-like" (Werbach, 2014). (Source: Springer)

Learning through Storytelling. **Storytelling** is the vivid description of ideas, beliefs, personal experiences, and life-lessons through stories or narratives that evoke powerful emotions and insights. It represents the use of stories or narratives as a communication tool to value, share, and capitalize on the knowledge of individuals. (Source: Springer)

STEM. **STEM** (Science, Technology, Engineering, and Math) is an integrated, interdisciplinary, and student-centered approach to learning that encourages critical thinking, creativity, collaboration, and design thinking across multiple disciplines. An important role of STEM education is to help students develop skills that will empower them later on in the workplace. This includes helping students develop skills that foster:

⇒ Critical thinking;
⇒ Flexible thinking;
⇒ Data-driven analytical inquiry;
⇒ Design (interdisciplinary) thinking;
⇒ Social responsibility;
⇒ Productivity;

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- ⇒ Leadership;
- ⇒ Teamwork;
- ⇒ Collaboration;
- ⇒ Communication. (Source: Techopedia)

Multimodality. To understand multimodal learning, you first have to know the different modalities and their characteristics.

- ⇒ Modes are channels of information. They include:
  - Speech
  - Audio
  - Written and print
  - Illustrations

An example is that people learn from images by reacting to visual cues such as photos and graphs. People can also learn from kinesthetics by reacting to tactile cues such as actions and movement. Multimodal learning is teaching a concept using more than one mode (visual, auditory, reading, writing, and kinaesthetic methods). By engaging the mind in multiple learning styles at the same time, learners experience a diverse learning style that collectively suits all of them. Thus it is meant to improve the quality of teaching by matching content delivery with the best mode of learning from the student. (Source: eLearning Industry

Flipped Classroom. It is a pedagogical approach in which the times and spaces inherent in the teaching and learning process are inverted: the exploration of content is first done before class by the students (e.g. through reading, video analysis, etc.) in a space that tends to be more individual than group-based; in class, students have the opportunity to interact with the teacher and with each other, in a fundamentally group space, in order to apply, develop, clarify the content previously explored. This inversion thus transforms the teaching-learning process into an interactive, dynamic, and personal logic. (Source: Bergmann & Sams,2014)

Other connected terms (pedagogical eclecticism):

- Adaptative teaching.
- Personal inquiry.
- Dynamic assessment.
- Crossover learning.
- Navigating knowledge.
- Learning through argumentation.
- Learning from animations.
- Learning to learn.
- Event-based learning.
- Learning for the future.
- Immersive learning.
- Open pedagogy.

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Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, literacy, citizenship, responsability

Knowledge
Main concept: The role of low-code programming in public health issues

Programming concepts:
- Basic and Intermediate programming expressions**,** statements, procedures, and variables.

ICT concepts:
- Programming solutions development and application; low-code development environments; low-code development in public health *(topic: nutrition habits).*

Knowledge - outcome assessment:
1. Elaborates on concepts of computational thinking/science.

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2. Recognizes and correctly outlines relevant concepts of low-code and block-based programming.
3. Easily outlines the importance of content creation-involved concepts.
4. Identifies and characterizes different programming languages and their applications.
5. Identifies and knows how to apply numerous basic/intermediate statements and expressions in MIT App inventor.
6. Justifies why low code is crucial to the future.

Skills (abilities/competences)
General:
- "Creactical skills" (Ohler, 2013) / 21st century key skills:
  - Communication: digital communication; digital literacy; traditional literacy; health literacy; public speaking; argue capability; learn to learn.
  - Collaboration: working in groups towards a goal/to solve a problem/answer a question; collaboration.
  - Critical thinking: perform reasoning and analysis to draw conclusions based on simple systems; decision-making process; problem-solving process; project-based thinking.
  - Creativity: involves initiative, entrepreneurship, taking risks and learning from risks.

Specific:
- Developing, enhancing, and practicing computational thinking and technology-based projects.
- Finding, analyzing, and interpreting multimodal content to map basic/intermediate principles of low-code programming.
- Deeply expanding the 21st century competences.

Skills – outcome assessment:
1. Identifies and conceptualizes core and detailed skills that are required for programming.
2. Can demonstrate that multimodal, gamification and flipped classroom approaches are in fact, key for the future of education.
3. Sketches possible technological solutions for needs/problems of the healthcare market.
4. Can fully transform creative ideas into basic and intermediate programmable concepts using content creation tools.
5. Feels able to explain the benefits of using low-code development environments for real life problems connected with lifestyles.

Affective/Attitudes/ Behaviour (*beliefs)*
- Adopting a citizen developer role in society, as well as having social and personal responsibility.
- Pursuing the adoption of critical thinking and problem-solving attitude as an individual and in connection with the needs of the community.
- Engaging in more challenging programming challenges/courses to further develop his/her interest in STEM.
- Adopting attitudes that mitigate public health risks.

Affective, Attitudes and behavior - outcome assessment:
1. Believes that low code is about innovation and creative problem-solving, that it should be explored in educational environments and that is a powerful tool for multimodal content creation.
2. Believes that technological skills are essential for effective citizenship and can lead to positive outcomes in educational, healthcare and business environments (e.g., fast development, scalability, simplicity, accessibility, low costs).
3. Believes that digital literacy translates into efficiency, access to things, knowledge, fulfillment, and happiness in personal and professional life, contributes to academic performance and improves student engagement.

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4. Believes that health is the most important constituent of life.
5. Intends to further improve his/her digital literacy and programming knowledge to influence "STEM adoption" in his/her living environments and boost public health literacy.
6. Is committed to develop further his/her digital literacy in order to communicate easily on any subject and has a positive attitude towards it.

Learning goals and outcomes

- Uses low-code environments and content creation tools as creative platforms/extensions to express ideas and knowledge.
- Easily uses online tools to create multimodal content.
- Understands and characterizes the most important components of programming and uses them to create apps/games from scratch.
- Knows and communicates the main principles of good nutrition patterns, how much they may influence our daily lives, as well as their contribution for life expectancy and quality of life.

<u>Assessment methods</u>

✓ Outcome assessment
  - Quantitative – A questionnaire (in paper or in digital format)
  - Qualitative - students project: a. basic app/quizz building activity b. additional multimodal resources regarding public health and technological principles.

✓ Process assessment – *assessment of the teaching-learning sequence sequence* – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

<u>Content</u> (relevant to learning goals & research topics)

STEM content

- Technical literacy.
- Basic programming expressions.
- Programming oriented math.
- Digital Literacy.
- Communicating science: Healthy lifestyles – nutrition habits.

Non-STEM content

- Teamwork
- Metacognition
- Proactivity
- Multimodality
- Autonomy
- Brainstorming/Mental Mapping.

<u>Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)</u>

<u>New (*developed by PAFSE team*):</u>

In order to provide simple and easy-to-use resources for teachers/students, only one DER is presented, in which all DLOs will be inserted.

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1. Animated, intuitive, and interactive *Nooc*[6] (*Nano Open Online Course*) using genially[7] concerning MIT App Inventor (Basic) and concepts to communicate science through technological content.
   - Informational multimodal resources (images, videos, sound, etc.) with content, challenges and solutions regarding basic low-code programming.
2. MIT AppInventor app(s) created by the team.
3. Questionnaires – quantitative and qualitative assessment of learnings - Student Interest and Choice in Science, Technology, Engineering and Mathematics (STEM) Survey (adapted from Roller et al. 2018 and Faber et al, 2013); Informed Consent – Students; Informed Consent – Legal Representatives; Process Assessment – Teachers; Scenarios Impact Assessment In Terms Of Students Knowledge, Skills, Attitudes And Behaviour.

Available resources (link): Low-code universe 2 - Nooc

From other sources/high-quality platforms[8]:
Tutorials and examples to aid teachers prepare and train the students:

- MIT AppInventor:
  - Teach your students
  - Setting up your classroom for teaching App Inventor 2
  - Teaching an app inventor course
  - Hello Codi! (*app example*)
  - The MIT App Inventor library: documentation & support
  - MIT App Inventor - tutorials
  - MIT App Inventor - Beginner videos
  - MIT App Inventor - Nooc
- Block-Programming:
  - Block-based Programming in Computer Science Education
  - Block coding 101
- Nutrition habits:
  - Referencial de educação para a saúde
  - Nutrition - CDC
  - Nutrition for Teens
  - Nutrition and teens
  - Take charge of your health: A guide for teenagers
  - Healthy Eating for a Healthy Weight
  - How dietary factors influence disease
  - Diet kills more people globally than tobacco and blood pressure

Observation:

- The PAFSE team provides examples of high-quality platforms that can be used by students to develop their app in the research project. However, teachers are encouraged to choose the resources they see fit, or even leave it up to the students, instigating their creativity and research capacity, since it is such a "mundane" topic. In case of the schools that have science/health teachers involved (in addition to/instead of ICT teachers), this is even more encouraged.

[6] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[7] Genially is the world-leader in interactive visual communication using low/no-code. It is an all-in-one online tool to create stunning presentations, interactive images, infographics, gamification, quizzes, breakouts, portfolios, etc. and enrich them with interactivity and animation effects in seconds.

[8] The majority will be included in the developed DER.

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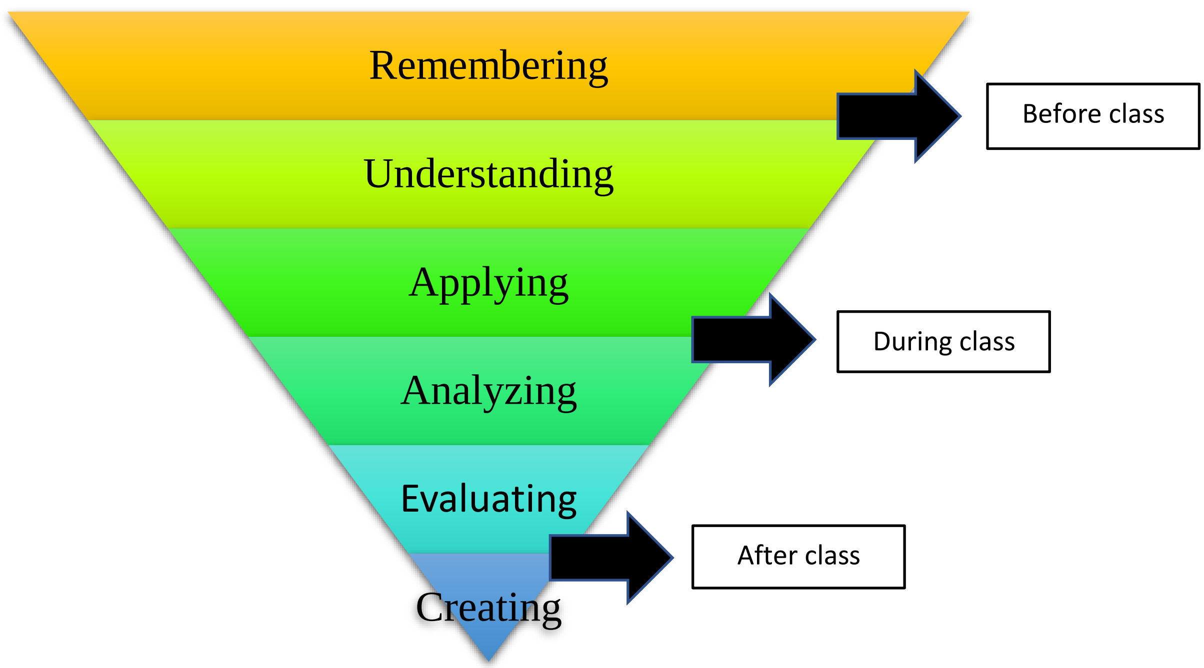
- Given that nutrition involves a panoply of different topics such as diseases, dietary guidelines, tyopes of food,etc, students can choose whichever appeals to them the most.

Teaching-learning activities

Principal target:
ICT classes /Biology classes /F.Q classes/Health Education classes (depending on the institution)
8h grade (+/- 13-14 years old students)
5-6 sessions/classes of 40-60 minutes
ICT teachers integrate other colleagues in the enactment of the scenario, as it aims to be interdisciplinary. The scenario provides the necessary tools for students to explore desirable behavior in an individual and public health perspective.

General note:

- This scenario focuses on learning by doing but also on learning by fully immersing on the topic. That being said, teachers are merely mediators and content curators, and support should be minimal. Students are supposed to solve the majority of their doubts by studying the issue and/or asking a peer.
- All the activities/theoretical aspects used in lessons will be available in the DER so you can all any information there.
- The lessons will have "Bloom's taxonomy" for flipped classroom as a background.
    - Students will have activities in which they will, independently and individually, explore specific (and always available) content at home and then bring findings/discussions to the class, creating a powerful sense of interaction and collaboration.
    - It is about building the knowledge themselves and then apply it at the classroom, in group.



Bloom's Taxonomy for "Flipped" Classrooms; version revised by Lorin Anderson

Lesson 1: Introduction to key concepts

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Learning objective: In the starting session, students will be exposed to various theoretical concepts (discussed in the workshop) they will need to use MIT App Inventor successfully and attain the scenario goals. The activities performed during this first lesson aim to engage students in these topics and explore some preliminary ideas.

Topics to be explored: Content Creation; Storytelling; Gamification; Programming; Computational science.

⇒ The teaching-learning script starts with a video play: Programming as a kid
- The teacher will project the short video to the classroom.
- When it finishes, pose the question: “What about you? Is that how you feel about programming?” and ask several random students to answer (you can also ask them to raise their hand).
    - If students responded positively to the question, ask: “What about gaming? Do you like gaming? Let’s take a look at other related short videos”
    - If students responded negatively to the question simply generate some discussion with different points of view and tell them that after the scenario enactment, their view on programming will be a lot different and then ask “What about gaming? Does that seem more interesting to you? Let’s take a look at other related short videos”
- Show them 2 more videos:
    - Gamification - definition
    - Learning through gamification
- At this point they will be very excited with this topic so profound it now.
    - Correlate gamification with storytelling and show them this short video.
    - Present them the detailed steps to create a storyboard
    - Correlate with the topic of “Multimodal content creation” by providing real examples.

⇒ Now start developing on the importance of digital literacy, pointing the fact that technology is everywhere, and we need to integrate it in education and business matters, as well as discussing the topic “programming languages” and “block-programming”, analyzing what they already know, as well as giving them some “basics”.

⇒ What is MIT App inventor and what will they use it for.
- Presentation
    - The best way to understand App Inventor is to use it.
    - The implementation of a program is done in two parts:
        - The creation of the user interface and the choice of resources that will be used in the application,
        - then block programming that uses the components (events, properties, procedures) associated with the components defined in the first part.
- SETUP
    - Activity: Each student should successfully SETUP independently.
    - Let them explore the platform until the rest of the class and provide them with some guides for consultation.
- Explain on what they will work on and attribute and elaborate on the topic “nutrition habits”.

⇒ Assign obligatory homework: Discovering code
- Since this is a homework activity, you won’t be able to guide the students, however, that is also the goal because it is where flipped classroom jumps in. Students will have the opportunity to acquire knowledge autonomously and without direct exposition of theory and will, afterwards, clarify doubts and discuss about it in the classroom.
- Ask students to open this website, watch the video and complete the tasks (phases of a game).

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- In less than an hour, they will become familiar with block sequences, conditional connections and loops. This will get them started on practicing basic notions of block-based programming and they will like doing this activity.
  - Tell them to setup the page to PT-PT since it's available, both video and game.
  - In case there are some fast and very curious minds or even has a taste for flappy bird, you can give them another example.
  - Ask them to write down (in their notebooks) any doubts, comments and general observations regarding the learning experience. Some questions to ponder on:
    - What did you learn about how apps and games work today?
    - How do you feel knowing you programmed, you gamified.
- Challenge students to share some aspect of their Hour of Code experience on social media using #hourofcode as a way to lend their voices to this worldwide movement. Students can share their game, images, videos or just their thoughts.

Lesson 2: Discovering coding 2.0

Learning objective: In this session, students will keep discovering code, this time, with the help of the teacher and a lot of reflective work will be simultaneously carried out. The plan takes up that of the courses of Professor Ralph Morelli and David Wolber. The pedagogical logic is that called *"BCCC" for "Build, Conceptualize, Customize, Create*": we start by doing (copying), then conceptualize (by experimentation and error research), customize existing functions, and finally create new applications, guided and then in free flight.

Topics to be explored: Block-programming principles.

⇒ Homework "correction"
- Start by talking a little bit about the work they did at home and what type of skills were being used in the process.
- Continue by elaborating on the expected learning outcomes topics
  - Define "coding" and "computer science"
  - Identify key computer science vocabulary
  - Make connections between computer science concepts and the real world
  - Identify places to go to continue learning computer science and coding
- Division of the class in small groups (4-5 people or as the teacher sees fit) in order to stimulate collaboration and capacity of exposing and discussing ideas, which will lead to a moment reflection on what they wrote about it.
  - Ask students to share their game, app or final product with the peers, pass by to take a look.
  - Give them a few minutes to discuss and then ask each group to present some bullet-points about the experience.
  - Listen to their feedback about it: clear their doubts; and listen to what kind of observations they have/how was the experience for them.
  - Ask how many felt the experience was easy/hard; pleasant/unpleasant.
- After discussing
  - Celebrate! Give them some certificates to keep it fun and make them proud of their work.
  - Tell them they can use the same website to practice in case they got interested and want to explore more.

- Maintain the groups formed and ask them to quickly scan MIT App Inventor Interface.
  - Give them a couple of minutes.
  - At this point they will be confused, as expected, so next provide them with some links Built-in blocks; Component reference and

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- Ask them to start creating the app “Paintpot” following a tutorial (if they are feeling particularly adventurous they can also do part 2); https://appinventor.mit.edu/explore/ai2/paintpot-part1; https://onvaessayer.org/appinventor/baseApps/paint.php
    - This tutorial will lead the students to:
        - define an application by how it reacts to a list of events (event programming or event driven programming),
        - choose the components you need and layout them (Design)
        - buttons to choose colors, line thickness, erase or take a photo,
        - a frame (canvas) to draw and display the photo,
        - horizontal arrangements to layout,
        - a camera (camera).
        - describe what the application should do for each event and then code this behavior in a script associated with that event,
        - define and use variables, for example for the size of points.
    - The steps in the realization of an application:
        1. Initial analysis: define what the application will do, for whom, what need it meets. In this phase, you need a pencil, a paper but also friends to whom you can submit your ideas. It's not programming, but it's important.
        2. The development:
            1. Design of the user interface and the choice of resources,
            2. Programming: scripts or sequences of instructions (or blocks) that follow an event,

It is most often an iterative process, ideas improve as they are realized, but be <u>careful to keep your priorities in mind</u>.

- Check VERY often what it looks like on your phone, test every step, don't wait until you finish a big piece,
- A mistake or a small accident quickly happened... especially when you are in the most hurry. Regularly save intermediate steps or versions, especially with checkpoints.
- Transfer your program often to mobile, preferably work in connected mode (or interactive debug),
- Test to develop and check proper functioning.
- In the design part:
    - Choose/find the components
    - Does the choice of component names have a theoretical or practical impact on the next programming phase? It has a practical impact because the name will allow us to remember what each component corresponds to when you write the program. For example: "ScanButton" allows you to remember that this is indeed the scan button. However, it doesn't matter to the program. We could very well have called this button "Michel" or "MaBicyclette". You can rename it and turn that the program works exactly the same. The difference is practical, neither computer nor theoretical.
    - The design allows you to choose the main properties of the components. It will be possible to modify these properties later in the program, but it is not always necessary.
- In the Programming section: the events and blocks used:
    - What events have we taken into account?
        - user intervention: Clicks on the buttons, frame touched or dragged,
        - and the events triggered after smartphone functions: the arrival of the photo after shooting.
    - Blocks have several shapes: which ones and what do they correspond to?

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- the same goes for the color?

1. Permanent transfer of the program to the phone or tablet: You have used two modes of communication with the mobile phone:
   - the first (connected mode), in the development phase, where the application remains controlled from the PC, which allows quick testing and modification, the second (build or build mode) where the application is downloaded to the laptop and works independently.

This app development isn't going to be easy since there were more basic apps to construct but you are there to provide as much help as they need.
If they don't finish in time, tell them to finish at home without worries.

Lesson 3: Practice makes perfect

Learning objective: during this lesson and as wrap-up moment on the "app creation" world, students are invited to challenge themselves and take it to the next level. Basic concepts where explored. This is the moment to explore even more.

Topics to be explored: Intermediate block-programming principles.

⇒ Activity 1: *Discovery Time -- App Experimentation*

- Play around with the following source code for the app Dancing Llama by experimenting and completing the following tasks:
  - the moveLlama procedure block. See how the corresponding blocks with that procedure also change names.
  - Rename the numberOfDances global variable block. See how the corresponding blocks with that procedure also change names.
  - Answer the question: Why does the numberOfDances displayed on the label only increase when the timer goes off and not when the phone is shaken?
  - What happens to the label when you shake the phone 3 times in a row?
- Randomness is an important and common task in computer programming. To decide whether or not the ghost in Pacman should turn left or right at an intersection is determined randomly or whether or not a mushroom should appear in a game of Mario Kart. The generation of random numbers can be used to make these decisions. If you would like the Pacman to turn left
- approximately 25% of the time and to turn right approximately 75% of the time, you can use blocks like this:
- In this "Pacman" program, there are two procedures: turnLeft and turnRight. A random fraction [*between 0 and 1*] is used to determine which one should be called. If this fraction is less than or equal to 0.25,
- Pacman will turnLeft. Otherwise if it is greater than .25, Pacman will turnRight. Although it is random what will happen, because there is a greater possibility of numbers to randomly choose that lie in the range [.25-1.0], it is more likely that Pacman will turnRight in this program.
- Basic (and advanced) algorithms are used all the time in Computer Science. Basic ones are used in app building to solve problems. In game apps, there is an algorithm that tells the score to increase by one when the mole is hit. Essentially an algorithm is a set of rules or instructions that defines a sequence of operations.

⇒ Activity 2: Divide the class into small groups and divide these 3 apps between then, assign randomly.

- In the end, a group of each app will present it, succinctly explain the process and give the templates to the colleagues (so they have a lot of material for the research project).
- Particularly, their assignment is to play with the source code and corresponding app for the following three games: Mole Mash, Get the Gold, and Space Invaders. Take notes about they like/dislike about them. Have them look at the blocks, components, and the design of the app.

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    - Mole Mash
    - Get the Gold
    - Space Invaders
  - Make them think about their observations of these games as well as develop their own game app. A game is defined as structured play. Sometimes games can be work as in the case of professional athletes. But mostly games are for fun. The key components of all games are goals (to hit the mole), rules (you only get points if you hit the mole), challenge (the mole moves randomly across the screen), and interaction (the user plays the game on the phone by touching the screen with a finger). This game can be a modification of any of the above apps or a new creation of your own.

Lesson 4: Practice makes perfect

Learning objective: during this lesson and as wrap-up moment on the “app creation” world, students are invited to challenge themselves and take it to the next level. Basic concepts where explored. This is the moment to explore.

Topics to be explored: Intermediate block-programming principles.
The last assignment was a big one, so they will probably need a lot of time.
This lesson is free for practice and continuing developing games.

Lesson 5: The final countdown

Learning objective: In this final session, a recap regarding the major practiced concepts concerning block programming is made, as well as of the used methodologies. In addition, students are prepared to the students research project.

⇒ Present the concept of a mental map by showing one representing the lessons.
⇒ Activity 1: Ask students to elaborate one, on an appropriate software, describing what they learnt.
⇒ Aiming to prepare the students for their final project, a presentation called “O meu Pitch em 5 p’s” (My pitch in 5 p’s) will be given, teaching students how to publicly present projects.
  - How to communicate science/health using these 5 pillars:
    - “Priorizar” (Prioritize).
    - “Pesquisar” (Research).
    - “Planificar” (Plan)
    - Personalizar (Personalize)
    - Produzir (Produce)
  - Provision of storyboard templates to prepare the pitch.
  - Explanation of what will be evaluated.

⇒ Quantitative assessment – questionnaire – impact assessment in terms of student’s knowledge, skills, attitudes and behaviour.

Lesson 6-forward:

This is the **School Project** described below.
Final sessions, moments of creative freedom, where students apply the programming concepts learned during previous sessions in a project linked with nutrition habits. They will work with the MIT AppInventor platform with the aim of presenting the project at the end of the sessions, or in another event created for that purpose.

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The projects will cover all the tools and themes explored. Students may choose, within the topic of nutrition habits, which sub-topics they want to explore and focus on. Regarding programming skills, they should follow a solid framework to create their own apps and are required to be as independent as possible.

Supplementary learning resources and educational activities

Regarding the school Research project:

- Production of multimodal content – Students can transfer and use the knowledge acquired to other classes.
- Public health reflection.
- Competition – reward of the best app ideas.

School Research Project (Ciência Viva)

Topics

Importance of digital literacy and real-life implications.

Basic/Intermediate technical features and principles of programming solutions development.

Possible applications of mobile applications in public health (e.g., in the promotion of nutrition habits).

Research management, design and administration

Challenge: Content exposition creation on one topic involving "nutrition habits", promoting not only technology, but also public health.

Method *(summary)*: Lessons 6 to 11 will be dedicated to the school research project. Students are, as usual, organized in groups and each group addresses the practiced programming and technological concepts and connects them to health.

Development process:

The project is based on the use of technology to create scientific artefacts. The five-six sessions will be lightly supervised by the teachers and developed by the students, with scheduled moments for checking the work development.

Groups of students will be instructed to create an interactive game or tool app that explores the topic of hygiene habits in some way, as well as some other resources (of their choice) that they see fit on the same topic:

During session 1, students are presented, not only, with software to use for content creation but also the norms to follow:

1. Each group should have, at least:
    a. 1 app on the theme of healthy habits (they can use existing templates or build from scratch and there is no need to be similar to those they tried, it's full on creativity)
    b. One other multimodal resource on the theme of healthy habits.
        i. It can be a mental/conceptual map, a quizz, a presentation, an interactive resource, an infographic, a story, a video, etc.
    c. A short portfolio with all the created resources.
2. Each group is required to:
    a. brainstorm a project idea, develop drawing(s) of the app/game on paper, creating a storyboard.
    b. meet regularly with the teacher to discuss the feasibility of the app and if necessary make any changes to their plan.
    c. Present a short (till 10 minutes) elevator pitch of your project idea to the class.
3. Create a portfolio (free structure, let the student be creative) write up of your project.

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Finishing session 1, the groups are created and ideas start being discussed.
During session 2, the teacher will pass by the groups to collect ideas and topics and, if valid, students can start working on their project. The teacher will provide all the needed help, even if that means that he is an contributor to the project.
From session 3-forward, the students will actively work on their project and are encouraged to exchange ideas with other groups.

Teaching-learning process milestones:
1. Students will be able to propose basic/intermediate programming solutions.
2. Students will be able to communicate the findings, motivations and limitations of various solutions considered in the work process.
3. Students will be able to identify and communicate the importance of digital literacy/end-user development in public health and citizenship.

Teaching-learning process for school project (summary):
1. Development of multimodal materials.
2. Mobile Applications development.
3. Presentation of all the resources created in the open schooling event, where students will be advocating better conditions for their community and show their relationship with public health and low-code environments.

Organization of the open schooling event:
1. Each project output (portfolio) is presented by the students in a community setting (e.g., exposition center, municipality, science fair) with appropriate/pre-prepared environment (computer and smartphone with the MIT App Inventor installed).
2. Students do a pitch on how mobile solutions can be used to address public health, like the case of good nutrition habits. Technical speeches to motivate peers to new technologies and technological environments. Students will also be advocating better conditions for their community and show their relationship with citizens health.
3. Students, parents, school community and relevant local stakeholders attend the event and recognize that mobile solutions can be used to address real life challenges, public health ones, and others. They also get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, community).

Data Analysis and Reporting
Content Analysis.
Multimodal resources.
Portfolio development.

Target Audience for Recommendations
School community and local stakeholders: students, parents, municipalities, engineers, public health authorities, and local enterprises.

Public Debate and Recommendations (based on research results)
Presentation of the resources produced by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.
Discussion and feedback.
Attribution of the prize of “best apps”.

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
Scenario topic: "Low-code development environments – Level 2 (Intermediate)"

Knowledge	
1. Elaborates on concepts of computational thinking/science.	**Question 1.1:** What do we mean by computational thinking? A) Understanding a complex problem and developing possible solutions. B) Using a computer. C) Focusing on what is important, ignoring what is unnecessary. **Question 1.2:** What is the name given to the process of breaking down a problem into smaller problems? A) Decomposition B) Abstraction C) Algorithm design **Question 1.3:** Which of the following is an example of thinking computationally? A) Planning out your route when going to meet a friend B) When going to meet a friend, wandering around until you find them C) When going to meet a friend, asking a parent to plan your route for you
2. Recognizes and correctly outlines relevant concepts of low-code and block-based programming.	**Question 2.1:** Why is block-programming different from text-based coding? A) Because it is a type of visual software development environment that allows developers to drag and drop application components. B) Because block-programming is based on syntax, therefore making it easier. C) Because it is a programming language specially made to teach kids how to code. **Question 2.2:** Why should one use low-code platforms? A) Low-code platforms are easier to learn, as well as more intuitive and faster. B) Low-code platforms are free. C) Low-code platforms offer better outcomes than "high code" ones.
3.Easily outlines the importance of content creation-involved concepts.	**Question 3.1:** What does gamification attempt to do? A) Create a world revolved around play B) Create a world shaped by games C) Create a game-based only world **Question 3.2:** Which of these is not one of steps of storyboard creation. A) Create a compelling selling text B) Writing the narrative C) Studying the target-audience **Question 3.3:** Which modes are employed to convey the meaning in an image? A) Visual (and gestures). B) Visual (and gestures) and sound. C) Visual (and gestures) and oral.
4. Identifies and characterizes different programming languages and their applications.	**Question 4.1:** What does run mean? A) To make a program complete an algorithm B) To make a website appear on screen C) To create code **Question 4.2:** What are lines of coding that repeat?

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	A) Loops B) Variables C) Procedures
5. Identifies and knows how to apply numerous basic/intermediate statements and expressions in MIT App inventor.	**Question 5.1:** A button that, when clicked on, displays a list of texts for the user to choose among. A) ListPicker B) ListView C) ListBox **Question 5.2:** Which is the file format which contains an App Inventor executable, needed to actually run the program on a device A) Apk B) Akp C) Aia **Question 5.3:** What is a global variable? A) Global variables can be set and read from any blocks in the workspace. B) Global variables exist only within their initialization block Interface. C) Global variables are types of blocks.
6. Justifies why low code is crucial to the future.	**Question 6.1:** Which of these is **not** a characteristic of low-code environments? A) Special skills (developer skills) are required. B) Cheaper to enterprises. C) Improves productivity and collaboration. **Question 6.2:** In what way could low-code contribute to enhance public health issues? A) Integrate patient and employee information across systems in hospitals. B) Develop cures for diseases. C) Scatter information regarding public health issues.
Skills	
1. Identifies and conceptualizes core and detailed skills that are required for programming.	**Question 1.1:** Which of the following proficiencies is important in a professional programmer? A) Problem-solving B) Entrepreneurial spirit C) Ability to teach and mentor **Question 1.2:** Which of the following proficiencies is **not** required in block-programming? A) Public speaking ability B) Resilience C) Creativity
2. Is able to demonstrate that multimodal, gamification and flipped classroom	**Question 2.1:** I feel able to enumerate to others some pros of multimodal and gamification strategies in specific curricula. 1) definitely true... 2) definitively false. **Question 2.2:**

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approaches are in fact, key for the future of education.	Public health might be benefited from approaches such as multimodality and gamification in terms of: A) Training of future profissionals B) Enhancement of facilities C) Curing diseases **Question 2.3:** I intend to integrate gamification and multimodality in future school projects. 1) definitely true... 1) definitively false. **Question 2.4:** For me, if school used gamification and multimodality in all curricula, it would be: 1) very significant... 2) very insignificant. **Question 2.5:** For me, the autonomy conceded by the flipped classroom approach is beneficial to the learning process: 1) definitely true... 2) definitively false.
3. Can fully transform creative ideas into basic and intermediate programmable concepts using content creation tools.	**Question 3.1:** I feel capable of conceiving a complex idea and subsequently turn it into a programable concept. 1) definitely true... 2) definitively false. **Question 3.2:** In the future, I will always search creativity in everything I do. 1) very probable... 2) very improbable. **Question 3.3:** I feel that programming stimulates my creativity skills. 1) strongly agree... 2) strongly disagree **Question 3.4:** I feel comfortable exploring block-programming environments. strongly agree... 2) strongly disagree
4. Sketches possible technological solutions for needs/problems of the healthcare market.	**Question 4.1:** A way of tackling information overload in public health facilities would be to: Have someone to do that management A) Use programming solutions B) Have someone qualified to manage. C) Buy fancy equipment. **Question 4.2:** I feel capable of enumerating different uses of low-code in the healthcare market. 1) strongly agree... 2) strongly disagree
5. Feels able to explain the benefits of using low-code development environments for real life problems connected with lifestyles.	**Question 5.1:** I feel capable of proposing low-code actions that benefit real life problems. 1) definitely true... 2) definitively false. **Question 5.2:** To aid tackling public health issues, people should rely on programming more. 1) strongly agree... 2) strongly disagree
Beliefs, attitudes and behavior	Instructions: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that technological skills are essential for effective citizenship and can lead to positive outcomes in educational, healthcare and business	**Question 1.1:** I intend to identify and address the problems of the community in relation to technological issues. 1) strongly agree... 2) strongly disagree. **Question 1.2:** The development of technological competences of my own can contribute to the global society's awareness about the importance of technology. 1) extremely likely... 2) extremely unlikely. **Question 1.3:** I can explain to my family and friends the importance of technology.

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environments (e.g., fast development, scalability, simplicity, accessibility, low costs).	1) strongly agree... 2) strongly disagree. **Question 1.4:** I think society still does not fully understand the importance of technology. 1) strongly agree... 2) strongly disagree. **Question 1.5:** I feel society takes for granted the benefits of technology. 1) strongly agree... 2) strongly disagree. **Question 1.6:** Among the following statements, choose the one that best describes what you currently think: 1) Low-code does not contribute to public health enhancement in any way. 2) I can see where low-code could contribute to public health enhancement in some way. 3) I can definitely see potential contributions of low-code to public health issues. 4) Low-code contributes to public health enhancement.
2. Believes that low-code development environments can be vital to solve real-life problems connected with public health and contribute for innovative solutions (since they are fast, cheap, adaptable, and flexible).	**Question 2.1:** I understand the importance of low-code environments for society. 1) strongly agree... 2) strongly disagree. **Question 2.2:** I can solve more complex problems now. 1) strongly agree... 2) strongly disagree. **Question 2.3:** Low-code empowers education and makes classes more effective. 1) strongly agree... 2) strongly disagree.
3. Believes that health is the most important constituent of life.	**Question 3.1:** Health is a fundamental component of quality of life. 2) strongly agree... 2) strongly disagree. **Question 3.2:** I am capable of adopting a healthy lifestyle that benefits quality of life. 2) strongly agree... 2) strongly disagree.
7. 4. .Believes that digital literacy translates into efficiency, access to things, knowledge, fulfillment, and happiness in personal and professional life contributes to academic performance and improves student engagement.	**Question 4.1:** I believe that digital literacy is important / useful in our daily lives. 1) strongly disagree... 2) strongly agree. **Question 4.2:** I believe that digital literacy improved my academic performance and my class interest. 1) strongly disagree... 2) strongly agree.
5. Intends to influence “STEM adoption” ” in his/her living environments and boost public health literacy.	**Question 5.1:** I commit to promoting STEM adoption. 1) strongly disagree... 2) strongly agree. **Question 5.2:** I commit to promoting public health literacy. 1) strongly disagree... 2) strongly agree.

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6. Is committed to develop further his/her digital literacy and programming skills in order to communicate easily on any subject and has a positive attitude towards it.	**Question 6.1:** I plan to keep improving my digital literacy. 1) definitely true... 2) definitively false. **Question 6.2:** I plan to keep improving my programming knowledge. 1) definitely true... 2) definitively false. **Question 6.3:** I feel digital literacy helps me with content exposition, problem-solving and creativity. 1) strongly disagree... 2) strongly agree. **Question 6.4:** I feel programming helps me with content exposition, problem-solving and creativity. 1) strongly disagree... 2) strongly agree. **Question 6.5:** I feel digital literacy helps me to develop 21st century skills. 1) strongly disagree... 2) strongly agree. **Question 6.6:** I feel programming helps me to develop 21st century skills. 1) strongly disagree... 2) strongly agree. **Question 6.7:** I feel digital literacy makes me to be more productive and proactive. 1) strongly disagree... 2) strongly agree. **Question 6.8:** I feel programming makes me to be more productive and proactive. 1) strongly disagree... 2) strongly agree. **Question 6.9:** Among the following statements, choose the one that best describes what you currently think: 1) I do not use technology, and I also have no intention of doing so. 2) I do not use technology, but I have been thinking about the possibility of starting to do so. 3) I never or rarely use technology, but soon I will start doing it on a regular basis. 4) I use technology regularly. 5) I use technology regularly and I will keep doing so. **Question 6.10:** Among the following statements, choose the one that best describes what you currently think: 1) I do not program, and I also have no intention of doing so. 2) I do not program, but I have been thinking about the possibility of starting to do so. 3) I never or rarely program, but soon I will start doing it on a regular basis. 4) I program regularly. 5) I program regularly and I will keep doing so. **Question 6.11:** For me, programming is: pleasant:_____:_____:_____:_____:_____:unpleasant good:_____:_____:_____:_____:_____:bad worthless:_____:_____:_____:_____:_____:valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

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3. Specifications for an educational scenario on the topic of "Low-code development environments – Level 3 (Advanced)"

Main partner responsible: UM (University of Minho)

Title of Educational Scenario: Connecting students to IT using low-code development environments to promote public health and digital literacy – Level 3 (Advanced)

Topic in School Curriculum: Block programming / Physical activity

School Subject: ICT classes/Biology/F.Q classes/Health Education classes (Interdisciplinarity[9])

Main resource: MIT App Inventor

Grade level: 9th grade (+/- 14-15 years old students)

Context and relevance to public health education

Every year, experts convened by the World Economic Forum and Scientific American make predictions about the emerging technologies expected to have major social, economic, and environmental impacts worldwide. While some of these technologies have been catapulted into public consciousness and are fully integrated into our lives, others have been slower to gain momentum, which is the case of low-code environments and that's the reason why it needs to be brought directly to the world's future, schools. In addition, there is clear evidence that early technology literacy (e.g., meaningful use of low-code platforms) is linked with better disposition and ability to follow STEM (Science, Technology, Engineering, Mathematics) curricula and careers.
Particularly, block-based coding or programming is an element of programming where text-based computer commands are groups together in pre-programmed blocks that drag and drop together to build computer programs such as animations and games. Block coding is considered "syntax-free" in that a user does not need to be careful about the order and requisite syntax of commands and punctuation, which need to be memorized in text-based programming. This means it has a tremendous potential to take education to the next level.
The educational scenario supports ICT teachers in exploring how coding can positively impact tech education, students' communication and social skills, job prospects, and public health literacy. The learning experience supports youths in understanding how STEM may contribute to create new and revolutionizing solutions to address the determinants of health, as well as stimulate their creativity, decision-making and problem-solving capabilities, and enhance their entrepreneurial mindset. This scenario will point physical activity as a core component of healthy lifestyles and apps as solutions to address this need and connected problems (e.g., child obesity). During the learning process, students will properly communicate evidence on the topic while improving their low-code and multimodal content creation skills.

Estimated Duration

5-6 classes of 40-60 minutes (lesson 1 – lesson 6)
5-6 sessions of 40-45 minutes for supplementary learning activities and school project (session 6 – session 12)

Classroom organization requirements

Classroom ergonomics:

9 Integrating knowledge and methods from different disciplines, using a real synthesis of approaches.

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- Create a space that is adaptable to the learning experience instead of having the learning experience adapted to the space (Bayse, 2015);
- Focused on the training of required skills and collaborative work;
- Teachers are merely content curators and learning facilitators – Students are required to be fully autonomous.

For the learning-through-teacher lessons, students will work alone/in groups and should have access to:

- An ICT classroom with regular functioning computers;
    - Setup - MIT App Inventor;
        - System Requirements - MIT App Inventor;
        - App tester - MIT App Inventor;
        - Pre-setup (Tech and Networking Specialists) - MIT App Inventor.
- An internet connection;
- A gmail account (to log in in MIT App Inventor);
    - Accounts and devices - MIT App Inventor.
- Any android device.

To carry out the research project, students will work in groups and the same equipment is required, as well as an open, curious, and creative mind.

Observations:
- No prior downloading of software is required;
- Students are welcome to use their own computers;
- Each student should have their own email account;
- App Inventor offers the ability to develop using the Android emulator that shows up in a window on the computer screen if the students don't have an android device. However, using the emulator isn't as good as a physical device, because students can't carry their apps around with them and some features might not be present;
- The navigator "Internet Explorer" is not supported;
- MIT App Inventor works as a cloud, therefore everything is stored online.

Prerequisite knowledge and skills

- Basic, intermediate, and advanced IT and ICT notions.

General content glossary

IT. **IT** (Information Technology) is the study, design, development, application, implementation, support, or management of computer-based information systems. (Source: Code Academy)

ICT. Information and communication technologies (**ICT**) is defined as a diverse set of technological tools and resources used to transmit, store, create, share or exchange information. These technological tools and resources include computers, the Internet (websites, blogs and emails), live broadcasting technologies (radio, television and webcasting), recorded broadcasting technologies (podcasting, audio and video players, and storage devices) and telephony (fixed or mobile, satellite, visio/videoconferencing, etc.). (Source: UNESCO)

Low-code. A **low-code** platform allows app development through the use of a graphical user interface (GUI) rather than traditional hand-coding. In other words, it is a type of visual software development environment that allows developers to drag and drop application components, connect them together and create mobile or web apps with little to no code. (Source: Techtarget)

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Block coding. **Block coding** is a process used in computer programming where text-based software codes change to a visual block format to create animated games, characters, and even stories. With block coding, kids can learn the basics and foundational concepts through visuals instead of text-based coding. (Source: Codingal)

Algorithm. An **algorithm** is a detailed step-by-step instruction set or formula for solving a problem or completing a task. In computing, programmers write algorithms that instruct the computer how to perform a task. When you think of an algorithm in the most general way (not just in regards to computing), algorithms are everywhere. A recipe for making food is an algorithm, the method you use to solve addition or long division problems is an algorithm, and the process of folding a shirt or a pair of pants is an algorithm. (Source: Tynker - Coding for Kids)

Programming language. A **programming language** is a set of commands, instructions, and other syntax use to create a software program. In other words, it is a language that allows a programmer to tell the computer what to do in a variety of circumstances. Languages that programmers use to write code are called "high-level languages." This code can be compiled into a "low-level language," which is recognized directly by the computer hardware. (Source: Techterms; Ageuk)

Event-driven programming. ***Event-driven programming*** is a programming paradigm in which the flow of program execution is determined by *events* - for example a user action such as a mouse click, key press, or a message from the operating system or another program. An event-driven application is designed to detect events as they occur, and then deal with them using an appropriate *event-handling procedure*. (Source: Technologyuk)

MIT App Inventor. **MIT App Inventor** is an intuitive, visual programming environment that allows everyone – even children – to build fully functional apps for Android phones, iPhones, and Android/iOS tablets. It is an open-source tool that aims to make programming and app building accessible to a wide variety of audiences (educators; researchers; government; etc.) Initially developed by Professor Hal Abelson and his team, App Inventor is managed by members of MIT's Center for Mobile Learning. (Source: MIT App Inventor)

IDE. An **IDE**, or Integrated Development Environment, enables programmers to consolidate the different aspects of writing a computer program and develop programs more efficiently. IDEs increase programmer productivity by combining common activities of writing software into a single application: editing source code, building executables, and debugging. (Source: Code Academy)

User Interface. The **user interface** (UI) is the look and feel of an operating system. A good interface puts the user first, making commands and access to apps easy to discover. For the programmer, understanding how the interface works and what impact it has on application design is extremely useful. (Source: O'Reilly)

Conditional blocks. Conditionals refer to expressions or statements that evaluate to true or false. If the condition is “true”, a particular section of text will be inserted into the message. If the condition is “false”, the text will not be inserted. An “ELSE” clause can be included as part of the conditional statement so that a different section of text will be inserted into the message when the condition is “false”. (Source: Isoft)

Loops are a way to tell a computer to do something many times in a row. Computers are really good at doing things over and over again, and doing them fast. (Source: technovationchallenge)

Lists - a way to organize multiple pieces of data in App Inventor (Source: technovationchallenge)

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Index - a number that tells you where a piece of data is in a list (Source: technovationchallenge)

Array - common name for lists in programming languages other than App Inventor (Source: technovationchallenge)

Variable. A **variable** is a container that holds a single number, word, or other information that you can use throughout a program. A variable is like a chest you can fill with different values. Component properties are variables that are built into a component. Event parameters are special variables that give you extra information about an event. Global variables have global scope, meaning that they can be set and read from any blocks in the workspace. Local variables have local scope, meaning that they exist only within their initialization block, which has space to add more blocks. (Source: Idtech; O'Reilly)

Procedure. A **procedure** is a set of instructions that is grouped together, given a name, and made available for later use. This makes your code easier to read, think about, and change. Ultimately, using a procedure is more powerful. The steps for getting started are straightforward. (Source: O'Reilly)

Sensors. Sensing Blocks allow your programs to "sense" user input and other things. (Source: MIT App Inventor).

Pedagogical glossary

Constructivism. Jean Piaget presented the theory of **constructivism**, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed in the mind of the learner. Learners don't receive ideas; rather they create them from their own base of knowledge. Some characteristics of constructivist learning are that it:

- ⇒ fosters critical thinking;
- ⇒ creates motivated and independent learners;
- ⇒ has lessons that include guided discovery, whereby the teachers acts as a guide to the learner, helping to point out inconsistencies in students' thinking. Students build their understanding by resolving these conflicts;
- ⇒ includes a minimal amount of direct instruction. (Source: MIT App Inventor)

Constructionism. Building from the idea of **constructivism**, Seymour Papert presented his theory of constructionism which suggests that new ideas are most likely to be created when learners are actively engaged in building some type of external artifact that they can reflect upon and share with others. Elements of a constructionist learning environment include:

- ⇒ a teacher who acts as a facilitator;
- ⇒ learners who investigate, create, and solve problems;
- ⇒ learner collaboration;
- ⇒ learners engaging in authentic tasks;
- ⇒ opportunity for feedback and multiple opportunities for revision. (Source: MIT App Inventor)

Problem-Based Learning. Problem-based learning is one type of constructivist learning theory that can be applied in a classroom setting. It is a method which allows students to learn about a subject by exposing them to multiple problems, so they will be able to construct their understanding of the subject through these problems. Problem-based learning typically:

- ⇒ begins with problem for students to solve or learn about;
- ⇒ includes problems that are somewhat ambiguous to mirror the complexity of real life;
- ⇒ uses an inquiry model;

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⇒ requires students to present a conclusion of the problem solving process, but does not necessarily require them to create a product as a result;
⇒ is driven by defined problems. (Source: MIT App Inventor)

Project-Based Learning. Project-based learning encompasses Papert's theory of constructionism where students build an artifact as part of the learning process. Project-based learning typically:
⇒ begins with an end product in mind;
⇒ includes production of an artifact, which typically raises one or more problems for students to solve;
⇒ asks students to use or present the product they have created;
⇒ is driven by the end product;
⇒ stresses that content knowledge and skills acquired during the production process are critical to success. (Source: MIT App Inventor)

Computational thinking. The term **Computational Thinking** (CT), coined by Jeannette Wing in 2006, describes solving problems, designing systems, and understanding human behavior based on the principles of computer science. CT includes analyzing and organizing data, automated problem solving and using it to solve similar problems. Nowadays, it has become necessary to solve complex technological problems. If sufficient background knowledge is available and the necessary new knowledge is acquired through critical thinking, CT may help to solve the problem. It is actually a hybrid of several other modes of thinking, like abstract, logical, algorithmic, constructive and modelling thinking, which summarizes all previous modes for solving the corresponding problem. (Source: IGI)

Brainstorming. Brainstorming is a group problem-solving technique that involves the spontaneous contribution of ideas from all members of the group. (Source: Merriam-Webster)

Collaborative learning. A **collaborative** (or cooperative) **learning** approach involves students working together on activities or learning tasks in a group small enough to ensure that everyone participates. Students in the group may work on separate tasks contributing to a common overall outcome or work together on a shared task. This is distinct from unstructured group work. Some collaborative learning approaches put mixed ability pairs, groups or teams together to work in competition with each other in order to drive more effective collaboration. (Source: Evidence For Learning)

Gamification. **Gamification** of education is a developing approach for increasing learners' motivation and engagement by incorporating game design elements in educational environments. It is often described as the use of game design elements in non-game contexts" (Deterding, Dixon, Khaled, & Nacke, 2011), "the phenomenon of creating gameful experiences" (Hamari, Koivisto, & Sarsa, 2014), or "the process of making activities more game-like" (Werbach, 2014). (Source: Springer)

Learning through Storytelling. **Storytelling** is the vivid description of ideas, beliefs, personal experiences, and life-lessons through stories or narratives that evoke powerful emotions and insights. It represents the use of stories or narratives as a communication tool to value, share, and capitalize on the knowledge of individuals. (Source: Springer)

STEM. **STEM** (Science, Technology, Engineering, and Math) is an integrated, interdisciplinary, and student-centered approach to learning that encourages critical thinking, creativity, collaboration, and design thinking across multiple disciplines. An important role of STEM education is to help students develop skills that will empower them later on in the workplace. This includes helping students develop skills that foster:
⇒ Critical thinking;
⇒ Flexible thinking;

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⇒ Data-driven analytical inquiry;
⇒ Design (interdisciplinary) thinking;
⇒ Social responsibility;
⇒ Productivity;
⇒ Leadership;
⇒ Teamwork;
⇒ Collaboration;
⇒ Communication. (Source: Techopedia)

Multimodality. To understand multimodal learning, you first have to know the different modalities and their characteristics.

⇒ Modes are channels of information. They include:
  - Speech
  - Audio
  - Written and print
  - Illustrations

An example is that people learn from images by reacting to visual cues such as photos and graphs. People can also learn from kinesthetics by reacting to tactile cues such as actions and movement. Multimodal learning is teaching a concept using more than one mode (visual, auditory, reading, writing, and kinaesthetic methods). By engaging the mind in multiple learning styles at the same time, learners experience a diverse learning style that collectively suits all of them. Thus it is meant to improve the quality of teaching by matching content delivery with the best mode of learning from the student. (Source: eLearning Industry

Flipped Classroom. It is a pedagogical approach in which the times and spaces inherent in the teaching and learning process are inverted: the exploration of content is first done before class by the students (e.g. through reading, video analysis, etc.) in a space that tends to be more individual than group-based; in class, students have the opportunity to interact with the teacher and with each other, in a fundamentally group space, in order to apply, develop, clarify the content previously explored. This inversion thus transforms the teaching-learning process into an interactive, dynamic, and personal logic. (Source: Bergmann & Sams,2014)

Other connected terms (pedagogical eclecticism):

- Adaptative teaching.
- Personal inquiry.
- Dynamic assessment.
- Crossover learning.
- Navigating knowledge.
- Learning through argumentation.
- Learning from animations.
- Learning to learn.
- Event-based learning.
- Learning for the future.
- Immersive learning.
- Open pedagogy.

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Competences / Learning Goals

Key Competences
STEM / Personal, social and learning to learn, literacy, citizenship, responsability

Knowledge
Main concept: The role of low-code programming in public health issues

Programming concepts:
- Advanced programming expressions, statements, procedures, and variables.

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ICT concepts:
- Programming solutions development and application; low-code development environments; low-code development in public health *(topic: physical activity).*

Knowledge - outcome assessment:
1. Elaborates on concepts of computational thinking/science.
2. Defines, correctly outlines, and ponders over key concepts of low-code programming.
3. Characterizes content creation aspects.
4. Accurately describes and discusses concepts regarding programming and selects appropriate indicators to describe them.
5. Successfully applies advanced statements, expressions, and procedures to create efficient and informative digital resources.
6. Describes how low-code can contribute for a solution impacting public health.

Skills (abilities/competences)
General:
- "Creactical skills" (Ohler, 2013) / 21st century key skills:
  - Communication: digital communication; digital literacy; traditional literacy; health literacy; public speaking; argue capability; learn to learn.
  - Collaboration: working in groups towards a goal/to solve a problem/answer a question; collaboration.
  - Critical thinking: perform reasoning and analysis to draw conclusions based on simple systems; decision-making process; problem-solving process; project-based thinking.
  - Creativity: involves initiative, entrepreneurship, taking risks and learning from risks.

Specific:
- Developing, enhancing, and practicing computational thinking and technology-based projects.
- Finding, analyzing, and interpreting multimodal content to map basic/intermediate principles of low-code programming.
- Be a totally independent technology user and a content creation provider.
- Deeply expanding the 21st century competences.

Skills – outcome assessment:
1. Identifies and conceptualizes core and detailed skills that are required for programming.
2. Can demonstrate that multimodal, gamification and flipped classroom approaches are in fact, key for the future of education.
3. Acquires technological literacy and creativity expression through ICT troubleshooting, and test of outcomes.
4. Uses programming languages to address personal health and various other life quests and is able to develop innovative solutions for real-world problems.
5. Can fully transform creative ideas into basic, intermediate and advanced programmable concepts using content creation tools.
6. Uses evidence-based argumentation to explain the benefits of using low code development environments to solve or mitigate real life problems connected with lifestyles.
7. Builds fully functional apps for Android/iOS devices

Affective/Attitudes/ Behaviour (*beliefs)*
- Adopting a citizen developer role in society, as well as having social and personal responsibility.
- Pursuing the adoption of critical thinking and problem-solving attitude as an individual and in connection with the needs of the community.

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- Engaging in more challenging programming challenges/courses to further develop his/her interest in STEM.
- Adopting attitudes that mitigate public health risks.

Affective, Attitudes and behavior - outcome assessment:
1. Believes that low code is about innovation and creative problem-solving, that it should be explored in educational environments and that is a powerful tool for multimodal content creation.
2. Believes that technological skills are essential for effective citizenship and can lead to positive outcomes in educational, healthcare and business environments (e.g., fast development, scalability, simplicity, accessibility, low costs).
3. Believes that digital literacy translates into efficiency, access to things, knowledge, fulfillment, and happiness in personal and professional life, contributes to academic performance and improves student engagement.
4. Believes that health is the most important constituent of life.
5. Intends to further improve his/her digital literacy and programming knowledge to influence "STEM adoption" in his/her living environments and boost public health literacy.
6. Is committed to develop further his/her digital literacy in order to communicate easily on any subject and has a positive attitude towards it.
7. Is committed to use apps in his/her routine and to create new ones, broadening his/her knowledge concerning programming and ICT.

Learning goals and outcomes

- Uses low-code environments and content creation tools as creative platforms/extensions to express ideas and knowledge.
- Dominates online tools to create multimodal content.
- Understands and characterizes components of programming and uses them to create fully functional apps/games from scratch.
- Knows and communicates the main principles of good nutrition patterns, how much they may influence our daily lives, as well as their contribution for life expectancy and quality of life.

<u>Assessment methods</u>

- ✓ Outcome assessment
  - Quantitative – A questionnaire (in paper or in digital format)
  - Qualitative - students project: a. basic app/quizz building activity b. additional multimodal resources regarding public health and technological principles.
- ✓ Process assessment – *assessment of the teaching-learning sequence sequence* – observation grid: reaching the target audience, and extent; implementation of the scenario as planned; run of the learning scenario as expected/organizational issues to be solved;

  duration of the teaching-learning sequence; number of people exposed; score for likeability – students ("how fun was it to do"/ how fun would be to do again/ how could it be better).

<u>Content</u> (relevant to learning goals & research topics)

STEM content
- Technical literacy.
- Advanced programming expressions.
- Programming oriented math.
- Digital Literacy.
- Healthy lifestyles – Physical activity.

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Non-STEM content
- Teamwork.
- Metacognition.
- Proactivity.
- Multimodality.
- Brainstorming.
- Mental Mapping.
- Autonomy.
- Self-studying.

Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)

New (*developed by PAFSE team*):

In order to provide simple and easy-to-use resources for teachers/students, only one DER is presented, in which all DLOs will be inserted.

1. Animated, intuitive, and interactive *Nooc*[10] (*Nano Open Online Course*) using genially[11] concerning MIT App Inventor (Basic) and concepts to communicate science through technological content.
    - Informational multimodal resources (images, videos, sound, etc.) with content, challenges and solutions regarding basic low-code programming.
2. MIT AppInventor app(s) created by the team.
3. Questionnaires – quantitative and qualitative assessment of learnings - Student Interest and Choice in Science, Technology, Engineering and Mathematics (STEM) Survey (adapted from Roller et al. 2018 and Faber et al, 2013); Informed Consent – Students; Informed Consent – Legal Representatives; Process Assessment – Teachers; Scenarios Impact Assessment In Terms Of Students Knowledge, Skills, Attitudes And Behaviour.

Available resources (link): Low code universe 3 - Nooc

From other sources/high-quality platforms[12]:
Tutorials and examples to aid teachers prepare and train the students:
- MIT AppInventor:
    - Teach your students
    - Setting up your classroom for teaching App Inventor 2
    - Teaching an app inventor course
    - Hello Codi! (*app example*)
    - The MIT App Inventor library: documentation & support
    - MIT App Inventor - tutorials
    - MIT App Inventor - Beginner videos
    - MIT App Inventor - Nooc

- Programming principles:
    - Article about programming for kids

[10] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[11] Genially is the world-leader in interactive visual communication using low/no-code. It is an all-in-one online tool to create stunning presentations, interactive images, infographics, gamification, quizzes, breakouts, portfolios, etc. and enrich them with interactivity and animation effects in seconds.

[12] The majority will be included in the developed DER.

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- Block-based Programming in Computer Science Education
- Block coding 101

- Physical activity:
  - Referencial de educação para a saúde
  - Promotion of Healthy Nutrition and Physical Activity Lifestyles for Teenagers: A Systematic Literature Review of The Current Methodologies
  - Physical activity
  - Essential physical fitness: what every teen needs to know
  - Physical activity guidelines: children and young people (5 to 18 years)

Observation:

- The PAFSE team provides examples of high-quality platforms that can be used by students to develop their app in the research project. However, teachers are encouraged to choose the resources they see fit, or even leave it up to the students, instigating their creativity and research capacity, since it is such a "mundane" topic. In case of the schools that have science/health teachers involved (in addition to/instead of ICT teachers), this is even more encouraged.
- Given that physical activity involves a panoply of different topics, students can choose whichever appeals to them the most.

Teaching-learning activities

Principal target:
ICT classes /Biology classes /F.Q classes/Health Education classes (depending on the institution)
9h grade (+/- 14-15 years old students)
5-6 sessions/classes of 40-60 minutes
ICT teachers integrate other colleagues in the enactment of the scenario, as it aims to be interdisciplinary. The scenario provides the necessary tools for students to explore desirable behavior in an individual and public health perspective.

General note:

- This scenario focuses on learning by doing but also on learning by fully immersing on the topic. That being said, teachers are mediators and content curators, and support should be minimal. Students are supposed to solve the majority of their doubts by studying the issue and/or asking a peer.
- All the activities/theoretical aspects used in lessons will be available in the DER so you can all any information there.
- Some lessons will have "Bloom's taxonomy" for flipped classroom as a background.
  - Students will have activities in which they will, independently and individually, explore specific (and always available) content at home and then bring findings/discussions to the class, creating a powerful sense of interaction and collaboration.
  - It is about building the knowledge themselves and then apply it at the classroom, in group.

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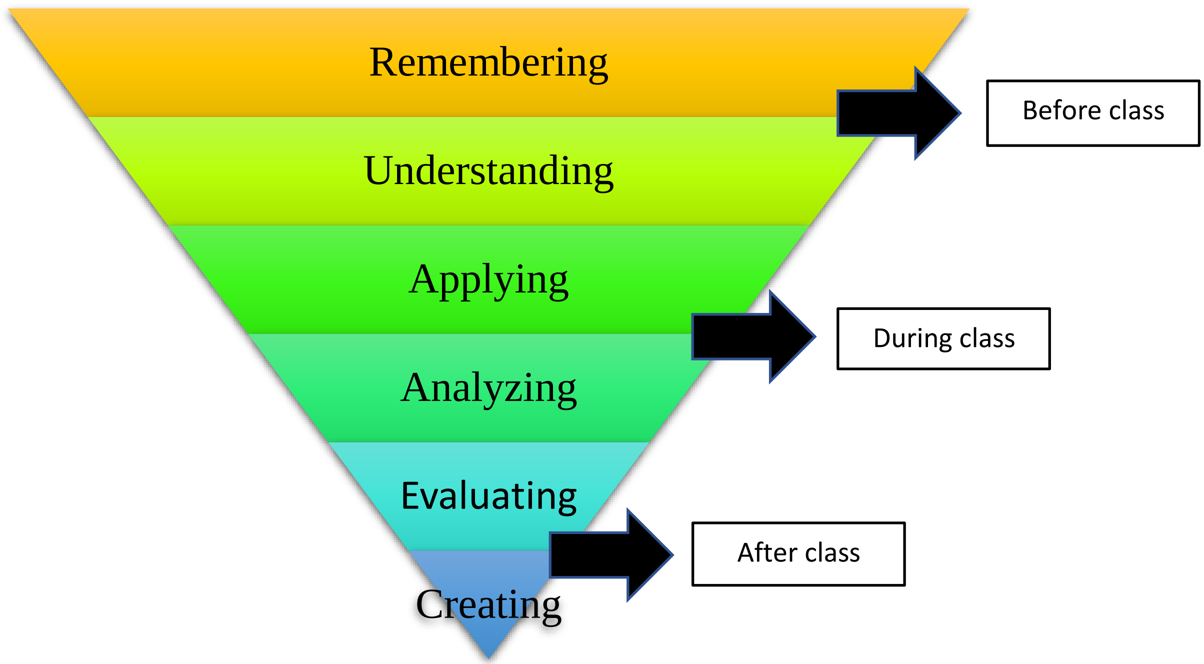

Bloom's Taxonomy for "Flipped" Classrooms; version revised by Lorin Anderson

Lesson 1: Introduction to key concepts

Learning objective: In the starting session, students will be exposed to various theoretical concepts (discussed in the workshop) they will need to use MIT App Inventor successfully and attain the scenario goals. The activities performed during this first lesson aim to engage students in these topics and explore some preliminary ideas.

Topics to be explored: Content Creation; Storytelling; Gamification; Programming; Computational science.

⇒ The teaching-learning script starts with asking when was the last time students programmed something, applied code, if they ever coded.
  - If the answer is favorable, tell them you will jump right in on it!
  - Is the answer is not favorable, show them this video.

⇒ Activity 1: Instead of handing and elaborating on the topic of "programming languages", "block-based coding", "programming" and related concepts, split them into small groups and ask them to carry out simple research on the subjects (keywords and short definitions) by creating mental maps on paper (after understanding the basics of mental mapping of course!).
  - Give them some time.
  - Ask for answers.
  - Using post-its, build a general mental map on the board. Students are supposed to attach ideas on the board.
  - Ask students to take a photo of that diagram as it will be useful on their journey as developers.

⇒ Smoothly correlate programming/technology/coding with gamification and multimodality.

⇒ Show them 2 videos:
    - Gamification - definition

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- Learning through gamification

At this point they will be very excited with this topic so profound it now.

- Correlate gamification with storytelling and show them this short video.
- Present them the detailed steps to create a storyboard
- Correlate with the topic of "Multimodal content creation" by providing real examples.
- Assign homework 1: Present presentation and quizz-making apps to them and defy them to create a simple 5 minute presentation (and possibly a quizz, if they are interested) explaining one of these concepts: "Programming languages"/"Low-code environments"/ "block-based programming"/ "MIT App Inventor"/"Gamification"/"Storytelling"/"Mental mapping/21st century competencies"
  - This is simply an example, any concept related to this educational scenario is fine, so teachers can freely choose.
  - Each group would get a single topic, and then would publicly expose it to peers.
  - The goal is that they fully understand concepts, in a deeper level.

⇒ Now start developing on the importance of digital literacy, pointing the fact that technology is everywhere, and we need to integrate it in education and business matters.

⇒ Let's get down to business and start using MIT App Inventor.

- Presentation
  - The best way to understand App Inventor is to use it.
  - The implementation of a program is done in two parts:
    - The creation of the user interface and the choice of resources that will be used in the application,
    - then block programming that uses the components (events, properties, procedures) associated with the components defined in the first part.
- SETUP
  - Activity: Each student should successfully SETUP independently.
  - Let them explore the platform until the rest of the class and provide them with some guides for consultation.
- Explain on what they will work on and attribute and elaborate on the topic "physical activity habits".

⇒ Assign homework 2: Discovering code

- Since this is a homework activity, you won't be able to guide the students, however, that is also the goal because it is where flipped classroom jumps in. Students will have the opportunity to acquire knowledge autonomously and without direct exposition of theory and will, afterwards, clarify doubts and discuss about it in the classroom.
- Ask students to open this website, watch the video and complete the tasks (phases of a game).
- In less than an hour, they will become familiar with block sequences, conditional connections and loops. This will get them started on practicing basic notions of block-based programming and they will like doing this activity.
  - Tell them to setup the page to PT-PT since it's available, both video and game.
  - In case there are some fast and very curious minds or even has a taste for flappy bird, you can give them another example.
  - Ask them to write down (in their notebooks) any doubts, comments and general observations regarding the learning experience. Some questions to ponder on:
    - What did you learn about how apps and games work today?
    - How do you feel knowing you programmed, you gamified.
- Challenge students to share some aspect of their Hour of Code experience on social media using #hourofcode as a way to lend their voices to this worldwide movement. Students can share their game, images, videos or just their thoughts.

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Lesson 2: Discovering coding 2.0

Learning objective: In this session, students will keep discovering code, this time, with the help of the teacher and a lot of reflective work will be simultaneously carried out. The plan takes up that of the courses of Professor Ralph Morelli and David Wolber. The pedagogical logic is that called *"BCCC" for "Build, Conceptualize, Customize, Create*": we start by doing (copying), then conceptualize (by experimentation and error research), customize existing functions, and finally create new applications, guided and then in free flight.

Topics to be explored: Block-programming principles.

⇒ Homework “correction”

- Start by talking a little bit about the work they did at home and what type of skills were being used in the process.
- Continue by elaborating on the expected learning outcomes topics
  - Define “coding” and “computer science”
  - Identify key computer science vocabulary
  - Make connections between computer science concepts and the real world
  - Identify places to go to continue learning computer science and coding
- Division of the class in small groups (4-5 people or as the teacher sees fit) in order to stimulate collaboration and capacity of exposing and discussing ideas, which will lead to a moment reflection on what they wrote about it.
  - Ask students to share their game, app or final product with the peers, pass by to take a look.
  - Give them a few minutes to discuss and then ask each group to present some bullet-points about the experience.
  - Listen to their feedback about it: clear their doubts; and listen to what kind of observations they have/how was the experience for them.
  - Ask how many felt the experience was easy/hard; pleasant/unpleasant.
- After discussing
  - Celebrate! Give them some certificates to keep it fun and make them proud of their work.
  - Tell them they can use the same website to practice in case they got interested and want to explore more.

- Maintain the groups formed and and divide these 3 apps between then, assign randomly.
  - In the end, a group of each app will present it, succinctly explain the process and give the templates to the colleagues (so they have a lot of material for the research project).
  - Particularly, their assignment is to play with the source code and corresponding app for the following three games: Mole Mash, Get the Gold, and Space Invaders. Take notes about they like/dislike about them. Have them look at the blocks, components, and the design of the app.
    - Mole Mash
    - Get the Gold
    - Space Invaders
  - Make them think about their observations of these games as well as develop their own game app. A game is defined as structured play. Sometimes games can be work as in the case of professional athletes. But mostly games are for fun. The key components of all games are goals (to hit the mole), rules (you only get points if you hit the mole), challenge (the mole moves randomly across the screen), and interaction (the user plays the game on the phone by touching the screen with a finger). This game can be a modification of any of the above apps or a new creation of your own.
  - The idea is having them know the interface and its components with practice

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Lesson 4: Practice makes perfect

Learning objective: during this lesson and as wrap-up moment on the "app creation" world, students are invited to challenge themselves and take it to the next level. Basic concepts where explored. This is the moment to explore.

Topics to be explored: Intermediate block-programming principles.
The last assignment was a big one, so they will probably need a lot of time.
This lesson is free for practice and continuing developing games.

Lesson 5: Go full on Sensors

Learning objective: during this lesson and as wrap-up moment on the "app creation" world, students are invited to challenge themselves and take it to the next level by introducing sensors.
The teacher will explain the concepts and provide guidance.
Topics to be explored: Advanced block-programming principles.
The theorectical concepts will look like this:

1. Building Location-Aware Apps
   - Using Location
   - Location Data
   - Using the Maps App with Intents
   - Saving Location Data
2. The Accelerometer
   - Detecting Tilt (and a Little Background Physics)
   - Other types of sensors (pedometer,etc,.)
3. Orientation sensor

⇒ Attribute this exercise to them:
Exercise: Pushpin
1. Part 1: Designing Current Location Readout
2. Programming Part 1: The Current Location Readout
3. Part 2: Pinning a Location to Remember Later
4. Programming Part 2: Pinning a Location
5. Extension Activities

⇒ Now it's autonomous practice time until they get it, let them watch tutorials, both in class and at home so they can get ready for the final research project:
- https://appinventor.mit.edu/explore/ai2/android-wheres-my-car
- https://appinventor.mit.edu/explore/displaying-maps
- https://www.youtube.com/watch?v=1ADwkt4WPng&t=1291s
- https://www.makerzine.com.br/educacao/faca-seu-proprio-app-para-medir-inclinacoes-com-mit-app-inventor/

Lesson 6: The final countdown

Learning objective: In this final session, a recap regarding the major practiced concepts concerning block programming is made, as well as of the used methodologies. In addition, students are prepared to the students research project.

⇒ Aiming to prepare the students for their final project, a presentation called "O meu Pitch em 5 p's" (My pitch in 5 p's) will be given, teaching students how to publicly present projects.
- How to communicate science/health using these 5 pillars:
  - "Priorizar" (Prioritize).

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    - "Pesquisar" (Research).
    - "Planificar" (Plan)
    - Personalizar (Personalize)
    - Produzir (Produce)
  - Provision of storyboard templates to prepare the pitch.
  - Explanation of what will be evaluated.

⇒ Quantitative assessment – questionnaire – impact assessment in terms of student's knowledge, skills, attitudes and behaviour.

Lesson 6-forward:

This is the **School Project** described below.
Final sessions, moments of creative freedom, where students apply the programming concepts learned during previous sessions in a project linked with nutrition habits. They will work with the MIT AppInventor platform with the aim of presenting the project at the end of the sessions, or in another event created for that purpose.
The projects will cover all the tools and themes explored. Students may choose, within the topic of nutrition habits, which sub-topics they want to explore and focus on. Regarding programming skills, they should follow a solid framework to create their own apps and are required to be as independent as possible.

Supplementary learning resources and educational activities

1. Regarding the school Research project:

- Production of multimodal content – Students can transfer and use the knowledge acquired to other classes.
- Public health reflection.
- Competition – reward of the best app.

School Research Project

Topics

Importance of digital literacy and real-life implications.
Basic/Intermediate/advanced technical features and principles of programming solutions development.
Possible applications of mobile applications in public health (e.g., in the promotion of nutrition habits).

Research management, design and administration

Challenge: Content exposition creation on one topic involving "physical activity habits", promoting not only technology, but also public health.

Method *(summary)*: Lessons 6/7 to 11/12 will be dedicated to the school research project. Students are, as usual, organized in groups and each group addresses the practiced programming and technological concepts and connects them to health.

Development process:

The project is based on the use of technology to create scientific artefacts. The five-six sessions will be lightly supervised by the teachers and developed by the students, with scheduled moments for checking the work development.
Groups of students will be instructed to create an interactive game or tool app that explores the topic of hygiene habits in some way, as well as some other resources (of their choice) that they see fit on the same topic:

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During session 1, students are presented, not only, with software to use for content creation but also the norms to follow:

1. Each group should have, at least:
    a. 1 app on the theme of physical activity that contains sensors (they can use existing templates or build from scratch and there is no need to be similar to those they tried, it's full on creativity)
    b. One other multimodal resource on the theme of healthy habits.
        i. It can be a mental/conceptual map, a quizz, a presentation, an interactive resource, an infographic, a story, a video, etc.
    c. A short portfolio with all the created resources.
2. Each group is required to:
    a. brainstorm a project idea, develop drawing(s) of the app/game on computer, creating a storyboard.
    b. meet regularly with the teacher to discuss the feasibility of the app and if necessary make any changes to their plan.
    c. Present a short (till 10 minutes) elevator pitch of your project idea to the class.
3. Create a portfolio (free structure, let the student be creative) write up of your project.

Finishing session 1, the groups are created and ideas start being discussed.
During session 2, the teacher will pass by the groups to collect ideas and topics and, if valid, students can start working on their project. The teacher will provide all the needed help, even if that means that he is an contributor to the project.
From session 3-forward, the students will actively work on their project and are encouraged to exchange ideas with other groups.
Since sensors were the last component to discuss and the teacher didn't have a lot of involvement, it will be very interesting to see how they do.

Teaching-learning process milestones:

1. Students will be able to propose basic/intermediate/advanced programming solutions.
2. Students will be able to communicate the findings, motivations and limitations of various solutions considered in the work process.
3. Students will be able to identify and communicate the importance of digital literacy/end-user development in public health and citizenship.

Teaching-learning process for school project (summary):

1. Development of multimodal materials.
2. Mobile Applications development.
3. Presentation of all the resources created in the open schooling event, where students will be advocating better conditions for their community and show their relationship with public health and low-code environments.

Organization of the open schooling event:

1. Each project output (portfolio) is presented by the students in a community setting (e.g., exposition center, municipality, science fair) with appropriate/pre-prepared environment (computer and smartphone with the MIT App Inventor installed).
2. Students do a pitch on how mobile solutions can be used to address public health, like the case of physical activity. Technical speeches to motivate peers to new technologies and technological environments. Students will also be advocating better conditions for their community and show their relationship with citizens health.
3. Students, parents, school community and relevant local stakeholders attend the event and recognize that mobile solutions can be used to address real life challenges, public health ones, and others. They also

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get high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, community).

Data Analysis and Reporting
Content Analysis.
Multimodal resources.
Portfolio development.

Target Audience for Recommendations
School community and local stakeholders: students, parents, municipalities, engineers, public health authorities, and local enterprises.

Public Debate and Recommendations (based on research results)
Presentation of the resources produced by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.
Discussion and feedback.
Attribution of the prize of "best apps".

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
Scenario topic: "Low-code development environments – Level 3 (Advanced)"

Knowledge	
1. Elaborates on concepts of computational thinking/science.	**Question 1.1:** What do we mean by computational thinking? A) Understanding a complex problem and developing possible solutions. B) Using a computer. C) Focusing on what is important, ignoring what is unnecessary. **Question 1.2:** What is the name given to the process of breaking down a problem into smaller problems? A) Decomposition B) Abstraction C) Algorithm design **Question 1.3:** Which of the following is an example of thinking computationally? A) Planning out your route when going to meet a friend B) When going to meet a friend, wandering around until you find them C) When going to meet a friend, asking a parent to plan your route for you
2. Defines, correctly outlines, and ponders over key concepts of low-code programming.	**Question 2.1:** Why is block-programming different from text-based coding? D) Because it is a type of visual software development environment that allows developers to drag and drop application components. E) Because block-programming is based on syntax, therefore making it easier. F) Because it is a programming language specially made to teach kids how to code. **Question 2.2:** Why should one use low-code platforms? A) Low-code platforms are easier to learn, as well as more intuitive and faster. B) Low-code platforms are free. C) Low-code platforms offer better outcomes than "high code" ones.

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3. Characterizes content creation aspects.	**Question 3.1:** What does gamification attempt to do? A) Create a world revolved around play B) Create a world shaped by games C) Create a game-based only world **Question 3.2:** Which of these is not one of steps of storyboard creation. A) Create a compelling selling text B) Writing the narrative C) Studying the target-audience **Question 3.3:** Which modes are employed to convey the meaning in an image? A) Visual (and gestures). B) Visual (and gestures) and sound. C) Visual (and gestures) and oral.
4. Accurately describes and discusses concepts regarding programming and selects appropriate indicators to describe them.	**Question 4.1:** What does run mean? D) To make a program complete an algorithm E) To make a website appear on screen F) To create code **Question 4.2:** What are lines of coding that repeat? A) Loops B) Variables C) Procedures
5. Successfully applies advanced statements, expressions, and procedures to create efficient and informative digital resources.	**Question 5.1:** Which is **not** a type of sensor A) Navigation B) Clock C) Accelerometer **Question 5.2:** A database in App Inventor that can permanently save data on a device. A) TinyDB B) CloudDB C) TinyWebDB **Question 5.3:** What is a global variable? D) Global variables can be set and read from any blocks in the workspace. E) Global variables exist only within their initialization block Interface. F) Global variables are types of blocks.

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6. Justifies why low code is crucial to the future.	**Question 6.1:** Which of these is **not** a characteristic of low-code environments? D) Special skills (developer skills) are required. E) Cheaper to enterprises. F) Improves productivity and collaboration. **Question 6.2:** In what way could low-code contribute to enhance public health issues? D) Integrate patient and employee information across systems in hospitals. E) Develop cures for diseases. F) Scatter information regarding public health issues.
Skills	
1. Identifies and conceptualizes core and detailed skills that are required for programming.	**Question 1.1:** Which of the following proficiencies is important in a professional programmer? D) Problem-solving E) Entrepreneurial spirit F) Ability to teach and mentor **Question 1.2:** Which of the following proficiencies is **not** required in block-programming? D) Public speaking ability E) Resilience F) Creativity
2. Can demonstrate that multimodal, gamification and flipped classroom approaches are in fact, key for the future of education.	**Question 2.1:** I feel able to enumerate to others some pros of multimodal gamification and flipped classroom strategies in specific curricula. 2) definitely true... 2) definitively false. **Question 2.2:** Public health might be benefited from approaches such as multimodality and gamification in terms of: D) Training of future profissionals E) Enhancement of facilities F) Curing diseases **Question 2.3:** I intend to integrate gamification and multimodality in future school projects. 2) definitely true... 1) definitively false. **Question 2.4:** For me, if school used gamification and multimodality in all curricula, it would be: 2) very significant... 2) very insignificant. **Question 2.5:** For me, the autonomy conceded by the flipped classroom approach is beneficial to the learning process: 2) definitely true... 2) definitively false.
3. Can fully transform creative ideas into basic, intermediate and advanced programmable concepts using content creation tools.	**Question 3.1:** I feel capable of conceiving a complex idea and subsequently turn it into a programable concept. 2) definitely true... 2) definitively false. **Question 3.2:** In the future, I will always search creativity in everything I do. 2) very probable... 2) very improbable. **Question 3.3:** I feel that programming stimulates my creativity skills.

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	2) strongly agree... 2) strongly disagree **Question 3.4:** I feel comfortable exploring block-programming environments. strongly agree... 2) strongly disagree
4. Uses evidence-based argumentation to explain the benefits of using low code development environments to solve or mitigate real life problems connected with lifestyles.	**Question 4.1:** I feel secure in my knowledge of these topics 1)strongly agree... 2) strongly disagree **Question 4.2:** I feel capable of enumerating different uses of low-code in the healthcare. 2) strongly agree... 2) strongly disagree **Question 4.3:** I think low-code only has advantages to society. 1)strongly agree... 2) strongly disagree **Question 4.4:** I feel capable of proposing low-code actions that benefit real life problems. 2) definitely true... 2) definitively false. **Question 4.5:** To aid tackling public health issues, people should rely on programming more. strongly agree... 2) strongly disagree
5. Builds fully functional apps for Android/iOS devices	**Question 5.1:** I feel capable of constructing a fully-functioning app. 3) definitely true... 2) definitively false.
Beliefs, attitudes and behavior	Instructions: There are no correct or incorrect answers; we are only interested in knowing your perspective.
1. Believes that technological skills are essential for effective citizenship and can lead to positive outcomes in educational, healthcare and business environments (e.g., fast development, scalability, simplicity, accessibility, low costs).	**Question 1.1:** I intend to identify and address the problems of the community in relation to technological issues. 1) strongly agree... 2) strongly disagree. **Question 1.2:** The development of technological competences of my own can contribute to the global society's awareness about the importance of technology. 2) extremely likely... 2) extremely unlikely. **Question 1.3:** I can explain to my family and friends the importance of technology. 2) strongly agree... 2) strongly disagree. **Question 1.4:** I think society still does not fully understand the importance of technology. 2) strongly agree... 2) strongly disagree. **Question 1.5:** I feel society takes for granted the benefits of technology. 2) strongly agree... 2) strongly disagree. **Question 1.6:** Among the following statements, choose the one that best describes what you currently think: 5) Low-code does not contribute to public health enhancement in any way. 6) I can see where low-code could contribute to public health enhancement in some way. 7) I can definitely see potential contributions of low-code to public health issues. 8) Low-code contributes to public health enhancement.
2. Believes that low code is about innovation and creative problem-solving, that it should be explored in educational environments and that is a powerful tool for	**Question 2.1:** I understand the importance of low-code environments for society. 2) strongly agree... 2) strongly disagree. **Question 2.2:** I can solve more complex problems now. 2) strongly agree... 2) strongly disagree. **Question 2.3:** Low-code empowers education and makes classes more effective. 2) strongly agree... 2) strongly disagree.

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multimodal content creation.	
3. Believes that health is the most important constituent of life.	**Question 3.1:** Health is a fundamental component of quality of life. 3) strongly agree... 2) strongly disagree. **Question 3.2:** I am capable of adopting a healthy lifestyle that benefits quality of life. 3) strongly agree... 2) strongly disagree.
4. .Believes that digital literacy translates into efficiency, access to things, knowledge, fulfillment, and happiness in personal and professional life contributes to academic performance and improves student engagement.	**Question 4.1:** I believe that digital literacy is important / useful in our daily lives. 1) strongly disagree... 2) strongly agree. **Question 4.2:** I believe that digital literacy improved my academic performance and my class interest. 1) strongly disagree... 2) strongly agree.
5. Intends to influence "STEM adoption" " in his/her living environments and boost public health literacy.	**Question 5.1:** I commit to promoting STEM adoption. 2) strongly disagree... 2) strongly agree. **Question 5.2:** I commit to promoting public health literacy. 2) strongly disagree... 2) strongly agree.
6. Is committed to develop further his/her digital literacy and programming skills in order to communicate easily on any subject and has a positive attitude towards it.	**Question 6.1:** I plan to keep improving my digital literacy. 2) definitely true... 2) definitively false. **Question 6.2:** I plan to keep improving my programming knowledge. 2) definitely true... 2) definitively false. **Question 6.3:** I feel digital literacy helps me with content exposition, problem-solving and creativity. 2) strongly disagree... 2) strongly agree. **Question 6.4:** I feel programming helps me with content exposition, problem-solving and creativity. 2) strongly disagree... 2) strongly agree. **Question 6.5:** I feel digital literacy helps me to develop 21st century skills. 1) strongly disagree... 2) strongly agree. **Question 6.6:** I feel programming helps me to develop 21st century skills. 1) strongly disagree... 2) strongly agree. **Question 6.7:** I feel digital literacy makes me to be more productive and proactive. 2) strongly disagree... 2) strongly agree. **Question 6.8:** I feel programming makes me to be more productive and proactive. 2) strongly disagree... 2) strongly agree. **Question 6.9:**

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	Among the following statements, choose the one that best describes what you currently think: 1) I do not use technology, and I also have no intention of doing so. 2) I do not use technology, but I have been thinking about the possibility of starting to do so. 3) I never or rarely use technology, but soon I will start doing it on a regular basis. 4) I use technology regularly. 5) I use technology regularly and I will keep doing so. **Question 6.10:** Among the following statements, choose the one that best describes what you currently think: 1) I do not program, and I also have no intention of doing so. 2) I do not program, but I have been thinking about the possibility of starting to do so. 3) I never or rarely program, but soon I will start doing it on a regular basis. 4) I program regularly. 5) I program regularly and I will keep doing so. **Question 6.11:** For me, programming is: pleasant:_____:_____:_____:_____:_____:unpleasant good:_____:_____:_____:_____:_____:bad worthless:_____:_____:_____:_____:_____:valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable
7. Is committed to use apps in his/her routine and to create new ones, broadening his/her knowledge concerning programming and ICT.	**Question 7.1:** I commit to utilize useful apps on a daily basis. 1)strongly disagree... 2) strongly agree. **Question 5.2:** I commit to build a lot of apps in the future. 1)strongly disagree... 2) strongly agree.

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Partnerships for Science Education

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